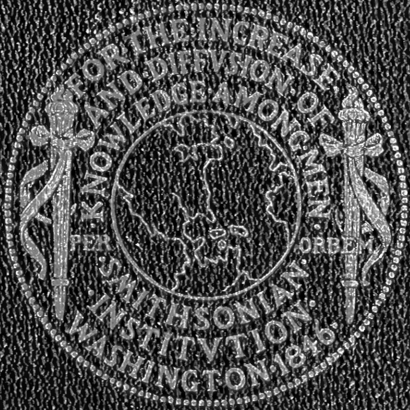
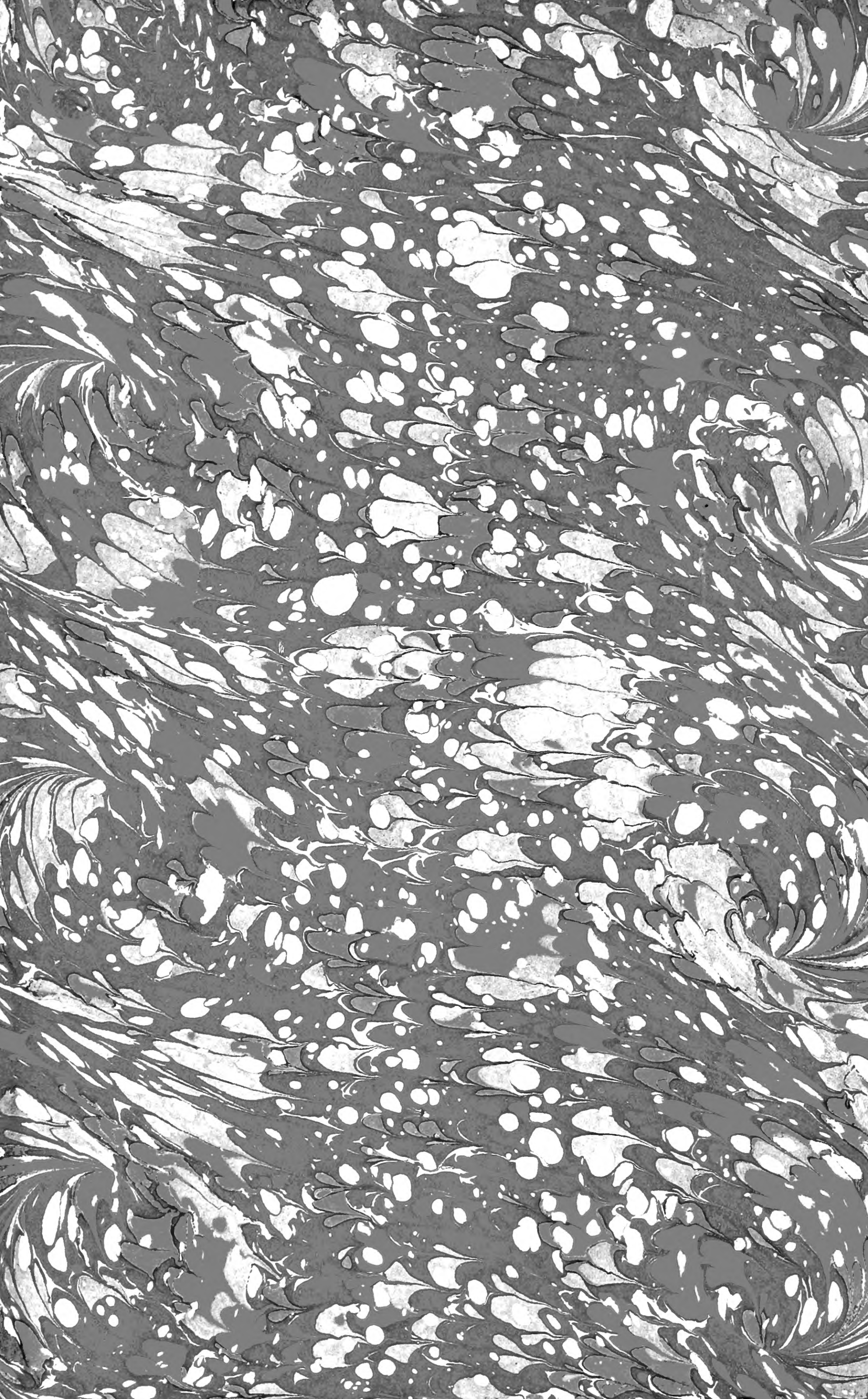
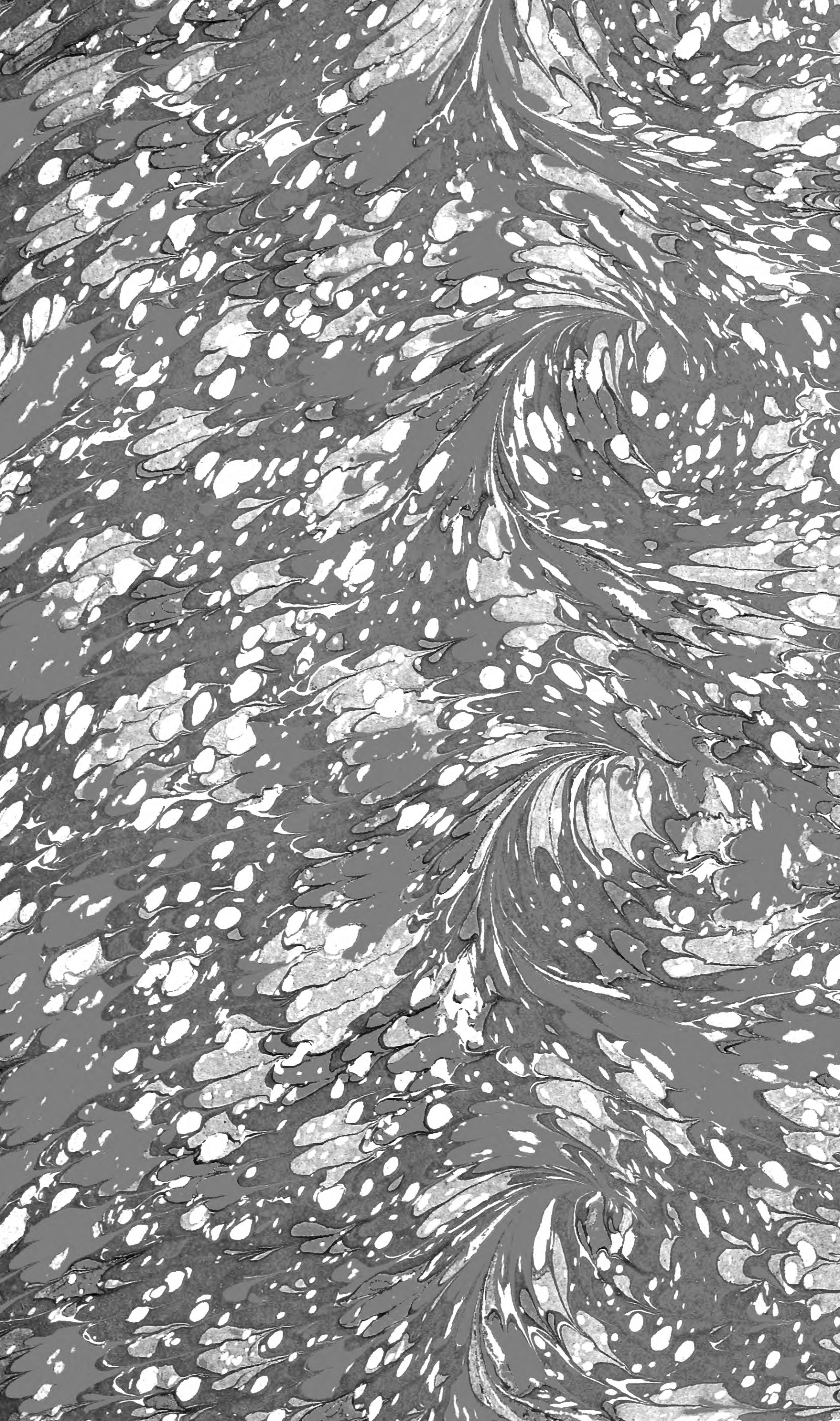

FOR THE INCREASE AND DIFFVSION OF KNOWLEDGE AMONG MEN
PER ORBEM
SMITHSONIAN INSTITVTION
WASHINGTON 1846





ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1857.

WASHINGTON:
WILLIAM A. HARRIS, PRINTER.
1858.

IN SENATE OF THE UNITED STATES,
June 3, 1858.

Resolved, That ten thousand additional copies of the Report of the Board of Regents of the Smithsonian Institution for the year 1857 be printed; five thousand for the use of the Senate, and five thousand for the use of the Smithsonian Institution: *Provided*, That the aggregate number of pages contained in said report shall not exceed four hundred and forty pages, without wood cuts or plates, except those furnished by the Institution: *And provided further*, That the entire amount of copy necessary to complete said Report be placed in the hands of the Superintendent of the Public Printing before the commencement of printing any portion of said Report.

Attest:

ASBURY DICKINS, *Secretary*.

LETTER

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

COMMUNICATING

The Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1857.

MAY 27, 1858.—Read.

JUNE 12, 1858.—Ordered to be printed; and that 10,000 additional copies be printed, 5,000 of which for the use of the Senate, and 5,000 for the use of the Smithsonian Institution.

SMITHSONIAN INSTITUTION,
Washington, May 26, 1858.

SIR: In behalf of the Board of Regents, I have the honor to submit to the Senate of the United States the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1857.

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

JOSEPH HENRY,
Secretary Smithsonian Institution.

HON. JOHN C. BRECKINRIDGE,
President of the Senate.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION UP TO JANUARY 1, 1858, AND THE PROCEEDINGS OF THE BOARD UP TO MAY 19, 1858.

To the Senate and House of Representatives:

In obedience to the act of Congress of August 10, 1846, establishing the Smithsonian Institution, the undersigned, in behalf of the Regents, submit to Congress, as a report of the operations, expenditures, and condition of the Institution, the following documents:

1. The Annual Report of the Secretary, giving an account of the operations of the Institution during the year 1857.
2. Report of the Executive Committee, giving a general statement of the proceeds and disposition of the Smithsonian fund, and also an account of the expenditures for the year 1857.
3. Report of the Building Committee.
4. Proceedings of the Board of Regents up to May 19, 1858.
5. Appendix.

Respectfully submitted.

R. B. TANEY, *Chancellor.*
JOSEPH HENRY, *Secretary.*

OFFICERS OF THE SMITHSONIAN INSTITUTION.

JAMES BUCHANAN, *Ex officio* Presiding Officer of the Institution.
ROGER B. TANEY, Chancellor of the Institution.

JOSEPH HENRY, Secretary of the Institution.
SPENCER F. BAIRD, Assistant Secretary.
W. W. SEATON, Treasurer.
WILLIAM J. RHEES, Chief Clerk.

ALEXANDER D. BACHE, JAMES A. PEARCE, JOSEPH G. TOTTEN,	Executive Committee.

RICHARD RUSH, WILLIAM H. ENGLISH, JOSEPH HENRY,	Building Committee.

REGENTS OF THE INSTITUTION.

JOHN C. BRECKINRIDGE, Vice President of the United States.
ROGER B. TANEY, Chief Justice of the United States.
JAMES G. BERRET, Mayor of the City of Washington.
JAMES A. PEARCE, member of the Senate of the United States.
JAMES M. MASON, member of the Senate of the United States.
STEPHEN A. DOUGLAS, member of the Senate of the United States.
WILLIAM H. ENGLISH, member of the House of Representatives.
L. J. GARTRELL, member of the House of Representatives.
BENJAMIN STANTON, member of the House of Representatives.
GIDEON HAWLEY, citizen of New York.
RICHARD RUSH, citizen of Pennsylvania.
GEORGE E. BADGER, citizen of North Carolina.
CORNELIUS C. FELTON, citizen of Massachusetts.
ALEXANDER D. BACHE, citizen of Washington.
JOSEPH G. TOTTEN, citizen of Washington.

MEMBERS EX OFFICIO OF THE INSTITUTION.

JAMES BUCHANAN, President of the United States.
JOHN C. BRECKINRIDGE, Vice President of the United States.
LEWIS CASS, Secretary of State.
HOWELL COBB, Secretary of the Treasury.
JOHN B. FLOYD, Secretary of War.
ISAAC TOUCEY, Secretary of the Navy.
AARON V. BROWN, Postmaster General.
J. S. BLACK, Attorney General.
ROGER B. TANEY, Chief Justice of the United States.
JOSEPH HOLT, Commissioner of Patents.
JAMES G. BERRET, Mayor of the City of Washington.

HONORARY MEMBERS.

ROBERT HARE, of Pennsylvania.
WASHINGTON IRVING, of New York.
BENJAMIN SILLIMAN, of Connecticut.
PARKER CLEAVELAND, of Maine.
A. B. LONGSTREET, of Mississippi.
JACOB THOMPSON, Secretary of the Interior

PROGRAMME OF ORGANIZATION

OF THE

SMITHSONIAN INSTITUTION.

[PRESENTED IN THE FIRST ANNUAL REPORT OF THE SECRETARY, AND ADOPTED BY THE BOARD OF REGENTS, DECEMBER 13, 1847.]

INTRODUCTION.

General considerations which should serve as a guide in adopting a Plan of Organization.

1. WILL OF SMITHSON. The property is bequeathed to the United States of America, "to found at Washington, under the name of the SMITHSONIAN INSTITUTION, an establishment for the increase and diffusion of knowledge among men."

2. The bequest is for the benefit of mankind. The government of the United States is merely a trustee to carry out the design of the testator.

3. The Institution is not a national establishment, as is frequently supposed, but the establishment of an individual, and is to bear and perpetuate his name.

4. The objects of the Institution are, 1st, to increase, and 2d, to diffuse knowledge among men.

5. These two objects should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths; and the second, to disseminate knowledge, thus increased, among men.

6. The will makes no restriction in favor of any particular kind of knowledge; hence all branches are entitled to a share of attention.

7. Knowledge can be increased by different methods of facilitating and promoting the discovery of new truths; and can be most extensively diffused among men by means of the press.

8. To effect the greatest amount of good, the organization should be such as to enable the Institution to produce results, in the way of increasing and diffusing knowledge, which cannot be produced either at all or so efficiently by the existing institutions in our country.

9. The organization should also be such as can be adopted provisionally, can be easily reduced to practice, receive modifications, or be abandoned, in whole or in part, without a sacrifice of the funds.

10. In order to compensate, in some measure, for the loss of time occasioned by the delay of eight years in establishing the Institution,

a considerable portion of the interest which has accrued should be added to the principal.

11. In proportion to the wide field of knowledge to be cultivated, the funds are small. Economy should therefore be consulted in the construction of the building; and not only the first cost of the edifice should be considered, but also the continual expense of keeping it in repair, and of the support of the establishment necessarily connected with it. There should also be but few individuals permanently supported by the Institution.

12. The plan and dimensions of the building should be determined by the plan of organization, and not the converse.

13. It should be recollected that mankind in general are to be benefitted by the bequest, and that, therefore, all unnecessary expenditure on local objects would be a perversion of the trust.

14. Besides the foregoing considerations deduced immediately from the will of Smithson, regard must be had to certain requirements of the act of Congress establishing the Institution. These are, a library, a museum, and a gallery of art, with a building on a liberal scale to contain them.

SECTION I.

Plan of Organization of the Institution in accordance with the foregoing deductions from the will of Smithson.

To INCREASE KNOWLEDGE. It is proposed—

1. To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and
2. To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

To DIFFUSE KNOWLEDGE. It is proposed—

1. To publish a series of periodical reports on the progress of the different branches of knowledge; and
2. To publish occasionally separate treatises on subjects of general interest.

DETAILS OF THE PLAN TO INCREASE KNOWLEDGE.

I.—*By stimulating researches.*

1. Facilities afforded for the production of original memoirs on all branches of knowledge.
2. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled Smithsonian Contributions to Knowledge.
3. No memoir on subjects of physical science to be accepted for publication which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.
4. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in

the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

5. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision be made.

6. The volumes of the memoirs to be exchanged for the transactions of literary and scientific societies, and copies to be given to all the colleges and principal libraries in this country. One part of the remaining copies may be offered for sale; and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

7. An abstract, or popular account, of the contents of these memoirs to be given to the public through the annual report of the Regents to Congress.

II.—*By appropriating a part of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects, and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects, so that, in course of time, each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made.

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts, accumulated in the offices of government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

DETAILS OF THE PLAN FOR DIFFUSING KNOWLEDGE.

I.—*By the publication of a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. These reports will diffuse a kind of knowledge generally interesting, but which, at present, is inaccessible to the public. Some of the

reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world, penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. *By the publication of separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises should, in all cases, be submitted to a commission of competent judges previous to their publication.

3. As examples of these treatises, expositions may be obtained of the present state of the several branches of knowledge mentioned in the table of reports.

SECTION II.

Plan of organization, in accordance with the terms of the resolutions of the Board of Regents providing for the two modes of increasing and diffusing knowledge.

1. The act of Congress establishing the Institution contemplated the formation of a library and a museum; and the Board of Regents, including these objects in the plan of organization, resolved to divide the income[*] into two equal parts.

2. One part to be appropriated to increase and diffuse knowledge by means of publications and researches, agreeably to the scheme before given. The other part to be appropriated to the formation of a library and a collection of objects of nature and of art.

3. These two plans are not incompatible one with another.

4. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies in the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

5. The Institution should make special collections, particularly of objects to illustrate and verify its own publications.

6. Also, a collection of instruments of research in all branches of experimental science.

7. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found in the United States.

8. Also, catalogues of memoirs, and of books and other materials, should be collected for rendering the Institution a centre of bibliographical knowledge, whence the student may be directed to any work which he may require.

9. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and, therefore, it will seldom be necessary to purchase articles of this kind.

10. Attempts should be made to procure for the gallery of art casts of the most celebrated articles of ancient and modern sculpture.

11. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union and other similar societies.

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[*]

The amount of the Smithsonian bequest received into the Treasury of the United States is	$515,169 00
Interest on the same to July 1, 1846, (devoted to the erection of the building)	242,129 00
Annual income from the bequest	30,910 14

12. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, &c.

13. For the present, or until the building is fully completed, besides the Secretary, no permanent assistant will be required, except one, to act as librarian.

14. The Secretary, by the law of Congress, is alone responsible to the Regents. He shall take charge of the building and property, keep a record of proceedings, discharge the duties of librarian and keeper of the museum, and may, with the consent of the Regents, *employ assistants.*

15. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art; distinguished individuals should also be invited to give lectures on subjects of general interest.

This programme, which was at first adopted provisionally, has become the settled policy of the Institution. The only material change is that expressed by the following resolutions, adopted January 15, 1855, viz:

Resolved, That the 7th resolution passed by the Board of Regents, on the 26th of January, 1847, requiring an equal division of the income between the active operations and the museum and library, when the buildings are completed, be and it is hereby repealed.

Resolved, That hereafter the annual appropriations shall be apportioned specifically among the different objects and operations of the Institution, in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance, and a compliance in good faith with the law.

REPORT OF THE SECRETARY FOR 1857.

To the Board of Regents:

Gentlemen: It again becomes my duty to present to you the history of the operations of another year of the Institution which the government of the United States has entrusted to your care. In an establishment of this kind, of which the policy has been settled and is strictly adhered to, there must of necessity be much sameness in the general form and character of the successive reports; but since the field of science is boundless, and new portions of it are continually presented for investigation, there will always be found in the details, facts of sufficient interest to relieve the routine of the statements relative to the condition of the funds and the scrutiny of the receipts and expenditures.

It might at first sight appear surprising that so constant a supply of materials for the Smithsonian Contributions and so many objects of interest, demanding the assistance of the Smithsonian fund, should be presented, but it will be evident, on reflection, that this results from the influence of the Institution itself in increasing the number of laborers in the field of science, as well as in accumulating the materials on which they are to be engaged. The tendency is constantly to expand the operations, and much caution and self-control are necessary to repress the desire to be more liberal in the assistance rendered to worthy objects, than the income will permit. Indeed, a charge is frequently made of illiberality for what is the result of restricted means. It must be evident that nothing is more important to the permanency and proper conduct of the Institution than the cautious and judicious management of its funds. Any embarrassment in this quarter would involve a loss of confidence in the directors, which would be fatal to the usefulness and efficiency of the establishment.

I have from the first expressed the regret that the original law of Congress directed the expenditure of so large a portion of the income on objects of a local character, and this feeling has been increased by the experience which time has afforded in regard to the good which could be effected by a more critical observance of the terms of the bequest, as well as by the increasing expense of sustaining a large building, a library, and museum. It is to be hoped, however, that at least a partial relief will hereafter be afforded by an annual appropriation, which it is reasonable to expect government will make for the keeping and exhibition of the collections of the various exploring expeditions which have been entrusted to the care of the Regents.

At the last session of Congress an appropriation was made for the construction and erection of cases to receive the collections of the United States Exploring Expedition and others in Washington, and also for the transfer and arrangement of the specimens. This appropriation was granted in accordance with the recommendation of the late Secretary of the Interior and the Commissioner of Patents, in order that the large room in the Patent Office occupied by the museum might be used for the more legitimate purposes of that establishment. We presume that the other part of the recommendation will also be carried out, namely, that the annual appropriation be continued which has heretofore been made for the care of this portion of the government property. While, on the one hand, no appropriation should be made which would serve to lessen the distinctive character of Smithson's bequest, on the other it is evident that the government should not impose any burdens upon the Institution which would impair its usefulness or divert its funds from their legitimate purpose.

It was stated in the last report that the extra fund of the Institution, which had been saved from the accrued interest, was invested in State Stocks. This investment was made because the fund was at the time drawing no interest, and because, until action could be procured by Congress in relation to receiving said fund into the United States Treasury, it was deemed the safest disposition of the money. Though a temporary depreciation of these stocks took place during the last year, there is no reason to regret the investment. Their marketable value is at present about the same as it was at the time they were purchased.

By reference to the report of the Executive Committee it will be seen that the expenditures during the year, though less than the amount of receipts, have somewhat exceeded the estimates. This has been occasioned, first, by unexpected repairs which were found necessary to the building, in consequence of an unprecedented hail storm, which destroyed several thousand panes of glass and did considerable injury to the roof and other parts of the edifice; secondly, by an expansion of the system of foreign exchanges, rendered necessary by the large amount of material entrusted to the Institution by the different agricultural and other societies of the country; and thirdly, the necessity we were under, on account of the financial pressure, of paying bills for publications which will appear during the present and the next year. The funds of the Institution are, however, still in a prosperous condition, but great care is required to prevent the accumulation of small expenses, which, individually, by reason of their insignificance, are allowed to occur, but which in the aggregate, at the end of the year, are found to have swelled into amounts of considerable magnitude.

Publications.—The ninth annual quarto volume of Contributions to Knowledge was completed and distributed during the first half of the year. It is equal in size and importance to the preceding volumes, and contains the following memoirs:

1. On the relative intensity of the heat and light of the sun upon different latitudes of the earth. By L. W. Meech.
2. Illustrations of surface geology, by Edward Hitchcock, LL.D., of Amherst College.
   Part 1. On surface geology, especially that of the Connecticut valley, in New England.
   Part 2. On the erosions of the earth's surface, especially by rivers.
   Part 3. Traces of ancient glaciers in Massachusetts and Vermont.
3. Observations on Mexican history and archæology, with a special notice of Zapotec remains, as delineated in Mr. J. G. Sawkins' drawings of Mitla, &c. By Brantz Mayer.
4. Researches on the Ammonia Cobalt bases. By Professor Wolcott Gibbs and Professor F. A. Genth.
5. New tables for determining the values of the co-efficients in the perturbative functions of planetary motion, which depend upon the ratio of the mean distances. By J. D. Runkle.
6. Asteroid supplement to new tables for determining the values of $b_{s}^{(i)}$ and its derivatives. By J. D. Runkle.

It was stated in the last report that Mr. L. W. Meech proposed to continue his interesting investigations relative to the heat and light of the sun, provided the Smithsonian Institution would pay the expense of the arithmetical computations. Though most of his time is necessarily occupied in other duties, he would cheerfully devote his leisure hours to the investigation with a view of extending the bounds of knowledge. During the past year an appropriation has been made of one hundred dollars for the purpose here mentioned, and we are assured, from what Mr. Meech has already accomplished, that this sum will be instrumental in producing valuable results. He proposes to determine, from several elementary formulas, the laws of terrestrial temperature for different latitudes. The first formula has been pretty thoroughly applied, and the annual temperature computed by it compared with the result of actual observation. The diurnal temperatures have also been deduced and seem to agree with actual observation within the presumed errors of the latter. The temperature, however, of the surrounding medium, derived from the *annual* temperature, differs widely from the results obtained by the *diurnal* temperatures. The author is inclined to attribute this difference to a defect in the law of radiation as generally received, which, deduced from experiments in the laboratory, he thinks inapplicable to the phenomena of terrestrial temperature. The second formula takes into account another cause of the variation of temperature, namely, the cooling due to the contact of the air; and the third formula includes also the effect of the absorption of solar heat in its passage through the atmosphere. The investigation will include the consideration of—1st, terrestrial radiation; 2d, contact of air; 3d, the sun's intensity; 4th, atmospheric absorption; 5th, the difference in radiating power of luminous heat by day and non-luminous heat by night. Among other inferences to be deduced is the relative heating or radiating powers of sea and continent, when the land is covered with foliage and vegetation, and when it is covered with ice and snow. These researches are intimately connected with the extended series of observations on the climate of the United States, now carried on at the expense and under the direction of the Institution.

The paper of Professor Gibbs and Dr. Genth, which forms a part of the 9th volume, has been republished in the American Journal of Science and in the London Chemical Gazette, due credit being given to the Smithsonian Contributions, from which it was copied. We regret to be informed by the authors of this interesting paper that the sum appropriated by the Institution for assisting in defraying the expense of the materials and apparatus employed in their researches was scarcely sufficient to compensate for more than one-fourth of their outlay. Limited means, and not a want of proper appreciation of the labors of these gentlemen, prevented their entire reimbursement for the pecuniary loss in the prosecution of their valuable researches. They intend, notwithstanding this, to continue their investigations, and to devote as much time to them as their other engagements and the means at their disposal will allow. Since this memoir has met the approval of the scientific world, it will be proper to make as liberal an appropriation as the demands on the limited income of the Institution will permit for the continuance of researches in the same line. The publication of the paper was of comparatively little expense, since it required no costly illustrations, and this may be an additional reason for granting a larger appropriation for further investigations in the same line.

The ninth volume also contains the supplement to the tables by J. D. Runkle, mentioned in the last report. The tables in this supplement are intended to facilitate calculations with reference to the asteroids. The search for these bodies has been prosecuted with so much vigor of late that their list now extends to more than fifty, and the mechanical labor required to calculate their places is so great that this can scarcely be expected to be accomplished, except by the use of general tables. The work of Gauss on the theory of the motion of the heavenly bodies leaves little to be desired, so far as the determination of their orbits is concerned; but this is by no means the case with regard to their perturbations by the larger planets. The tables therefore will afford an important means of facilitating the advance of our knowledge, particularly of this class of the members of our solar system.

The third part of the Nereis Boreali-Americana, by Dr. William H. Harvey, has been completed and will be included in the tenth volume of the Contributions. Two hundred extra copies of the text of the preceding parts having been struck off before the distribution of the types, and the drawings on the lithographic stones having been preserved, an equal number of plates from the latter have been printed and colored, so that we shall be enabled to make up two hundred copies of the complete work to be offered for sale, which will serve, it is hoped, to reimburse, in some degree, the heavy expense incurred in the publication of this interesting addition to the science of botany. It may be proper to mention that the work was published in numbers, in order that the whole expense should be defrayed by the appropriation of different years, as well as to furnish the author the opportunity of rendering the work more complete by more extended research.

For the purpose of classification, the sea plants have been grouped under three principal heads which are readily distinguished by their general color.

They are as follows:

1. Melanospermeæ—plants of an olive-green or olive-brown color.
2. Rhodospermeæ, or plants of a rosy-red or purple color.
3. Chlorospermeæ, or plants of a grass, rarely of a livid purple color.

The numbers of the work already published relate to the first two divisions, and the third, now about to be issued, will contain the last, with an appendix describing new species discovered since the date of the former parts.

The text of the first part of the work on Oology, mentioned in preceding reports, has been printed; but the publication of the plates to accompany it will be so expensive that we were obliged to defer it until the present year. In the meantime the author will proceed with the preparation of the other parts of the memoir, and the whole will be completed as soon as the funds of the Institution will permit. From an accidental oversight in the preparation of the last Report, I neglected to mention the fact that the author of this interesting work is Dr. Thomas M. Brewer, of Boston. The omission of his name in the reports would not only be unjust to himself, but might also prevent him from receiving in some cases additional information relative to his labors from correspondents who are engaged in the same line of research. The announcement of the fact of the intended publication of this memoir has induced a number of persons to enter into correspondence with the Institution on the subject, and we doubt not that these remarks will tend to call forth other additions to our knowledge of this branch of natural history.

Since the date of the last Report a grammar and dictionary of the Yoruba language of Africa have been accepted for publication. Thi work is another contribution from the missionary enterprise of the present day, and has been prepared by the Rev. Thos. J. Bowen, of the Southern Baptist Missionary Board, from materials collected during a residence of six years in Africa, and revised and rewritten with the aid of W. W. Turner, esq., of Washington. The grammar and dictionary are prefaced by a brief account of the country and its inhabitants. The long residence of the author in this part of the interior of Africa has enabled him to gather more minute knowledge of its topography, climate, and productions, and of the political, social, and moral relations of its inhabitants than has before been obtained. He has collected interesting information as to the habits of thought and action of the people, and their capacity for moral and intellectual culture, which would have escaped the casual notice of the mere traveller.

Yoruba is a country of Western Africa, situated to the east of Dahomey, and extending from the Bight of Benin, in a northerly direction, nearly to the Niger. It is between the countries explored by the distinguished travellers, Barth, on the north, and Livingstone, on the south. The author describes it as a beautiful and fertile region, densely inhabited by a population devoted to agricultural pursuits, who do not dwell on the lands they cultivate, but live clustered together in villages and towns, some of which contain from 20,000 to 70,000 inhabitants. The people are generally of a primitive, simple and harmless character, and governed by institutions patriarchal rather than despotic. In their appearance they resemble the Caucasian race, while their mental powers and general moral impulses are considerably advanced in the scale of intelligence. They have, indeed, already attained no inconsiderable degree of social organization, while they have escaped some of the more depraved incidents of an advanced civilization.

The language, which is said to be spoken by about two millions of people, is represented by Professor Turner to be very homogeneous in its structure, almost all of it being derived from some five hundred primitive words. "Its articulations are sufficiently easy to imitate, and there is a system of vocalic concords recurring through the whole, which, together with the multiplicity of vowels, renders it decidedly euphonious. The great difficulty is found in the tones and accents, which can be discriminated only by a good ear, and must be uttered correctly to make the speaker intelligible. The Yoruba has neither article nor adjective, properly so called, and it is almost wholly destitute of inflection. The verbal root remains unchanged through all the accidents of person, mood, and tense, which are indicated by separate pronouns and particles. The plurality of nouns is also indicated by the aid of a plural pronoun. The numerals are based on the decimal system, yet many of them are formed by subtraction instead of addition or multiplication, as with us. Thus 15 is literally $10 + 5$; but $16 = 20 - 4$, $17 = 20 - 3$, &c. Although this language is spoken by a rude people, it abounds in abstract terms, and the missionary finds no difficulty in expressing in it the ideas he desires to communicate."

It is believed that this work will be received by the student of ethnology as an interesting addition to this science, and that its publication will not only facilitate the labors of the missionary, but be productive of valuable commercial results. The country in which the language is spoken is rich in natural and artificial productions, and as the inhabitants are anxious to establish relations of trade with other parts of the world, it would seem to offer a new and tempting field to mercantile enterprise.

Under the head of publications, we may allude to the Appendix to the Annual Report of the Regents. Previous to 1853 this report was in a pamphlet form, and only in one or two cases were a few extra copies ordered. Since that date an annual volume has been presented to Congress, of which twenty thousand extra copies have been printed. The liberal distribution of this work has met with general approbation, the applications to the Institution for copies have been constantly increasing, and, in connexion with the Report of the Patent Office, no document has become more popular or is better calculated to advance the cause of knowledge among the people. The object is, as far as possible, to distribute this volume among teachers, and through them to diffuse precise scientific knowledge to the rising generation. It is made also the vehicle of instruction, in the line of observations, to all who are desirous of co-operating in the investigation of the natural history and physical geography of this country. The wide distribution of this report has tended, more than any other means, to make known the character of the Institution, and to awaken an interest throughout the whole country in its prosperity.

In order to render the series complete, the first volume—that for 1853—contained a reprint of the previous reports of the Secretary, from which a connected history of all the operations of the Institution from the beginning may be obtained. These volumes are illustrated by a large number of wood cuts, which have been provided at the expense of the Smithsonian fund. We have, however, to regret that, from the rapidity with which Congressional documents are hurried through the press, we have not been allowed in all cases revised copies of the proof. We cannot, therefore, be held entirely responsible for inaccuracies of the press any more than for the style of printing or the quality of the paper.

It is a part of the settled policy of the Institution to appropriate its funds, as far as the original law of organization will allow, to such objects only as cannot as well be accomplished by other means; and accordingly, in several instances, the printing of papers previously accepted for publication has been relinquished because it was subsequently found that the works could be given to the public, under certain conditions, through other agencies. In such cases the favorable opinion expressed by the Institution as to the character of the work, or the assistance rendered by the subscription on the part of the Regents, for a number of copies to be distributed in exchange for other books among our foreign correspondents, has been sufficient to induce some liberal minded parties to undertake the publication, rather as an enterprise connected with the reputation of their establishments, than as a matter of profit. Karl

Among the works of this class is the "Theory of the Motion of the Heavenly Bodies," by the celebrated Gauss, translated by Captain C. H. Davis, U. S. N., late superintendent of the Nautical Almanac, which was originally accepted by us for publication, but was afterwards relinquished to Messrs. Little & Brown, of Boston, who have shown in this instance, as well as in others of a similar character, a liberality which cannot be otherwise than highly appreciated by a discerning public. This book, which is essential to the advance of practical astronomy, was published in Latin, in Hamburg, in 1809, and is now of difficult access, as well as of restricted use, on account of the language in which it appeared. It gives a complete system of formulas and processes for computing the movement of a body revolving in an ellipse, or in any other curve belonging to the class of conic sections, and explains a general method of determining the orbit of a planet or a comet from three observations of the position of the body as seen from the earth. The essay was called for at the time it was produced by the wants of science. The planet Ceres, discovered on the first day of the present century by Piazzi, of Italy, had been lost to astronomers in its passage through the portion of the heavens illuminated by the beams of the sun, and could not be found by the means then known, when Gauss, from a few observations of its former place, calculated its orbit, and furnished an ephemeris by which it was readily rediscovered. The methods employed in this determination were afterwards given in a systematic form in the work now translated. The copies subscribed for by the Institution, on account of exchanges, and those paid for by the Navy Department, for the use of the computers of the Nautical Almanac, were sufficient to secure the publication of the work, which could not have been undertaken without these aids.

In accordance with the same policy the Institution has subscribed for a few copies of a work on "The Pleiocene Fossils of South Carolina,'' by M. Tuomey and F. S. Holmes. This work received the commendation of some of the distinguished members of the American Association for the Advancement of Science, at its meeting in Charleston, in 1850, and its publication was undertaken at the risk and cost of the authors. The actual expense, however, far exceeded their estimate, and without the liberal aid of the legislature of South Carolina they could not have escaped heavy loss, or been enabled to complete the work in a proper style of art. To aid the same enterprise the Institution was induced to make the subscription above mentioned for copies to be distributed to foreign societies. We regret to state that before the work was fully completed the science of the country was called to mourn the loss of Professor Tuomey, of the University of Alabama, who, during the past year, was prematurely snatched away from his family and friends in the flower of his age. His works, however, will remain as an inheritance to the cause of knowledge and the best monument to his memory. We have been gratified to learn that, at the late session of the legislature of South Carolina, a resolution was passed authorizing a continuance of the patronage of the State to the publication of these researches, and consequently Professor Holmes has signified his intention to publish two additional volumes on the Eocene and the Post Pleiocene Fossils, to which the subscription of the Institution will also be extended.

Another work, belonging to the same class, is the series of "Contributions to the Natural History of the United States of America,'' by Professor Louis Agassiz. It has been mentioned in a previous report that this distinguished *savan* was preparing a series of papers to be presented to the Smithsonian Institution, and that the plates for some of these had been engraved. But the number of these contributions, and the cost of their illustration, would have absorbed a larger portion of the Smithsonian fund than could have properly been devoted to the labors of one individual. Fortunately, however, the reputation and popularity of Professor Agassiz have enabled his friends to procure subscribers for an independent work, containing the result of his valuable investigations, in numbers unprecedented in the annals of science of this or of any other country. In order to assist this enterprise in the beginning, and to relieve its own funds, the Institution subscribed for copies, to be distributed among foreign libraries, in exchange for rare works of a similar character, with which to enrich its own library.

The Institution has also facilitated the researches described in the first two volumes of the work in question, and I may quote the following sentence containing the acknowledgment of the author for the services which have thus been rendered him: "Above all, I must mention the Smithsonian Institution, whose officers, in the true spirit of its founder, have largely contributed to the advancement of my researches by forwarding to me for examination not only all the specimens of Testudinata collected for the museum of the Institution, but also those brought to Washington by the naturalists of the different parties that have explored the western Territories, or crossed the continent with the view of determining the best route for the Pacific railroad. These specimens have enabled me to determine the geographical distribution of this order of reptiles with a degree of precision which I could not have attained without this assistance." Besides this, the Institution caused special collections of turtles to be made for Professor Agassiz, from those parts of the country from which no specimens had previously been obtained.

It was originally intended, as announced in the prospectus, to issue one volume a year, but the author found that the first volume was insufficient to contain all the matter which he had designed to give in it. Its publication was therefore delayed, that the whole of this part of his general subject might be presented at once, and hence two volumes have been issued together. The large subscription which has been obtained has enabled the publishers to extend the original plan, and to expend a much greater sum on the engravings than was at first thought possible. The work will serve to increase and extend the reputation of the illustrious author, as well as to afford a striking example of the liberality of our country and its growing appreciation of abstract science.

Under the head of publications, and in justice to the memory of a distinguished naturalist, a profound scholar, and a worthy man, the late Dr. Gerard Troost, of Tennessee, it ought to be stated in this Report, that after his death, several years ago, a memoir he had prepared on the organic remains known as Crinoidea, illustrated by a collection of specimens, was presented to the Smithsonian Institution for publication. It was submitted to two naturalists of high reputation, and found by them to be an important addition to knowledge, though left by its author in an unfinished condition. The gentlemen to whom it was referred generously offered to supply the deficiencies, and to prepare the work for the press. Their engagements, however, have since been such as to prevent up to this time the completion of the task which they undertook to accomplish. One of the gentlemen to whom the paper was referred, Prof. James Hall, in whose possession the specimens now are, states that he had hoped long since to put the memoir in such a form as to do justice to the memory of Dr. Troost, and be in accordance with the latest views of the subject. To do this, however, required an examination of other specimens, and for this object he had never been able to find time. At present he is engaged in a geological report of Iowa, in which there are several plates of Crinoids, and any which may be identical with those described by Dr. Troost will be accredited to him. We regret exceedingly this long delay in the publication of the labors of one so highly esteemed in life and gratefully remembered in death. It has, however, been caused by circumstances over which we had no control, and which have given us considerable disquietude.

The new and extended series of Meteorological and Physical Tables, which has been in course of preparation for several years, is at length completed and ready for distribution. It forms a volume of 634 large octavo pages, which may be divided into separate parts, each distinct in itself. A copy of these tables will be sent to each of the meteorological observers, and it is believed that a considerable number may be sold in this country and Europe, from which something may be derived towards compensating the author, Prof. Guyot, for the unwearied labor and attention he has bestowed upon the work.

At the request of the Institution, Baron Osten Sacken, of the Russian legation, who has made a special study of Dipterous Insects has prepared a catalogue of the previously described species of this continent, analogous to that of Melsheimer's catalogue of the Cleoptera of the United States, which was published some years ago by this Institution.

It frequently happens that the same animal is described by different naturalists under different names, and there may be among the species enumerated in this catalogue some of this character, but in the present state of the knowledge of American Diptera the publication of a complete synonymical catalogue is impossible. Yet a list like the one just completed is an indispensable preparatory work for the future study of this branch of entomology. The catalogue includes the species inhabiting not only the North American continent in general, but also those in Central America and in the West Indies. It also gives the principal localities where each species has been found. In a list like this, says the author, completeness is the principal merit; the symmetrical arrangement is but of secondary importance.

The groups adopted by Meigen and Wiedemann are retained, avoiding the subdivisions introduced by modern authors.

The publication of this list, we trust, will very much facilitate the study of entomology, and it is a special object of this Institution to encourage individuals to devote themselves to particular subjects of research. The field of nature is so extended that unless it be minutely subdivided, and its several parts cultivated by different persons, little progress of a definite character can be anticipated. To collect the materials for wider generalizations, microscopic research is necessary in every direction, and men enthusiastically devoted to one object are required in every branch of knowledge in order that the whole may be perfected. It is true, before entering on an investigation of this kind, that it is desirable for the individual to have a general knowledge of the different branches of science, since they are all intimately connected; and the student can then narrow his field of view until it comes within the scope of his mental abilities, or the means which he may have at his disposal for its advancement. As a general rule, however, the ability to enlarge the bounds of science can only be obtained by almost exclusive devotion to a few branches.

It is scarcely possible to estimate too highly, in reference to the happiness of the individual as well as to the promotion of knowledge, the choice in early life of some subject to which the thoughts can be habitually turned during moments of leisure, and to which observation may be directed during periods of recreation, relative to which facts may be gleaned from casual reading, and during journeys of business or of pleasure. It is well that every one should have some favorite subject of which he has a more minute knowledge than any of his neighbors. It is well that he should know some one thing profoundly, in order that he may estimate by it his deficiencies in others.

In this connexion it may be proper to remark that the association of individuals in the same community, each with a special and favorite pursuit, each encouraging the others, each deferring to the others, and each an authority in his own specialty, forms an organization alike valuable to the individual, the community, and the public generally. To induce and encourage the establishment of such associations is one of the objects of the Institution. It is suprising what interest may be awakened, what amount of latent talents developed, and what dignity imparted to the pursuits of a neighborhood by a society in which the knowledge of each becomes common property, and the labors of each one are stimulated by the appreciation and applause of his fellows.

I am acquainted with no plan of adult education better calculated to elevate the mental character of a community or to develop the local natural history of a district than that of a well organized and efficiently conducted association of this kind. Such establishments, I am happy to say, are now becoming common in every part of the United States. They have taken the place, in many cases, of the debating societies, which were formerly instituted for mental improvement. To the latter it might justly be objected that they tend to promote a talent of sophistical reasoning, rather than to engender an uncompromising love of truth. The habit of fluent speaking may undoubtedly be cultivated at the expense of profound thought, and however promotive at times of the temporary interests of the individual, can never be supposed to tend to the permanent advancement of the species.

Meteorology.—The system of meteorological observations under the direction of the Institution and the Patent Office has been so repeatedly described in previous reports that it will scarcely be necessary to give any more at this time than an account of the present state of the work. The system was commenced in 1849, and has since then been gradually improving in the number of observers, character of the instruments, and the precision with which the records are made. The Institution has awakened a wide interest in the subject of meteorology, and has diffused a considerable amount of information with regard to it which could not readily be obtained through other means. The manufacture of instruments, compared with standards furnished by the Institution from London and Paris, has been an important means of advancing the science. The work is still continued by James Green, 173 Grand street, New York, and during the past year an increasing number of full sets has been purchased by observers. The Institution has continued to distribute rain-gages, with which observations are now made on the quantity of aqueous precipitation in nearly every State and Territory of the Union.

We are indebted to the National Telegraph line for a series of observations from New Orleans to New York, and as far westward as Cincinnati, Ohio, which have been published in the "Evening Star," of this city. These reports have excited much interest, and could they be extended further north, and more generally to the westward, they would furnish important information as to the approach of storms. We hope in the course of another year to make such an arrangement with the telegraph lines as to be able to give warning on the eastern coast of the approach of storms, since the investigations which have been made at the Institution fully indicate the fact that as a general rule the storms of our latitude pursue a definite course.

The materials which have been collected relative to the climate of the North American continent are as follows:

1st. A miscellaneous collection of MSS. and other tables relative to the climate of the United States. This series will be enriched by a reference list to all the meteorological records, which are to be found in the extensive library of Mr. Peter Force, of this city, and other accessible sources of information.

2d. The observations made under the direction of this Institution since 1849.

3d. A series of observations made by Dr. Berlandier in Mexico.

4th. Observations made in the British possessions.

5th. The record of observations made by government and other exploring expeditions.

6th. Copies of the observations made under the direction of the Surgeon General at the military posts.

7th. Copies of the observations made at the expense of the States of New York, Massachusetts, Pennsylvania, Maine, and Missouri.

8th. A series of observations from Bermuda and the West Indies.

Besides these, the Institution is endeavoring to obtain, by means of its exchanges, a full series of all observations which have been made in foreign countries, and to form a complete meteorological library.

Complaint has been made on account of the delay in publishing deductions from the materials which have thus been collected, but, with the limited means of the Institution, it should be recollected that all objects enumerated in the programme of organization cannot be simultaneously accomplished. The reductions have been steadily pursued for the last five years, and all the funds, not otherwise absolutely required, have been devoted by the Institution to this object.

It will be a matter of astonishment to those not practically acquainted with the subject, to be informed as to the amount of labor required for the reduction of the returns made to this Institution for a single year. During 1856 the records of upwards of half a million of separate observations, each requiring a reduction involving an arithmetical calculation, were received at the Institution. Allowing an average of one minute for the examination and reduction of each observation, the amount of time consumed will be nearly 7,000 hours, or, at the rate of seven hours per day, it will be 1,000 days or upwards of three years, or, in other words, to keep up with the reduction of the current observations the whole available time of three expert computers is required. This is independent of the labor expended in the correspondence, preparation and distribution of blank forms, and the deduction of general principles. The work has been prosecuted, therefore, as rapidly as the means at the disposal of the Institution would permit. Since the arrangement was made with the Patent Office, from twelve to fifteen persons, many of them females, have been almost constantly employed, under the direction of Prof. Coffin, in bringing up the arrears and in reducing the current observations.

All the materials collected at the Institution are in the process of being arranged and bound in accessible volumes, with proper indices, to be used by all who may be desirous of making special investigations on any point relative to the climate of this country.

During the past year the reductions for 1855 were printed in pamphlet form and distributed to observers for criticism and suggestions as to improvements which might be adopted in the subsequent publication of the entire series.

Exchanges.—The system of international exchange has been carried on during the past year with unabated zeal, and we trust with undiminished good results. A large amount of scientific material has passed through our hands in its transfer to and from societies and individuals in this and other countries. The returns made to the Institution during 1857 for its own publications consist of 555 volumes, 1,067 parts of volumes, and 138 charts. These works embrace most of the current volumes of scientific transactions, and are of the highest importance as aids in original research. The number would be very much increased if the contents of several large cases, which were accidentally delayed until the beginning of this year, were included.

The importance of the exchanges is not to be estimated by the commercial value alone of the books received. In addition to this we must consider the effect which it produces in bringing into immediate communication the cultivators of literature and science in this country with those abroad, of distributing among our societies publications of a class, the existence of which would scarcely otherwise be known, and of facilitating the diffusion of knowledge which, by the ordinary modes of transmission, would not be attained, except, perhaps, in the course of years.

The system has now attained a great development, and increases measurably every year. The expenses hitherto have been principally borne by the Institution, but their amount has now become so great as seriously to interfere with other operations, and I therefore think it advisable that a charge be made, to the parties receiving a certain amount of packages annually, sufficient to reimburse some of the outlay of the Smithsonian funds. What would not be felt by each one individually would, in the aggregate, materially lessen the burden of expense connected with this part of the operations, which amounted, in 1857, to about $3,000.

The expenses of the Smithsonian exchanges would be considerably greater than they are but for the liberality of various transportation companies in carrying packages free of cost. No charge on freight is made by the United States Mail Steamship Company, the Panama Railroad, or the Pacific Mail Steamship Company, forming the mail line from New York to San Francisco, while the agents of the line in these two cities, Messrs. I. W. Raymond and A. B. Forbes, serve the Institution in various ways. The California Express Agency of Wells, Fargo & Co., has also acted with the greatest liberality, and the same should be stated of the old line of Bremen and New York steamers. None of the domestic agents of distribution—namely, Hickling, Swan & Brewer, of Boston; D. Appleton & Co., New York; J. B. Lippincott & Co., Philadelphia; John Russell, Charleston; B. M. Norman, New Orleans; Dr. Wislizenus, St. Louis; H. W. Derby, Cincinnati; and Henry P. B. Jewett, of Cleveland—make any charge for services; and the same may also be said of Messrs. Oelrichs & Lürman, of Baltimore.

The amount of labor involved in the exchanges is, of course, very great, as will be readily inferred from an examination of the tables of receipts and transmissions during the past year, given by Professor Baird. The entries in the several record books fill over 700 pages; the circulars, invoices, and acknowledgments, exceed 4,300, in addition to over 600 receipts for packages. For a detailed account of all the operations of the exchanges I would refer to the accompanying report of Professor Baird.

Explorations, researches, &c.—It was stated in the last report that the magnetic instruments belonging to the Institution were given in charge of Baron Müller, for investigations in Mexico and Central America. Two series of records of observations have been received, but for nearly a year past nothing further has been heard from the expedition. We should regret the loss of the instruments, although the cost of them has been more than repaid by the services they have rendered to science in the Arctic expedition under Dr. Kane, and in the results which have already been obtained from them in Mexico.

The self-registering apparatus in the observatory on the Smithsonian grounds, established at the joint expense of the Coast Survey and the Institution, has continued to record the variations in the horizontal direction of the magnetic force during a considerable portion of the past year. The interruptions which have taken place have been principally caused by the impurities of the city gas, the exhalations from which have interfered with the photographic process. The records obtained, however, will furnish valuable data for studying, in connexion with similar observations in other parts of the globe, the character of the magnetic force, and to assist in determining how far the changes are merely local, or to what extent they affect the whole earth.

Laboratory.—During the past year the laboratory has been under the charge of Dr. E. W. Hilgard, recently appointed State geologist of Mississippi. Among others, a series of experiments was made by him, under direction of the Secretary, at the expense of the Navy Department, relative to the vapor from a modification of bi-sulphuret of carbon as a substitute for steam applied to mechanical purposes. The result of these investigations was unfavorable to the substitution of this material in the way proposed. Although a greater amount of pressure is produced at the same temperature than in the case of steam, yet the amount of work relative to the absolute quantity of heat employed is by no means in accordance with this, the density of the vapor and its greater specific heat require a corresponding amount of fuel, and when we consider the fact that the bi-sulphuret of carbon is not a natural but a factitious substance, of which the vapor, when combined with air, is highly explosive and extremely offensive on account of its odor and the greater complexity of the engine required for its use, its application in the place of steam would be far from advantageous.

Another series of investigations was conducted in the laboratory relating to the prevention of counterfeiting bank notes, particularly by photography; but as this was intended especially for private use, the expenses were paid by the parties interested.

The Institution does not consider it a part of its duty to volunteer an opinion as to the practicability of the new projects with which the public mind is frequently agitated; but when directly called upon by the government or other parties of influence to pronounce a judgment on any point of practical or applied science, it does not shrink from the responsibility, but, after diligent and cautious inquiry, gives the conclusions, whatever they may be, at which it has arrived.

Library.—Extensive alterations are in the process of being made in the wing of the building appropriated to the library, for the better accommodation of the books. The shelving has been arranged in two stories of alcoves, thereby more than doubling the space. Each lower alcove is separately secured by a door; a precaution which has been found necessary in the library of the Institution as well as in that of Congress. It is a fact to be regretted, but which it is necessary to mention in order to vindicate the restrictions imposed upon an indiscriminate access to the books, that there is in some quarters a lamentable want of honesty with regard to the use of property of a public character. Not only are works in many cases mutilated, merely to avoid the labor of copying a few pages, but valuable sets are sometimes broken by actual theft.

The appropriation for the library must not alone be measured by the sum assigned for the "cost of books;" it must be recollected that the library is principally increasing by means of the exchanges; that every year the Institution sends abroad, besides all the public documents which it can procure, some hundreds of copies of the quarto volumes of its transactions, the marketable value of which is several thousand dollars. It therefore ought to be distinctly understood that the library is constantly increasing by the addition of the most valuable series of the transactions of literary and scientific societies in all parts of the world, and that this is at the expense of what are denominated the active operations of the Institution. It is true the number of books directly purchased is comparatively small, but indirectly procured in the way stated the annual addition is valuable.

Among the numerous donations received during the past year it is of course impossible in this report to particularize more than a few of the most important. The Academies of Science of Vienna, St. Petersburg, and of Brussels, have all contributed largely both of their older and more recent issues. The Real Sociedad Economica, of Havana, has been particularly liberal in this respect, furnishing nearly complete series for many years back, as have also the Horticultural societies of Paris and Berlin. The most extensive single gift during the year has been that of the Dictionnaire des Sciences Naturelles, in 72 volumes, and the Histoire Naturelle des Mammirfèes, of Buffon and Daubenton, in 15 volumes, from the Herzogliche Bibliothek der

Friedensteinschen Sammlungen, Gotha. The British Admiralty has contributed a full set of all the charts published by it during the year, We may also mention, as an object of special interest of this class, a valuable set of historical maps, presented by Justus Perthes, the celebrated geographical publisher of Gotha, exhibiting the political condition of Europe from the beginning of the third century down to the time of the crusades. The limits of the several empires are exhibited by different colors, and the whole are on such a scale as to be adapted for instruction in schools or academies. To render this interesting work more generally known in this country, it is proposed to exhibit the maps in the reading room and to translate and print the pamphlet of explanations for the use of the visiters to the Institution.

Among the curiosities of the library received during the past year the most prominent is an ornamental album, presented through the Department of State, from Miss Contaxaki, a native of the isle of Crete. This work was designed as a contribution to the universal exhibition at Paris in 1855, where it received a diploma for the artistic merit displayed in its execution. The "Classical Bouquet," as it is called, consists of illustrations of the principal monuments and places in Greece, to which are added a few from the author's native isle of Crete. These illustrations are accompanied by quotations from the most illustrious Greek authors, beautifully illuminated, while many of the pages are adorned with pressed flowers culled from the places which the drawings represent. The book itself is a large quarto, covered with blue velvet heavily embroidered, and lettered with silver. It is inclosed in a case, made of olive wood of the country, about a foot and a half square, richly carved and ornamented with appropriate devices. This work was transmitted to the United States through Charles C. Spence, esq., and affords a favorable specimen as well of the present state of the arts in that country, which was the birthplace of the true and the beautiful, as of the talents, the taste, and the unwearied industry of the lady who devised and principally executed it.

The library possesses an extensive collection of pamphlets, including the separate theses of the candidates for graduation or honors at the German universities; also a series of the annual reports of the public institutions and societies in this country. During the past year these have been classified, a large number of them bound, and the remainder arranged in pasteboard boxes, labeled and placed on the shelves as volumes.

The binding of the books received through exchange continues to be a large item of expense, and we have devoted the remainder of the appropriation for the library, not expended in the purchase of books or for clerical service, to this object.

In relation to the books received by the copyright law, I have but little to say in addition to what has been stated in preceding reports. The provisions of the act are still disregarded, to a considerable extent, by the larger publishers, and, as a general rule, works are received of but little value in themselves and inconsistent with the character of the library of the Institution. Though the cost of postage has been diminished by the law of Congress authorizing the free transmission of copyrights, yet it has by no means exempted the Institution from a large item of expense on this account. The publishers frequently inclose within the packages letters relating to the proper direction of the certificates and other matter pertaining to the copyright, and by a decision of the Post Office Department all such communications are charged with letter postage. Though the sum in each case appears insignificant, yet in the aggregate it may amount, in the course of a year, to several hundred dollars; and since the system from the beginning has been of no real benefit to the Institution, we have addressed a circular to each publisher who forwards a copyright and neglects to pay the postage on the accompanying letters, apprising him of the fact.

In conclusion, I may state that though the copyright law was undoubtedly intended to enrich the library of the Institution, yet the non-compliance with it of some of the principal publishers, and the reception of a large amount of worthless matter involving expense in its transportation and care has entirely defeated this object. The cost of the system has been at least ten times greater than the value of the books received; nor is this all; a compliance with the act has constantly subjected the Institution to unmerited censure. We have therefore been a loser both in funds and in the friendly feeling of an influential portion of the community, and it is to be hoped that Congress will, at its present session, essentially modify the existing law. The deposit of a single copy of each article in the Patent Office, instead of the three now sent to Washington, would be sufficient to secure the rights of the author, and answer all the objects of a complete collection of this class of American publications.

Museum.—The general plan and objects of the collections which have been assiduously formed through the agency of the Smithsonian

Institution have been given in several of the preceding reports, and it will be sufficient, at this time, to repeat that they are intended to exhibit the distribution and development of the plants and animals, as well as to illustrate the geological and mineralogical character of the North American continent. The number of specimens required for these purposes is great, since all the varieties from every locality require attention. During the past year specimens have been collected by ten government expeditions and six private exploration parties. Some of the returns from these are now on the way, and will greatly enhance the number and value of the materials before received. According to the statement of Professor Baird, hereto appended, the catalogued specimens of animals at the end of the year 1857, amounted to: mammals, 3,200; birds, 8,766; skeletons and skulls, 3,340; reptiles, 239; fishes, 613.

During the year several persons have availed themselves of the use of the collections and library in the prosecution of original researches, and, as usual, several government expeditions, which have been sent out for surveys, the construction of roads and for military purposes, have been provided with instructions as to the mode of collecting specimens and observing meteorological and other natural phenomena. No opportunity of adding to our store of information, in regard to the physical geography and natural history of the western portion of this continent, has been suffered to pass without being improved, and I may safely say, that since the establishment of the Institution more has been done to ascertain and make known the character of the less inhabited portion of our continent than all which had been previously accomplished in this line. The survey of routes from the Gulf of Mexico to the Pacific has served of late to add much to our knowledge of Central America, and during the past year the British government has sent out a party for the exploration of the country north of the limits of the United States and between the great lakes and the Pacific ocean. This survey, in connexion with that along the 49th parallel of latitude, now in progress for determining the boundary line between the United States and the British possessions, will add to the natural history of the northern portion of our territory, and will furnish the data necessary to delineate more accurately the great mountain system which determines the climate and physical peculiarities of the western portion of this continent.

Smithson's personal effects.—The bequest of James Smithson included all his personal effects, and these were obtained by Hon. Richard Rush, the agent of the American government, through whom the legacy was procured. They were delivered by him to the Secretary of State, and afterwards deposited in the museum of the Patent Office, where they remained until the last year, when they were transferred to the Regents' room in the Smithsonian building. They have been arranged for exhibition in a large case of black walnut, and now form an interesting portion of the collections of the Institution. They consist of a very extensive series of rare though minute specimens of mineralogy, of the table service of plate of Smithson, and of the portable chemical and mineralogical apparatus with which he made his investigations. Besides the above mentioned articles, the Institution has had in its possession for several years the library of Smithson, containing 115 volumes, and a collection of manuscripts, principally consisting of what would appear to be the materials of a philosophical dictionary. The whole collection taken together serves to exhibit the character of the man, and clearly to indicate his intention as to the nature of the Institution to which he gave his name. It serves to strengthen the conviction, if anything of this kind were needed, that the proper interpretation of the will has been given by the Regents in adopting the plan which makes active operations, the discovery of new truths, and a diffusion of these among men, the prominent object of the establishment.

In this connexion, it may be interesting to repeat a statement made in a former report, that the Institution is in possession of two likenesses of Smithson; one, a portrait of him while a youth, in the costume of a student at Oxford, the other a medallion, from which a steel engraving has been executed. The first was purchased from the widow of John Fitall, the servant of Smithson, and the other was among his effects, and identified by a paper attached to it, on which the words "my likeness" were written in Smithson's own hand. A list of the papers published by Smithson, and a record of all the facts which could be gathered in relation to him, have been made, to serve hereafter for a more definite account of his life and labors than has yet appeared.

Gallery of Art.—During the past year this apartment of the Smithsonian building has been enriched by a faithful copy, in Carrara marble, of the "Dying Gladiator," one of the most celebrated statues of antiquity. This copy, which is said to be the only one in marble in existence, has been deposited here by its owner, F. W. Risque, esq., of the District of Columbia, to whom the public of this country is indebted for his liberality in the purchase and free exhibition of so costly and interesting a specimen of art. It is by Joseph Gott, an English sculptor of high reputation, and its faithfulness, as a representation of the original, is vouched for by a certificate, among others, from our lamented countryman, Thomas Crawford.

The Stanley collection of Indian portraits, which is still in the Gallery, has, during the past year, been increased by a number of new pictures, and continues to be an object of interest to the visitors of the national capital. This collection, now the most extensive in existence, of Indian portraits, ought, as we have stated in previous reports, to be purchased by government. It is a sacred duty which this country owes to the civilized world to collect everything relative to the history, the manners and customs, the physical peculiarities, and, in short, all that may tend to illustrate the character and history of the original inhabitants of North America. The duty which Mr. Stanley owes to his family will not permit him to retain the collection unbroken, and unless Congress make an appropriation for its purchase, he will be obliged to dispose of it in portions. Such an event would be a lasting source of regret; and, from the interest which a number of distinguished members of the Senate and House of Representatives have expressed in regard to the purchase, we doubt not that the proposition will in due time be favorably entertained.

Lectures.—During the past season the usual number of lectures has been given, without any diminution in the size of the audience and the apparent interest of the public.

In connexion with this subject, we may mention, complaints have frequently been made against the Institution, on account of the bad condition of the walks leading to the building ; but it should be recollected that the grounds belong to the government and are not under the control of the Regents. A plank walk has, however, been laid down along the principal thoroughfare and lighted, on nights of lectures, at the expense of the Institution.

The Smithsonian lecture-room is found to be the most commodious apartment in the District for public meetings, and almost constant applications are made for its use. This is granted in all cases, provided the actual expense of lighting, heating and attendance be paid, and the object for which it is required be consistent with the character of the Institution, and not merely intended to advance individual interests. The rule which excludes from the lectures any subject connected with sectarianism, *discussions in Congress* and the political questions of the day, has been strictly observed.

The following is a list of the lectures which were delivered during the winter of 1857–'58:

Seven lectures by Professor John LeConte, of the South Carolina College, on "The Physics of Meteorology."

One lecture by Hon. H. W. Hilliard, of Alabama, on the "Life and Genius of Milton."

Two lectures by Dr. I. I. Hayes, of Philadelphia, on "Arctic Explorations."

One lecture by Rev. T. J. Bowen, of Yoruba, Africa, on "Central Africa—the Country and People."

One lecture by D. K. Whitaker, esq., of Charleston, S. C., on the "Genius and Writings of Sir Walter Scott."

Two lectures by Professor C. C. Felton, of Harvard College, Cambridge, Mass., on "Modern Greece."

Four lectures by Dr. James Wynne, of New York, on the "Duration of Life in Various Occupations."

Three lectures by Professor J. P. Espy, on "The Law of Storms."

Five lectures by Rev. J. H. McIlvaine, of Rochester, N. Y., on "Comparative Philology in some of its bearings upon Ethnology, and embracing an account of the Sanscrit and Persian Arrowhead Languages."

Three lectures by G. Gajani, on "The Catacombs, the Coliseum, and the Vatican of Rome."

One lecture by Professor Schele de Vere, of the University of Virginia, on "John Law and the Celebrated Mississippi Speculation."

From the foregoing statements we think it will be generally acknowledged that the Institution is steadily pursuing a course of usefulness well calculated to make the name of its founder favorably known and the results of his bequest highly appreciated in every part of the civilized world, that its funds are in a good condition, and that the prospect of its future influence in the promotion of knowledge is even more cheering than at any period of its past history.

Respectfully submitted.

JOSEPH HENRY,
Secretary S. I.

WASHINGTON, *January*, 1858.

APPENDIX TO THE REPORT OF THE SECRETARY.

SMITHSONIAN INSTITUTION,
Washington, December 31, 1857.

SIR: I have the honor, herewith, to present a report, for 1857, of the operations you have entrusted to my charge, namely, those which relate to the printing, to the exchanges, and to the collections of natural history.

Respectfully submitted.

SPENCER F. BAIRD,
Assistant Secretary Smithsonian Institution.

JOSEPH HENRY, LL.D.,
Secretary Smithsonian Institution.

PUBLICATIONS.

The publications of the Institution for the year consist of the ninth volume of Smithsonian Contributions to Knowledge, embracing 484 pages of quarto text and 22 plates, and of the annual report to Congress, an octavo volume of 468 pages. Considerable progress has also been made with the printing of the tenth volume of Smithsonian Contributions, 136 pages and five plates being finished.

The catalogue of North American Diptera, by Baron Ostensacken, is nearly through the press and will include 112 octavo pages.

EXCHANGES.

The system of international exchanges so successfully prosecuted by the Institution since its establishment has been carried on during the year with the happiest results. A large amount of scientific material has passed through its hands and has been promptly transmitted to its destination. The general details of the system will be presented hereafter.

The returns made to the Smithsonian Institution for its own donations will be found in the following table:

A.—*Receipt of books, &c., by exchange in* 1857.

Volumes—	Octavo	404	
	Quarto	146	
	Folio	5	
			555
Parts of volumes and pamphlets—	Octavo	775	
	Quarto	255	
	Folio	37	
			1,067
Charts and maps			138
			1,760

The works received embrace most of the current volumes of scientific transactions, with some back series, and are of the highest importance as materials of scientific research.

In the following tables are exhibited the chief statistics of exchange during both 1856 and 1857. The last annual report did not fully cover the subject, owing to the fact that a supplementary sending was required in January, 1857, to complete that of July, 1856, and a report for 1856 could not reasonably include what was actually not performed till the ensuing year. In presenting the series of tables throughout, those of transmissions for 1856 are to be understood as embracing parcels forwarded in January 1857. This will explain the apparent disproportion in amount for the two years, as much of what was sent in the beginning of 1857 would otherwise not have gone until the ensuing summer.

B.

Table showing the statistics of foreign exchanges of the Smithsonian Institution in 1856.

Distributed through—	Principal addresses of parcels.	Addresses of sub-parcels inclosed.	Total of addresses.	Number of principal packages.	Number of sub parcels inclosed.	Total of parcels.	Number of boxes used.	Bulk of boxes in feet.	Weight of boxes in pounds.
. *Dr. F. Flügel, Leipsic.*									
Sweden	8	21	....	22	25	....	......	......	....
Norway	5	7	....	13	7	....	......	......	....
Iceland	1	......	....	3	......	....	......	......	....
Denmark	6	19	....	17	25	....	......	......	....
Russia	25	29	....	73	32	....	......	......	....
Holland	17	17	....	46	18	....	......	......	....
Germany	155	193	....	414	240	....	......	......	....
Switzerland	15	20	....	39	21	....	......	......	....
Belgium	9	15	....	29	18	....	......	......	....
Total	241	321	562	656	386	1,042	42	310	10,428
2. *H. Bossange, Paris.*									
France	79	120	....	187	142	....	......	......	....
Italy	42	33	....	95	33	....	......	......	....
Spain and Portugal	6	1	....	14	1	....	......	......	....
Total	127	154	281	296	176	472	13	126	4,129
3. *The Royal Society and H. Stevens, London.*									
Great Britain and Ireland	117	231	348	260	253	513	9	94	2,914
4. *Other channels*	26	10	36	39	10	49	6	26	800
Grand total	511	716	1,227	1,251	825	2,076	70	536	18,271

C.

Table showing the statistics of foreign exchanges of the Smithsonian Institution in 1857.

Distributed through—	Principal addresses of parcels.	Addresses of sub-parcels inclosed.	Total of addresses.	Number of principal packages.	Number of sub-parcels inclosed.	Total of parcels.	Number of boxes used.	Bulk of boxes in cubic feet.	Weight of boxes in pounds.
1. *Dr. F. Flügel, Leipsic.*									
Sweden	9	15	......	22	23	......	......	......	......
Norway	5	4	......	10	7	......	......	......	......
Iceland	1	......	......	3	......	......	......	......	......
Denmark	6	10	......	12	16	......	......	......	......
Russia	25	20	......	47	37	......	......	......	......
Holland	17	9	......	32	12	......	......	......	......
Germany	142	160	......	293	232	......	......	......	......
Switzerland	15	20	......	28	26	......	......	......	......
Belgium	7	16	......	18	29	......	......	......	......
Total	227	254	481	465	382	847	19	183	6,928
2. *H. Bossange, Paris.*									
France	69	63	......	114	77	......	......	......	......
Italy	32	24	......	51	32	......	......	......	......
Spain	5	......	......	10	......	......	......	......	......
Portugal	2	1	......	3	1	......	......	......	......
Total	108	88	196	178	110	288	6	63	2,410
3. *The Royal Society and H. Stevens, London.*									
Great Britain and Ireland	121	108	229	233	158	390	10	118	3,910
4. *Other channels*	49	10	59	90	10	100	5	20	1,000
Grand total	505	460	965	965	660	1,625	40	384	11,248

D.—*Packages received by the Smithsonian Institution for foreign distribution in* 1856 *and* 1857.

	No. of packages	
	1856.	1857.
Albany, N. Y.—		
New York State Agricultural Society	5	43
New York State Medical Society	6	--------
Prof. James Hall	8	--------
Baltimore, Md.—		
Philip R. Uhler	25	--------
Baton Rouge, La.—		
Institution for Mutes and Blind	18	--------
Boston, Mass.—		
American Academy of Arts and Sciences	392	98
Boston Society of Natural History	65	56
Historic-Genealogical Society	1	--------
Prison Discipline Society	32	--------
Dr. Warren	5	--------
B. Homer Dixon	--------	7
W. H. Dixon	5	--------
Ed. Jarvis	--------	84
Ed. Tuckerman	--------	10
W. H. Prescott	8	--------
Heirs of Amos Binney, M. D	--------	49
Cambridge, Mass.—		
American Association for Advancement of Science	28	--------
Cambridge Observatory	--------	210
J. D. Runkle	50	--------
Prof. Asa Gray	1	32
Prof. D. Treadwell	200	--------
Charleston, S. C.—		
Dr H. W. Ravenel	2	--------
Chicago, Ill—		
Col. J. D. Graham, U. S. A	--------	66
Cincinnati, Ohio—		
M. L. Knapp, M. D	24	--------
D. Vaughan	24	------
Columbus, Ohio—		
Ohio State Board of Agriculture	--------	274
Frankfort, Ky.—		
Geological Survey of Kentucky	--------	50
Georgetown, D. C.—		
Georgetown College	2	--------
Granada, Nicaragua—		
President Rivas	100	--------
Hartford, Conn.—		
Hon. Henry Barnard	283	--------
Mr. Potter	22	--------
Lansing, Mich.—		
Michigan State Agricultural Society	50	--------
Lebanon, Tenn.—		
Prof. Safford	--------	6
Lowell, Mass.—		
James B. Francis	16	--------
Madison, Wis.—		
Wisconsin State Agricultural Society	--------	14
Historical Society of Wisconsin	--------	40
New Brunswick, N. J.—		
Prof. Geo H. Cook	--------	5

D—Continued.

	No. of packages.	
	1856.	1857.
New Haven, Conn.—		
American Journal of Science	48	20
American Oriental Society	4	--------
Prof. D. Olmsted	10	7
New York—		
American Geographical and Statistical Society	--------	57
New York Lyceum of Natural History	86	--------
Prof. W. Gibbs	--------	90
Philadelphia, Pa.—		
American Philosophical Society	42	79
Academy of Natural Sciences	300	173
Central High School of Philadelphia	100	100
Historical Society of Pennsylvania	4	--------
Pennsylvania Institute for the Blind	45	53
Philadelphia Library Company	19	--------
Dr. Horner, U. S. N	100	--------
Isaac Lea	171	178
Dr. Joseph Leidy	134	47
Dr. J. A. Meigs	--------	44
Providence, R. I—		
State of Rhode Island	--------	6
St. Louis, Mo—		
St. Louis Academy of Science	--------	161
Dr. B. F. Shumard	12	--------
San Francisco, Cal—		
California Academy of Natural Sciences	50	--------
Santiago, Chile—		
University of Chile	140	--------
Savannah, Ga—		
Dr. Jos. Jones	50	--------
Toronto, Canada—		
Canadian Institute	--------	17
Washington, D. C.—		
U. S. Patent Office	250	250
Ordnance Bureau	46	--------
U S Coast Survey	67	497
National Observatory	--------	73
Light-House Board	3	--------
Secretary of War	120	114
Surgeon General	--------	50
Major W. H. Emory, U. S. A	96	--------
W. P. Blake	50	--------
Dr. J. S. Newberry	20	--------
Lieut. J. C. Ives, U. S. A	18	--------
Lieut. G. K. Warren, U. S. A	20	--------
Lieut. J. M. Gilliss, U. S. N	--------	25
Wm. Stimpson	--------	50
J. C. G. Kennedy	--------	50
W. J. Rhees	--------	100
Miscellaneous	133	120
Total	3,510	3,397
Supposing each parcel to contain an average of one and a half pieces, the number of these would be	5,265	5,095
Add of Smithsonian volumes and memoirs, about	2,500	2,500
Add volumes of public documents obtained and distributed, about	1,500	1,000
Approximate total of volumes and pamphlets sent abroad by the Institution	9,265	8,595

E.—*Addressed packages received by the Smithsonian Institution from Europe, for distribution in America.*

	No. of packages.	
	1856.	1857.
Albany, N. Y.—		
New York State Library	9	9
Boston, Mass.—		
American Academy of Arts and Sciences	42	53
Boston Society of Natural History	30	39
Bowditch Library	1	--------
Cambridge, Mass.—		
American Association for Advancement of Science	7	7
Cambridge Astronomical Journal	24	19
Cambridge Observatory	9	9
Harvard College	22	19
Charleston, S. C.—		
Literary and Philosophical Society	2	--------
Columbus, Ohio—		
Ohio State Board of Agriculture	14	24
Georgetown, D. C.—		
Georgetown College	3	--------
Lansing, Mich.—		
Michigan State Agricultural Society	8	13
Madison, Wis—		
Wisconsin State Agricultural Society	22	22
New Haven, Conn.—		
American Journal of Science	5	5
American Oriental Society	1	--------
New Orleans, La.—		
New Orleans Academy of Natural Sciences	12	16
New York—		
American Geographical and Statistical Society	24	19
New York Lyceum of Natural History	24	25
Philadelphia, Pa.—		
American Philosophical Society	74	55
Academy of Natural Sciences	57	62
Franklin Institute	9	7
San Francisco, Cal.—		
California Academy of Natural Sciences	4	19
Santiago, Chile—		
University of Chile	1	6
Observatory	2	7
Washington, D. C.—		
U. S. Patent Office	37	57
National Institute	3	3
Bureau of Ordnance and Hydrography	1	3
U. S. Coast Survey	27	24
National Observatory	23	63
Surgeon General	1	--------
United States Agricultural Society	2	--------
Library of Congress	17	10
Worcester, Mass—		
American Antiquarian Society	1	--------
Miscellaneous addresses, institutions	437	330
Individuals	318	320
Total	1,245	1,273

In addition to the above, 142 volumes were received from five European institutions for distribution to such addresses as might be selected by the Smithsonian.

DETAILS OF THE SYSTEM OF EXCHANGES.

As the system of international exchange now carried on by the Smithsonian Institution has attained a very great development, a sketch of the mode of conducting it may not be amiss at the present time. The subject may be considered under two heads, one relating to the parcels received from parties in the United States for transmission to foreign countries, and the other having reference to receipts from abroad for institutions and individuals in America. In connexion with this subject, it may be stated that a large room in the Institution, measuring 70 feet by about 25, is devoted to the department of exchanges, and, besides containing the stock on hand of Smithsonian publications and of miscellaneous documents, is fitted up on one side with a series of large binns, each one devoted to a particular portion of the world, and appropriately labelled. The floor of the room is occupied by a series of long tables, five feet wide, on which parcels are made up or unpacked. Printed addresses are arranged in small pigeon holes, and include nearly all the correspondents of the Institution, domestic and foreign, amounting, at the present time, to nearly one thousand names.

Operations connected with transmissions from the United States.—The transmissions of the Smithsonian Institution are regulated, in a measure, by the time when the annual volume of Smithsonian Contributions is completed. One or two months before this time, a circular letter of advice is transmitted to all the institutions and individuals in the United States and the Canadas known or supposed to have a desire to avail themselves of the facilities of the Smithsonian system of exchanges, and the conditions stated upon which parcels will be received. If any society or individual have published a work likely to be of interest to the scientific and literary world abroad, and no indication is given of an intention to distribute copies, a special application is made for them, and no effort left untried to secure to the foreign investigators the benefit of all original and useful American material. Such appeals are generally responded to very favorably, and very many publications of the different bureaus of the government, of States, and of State agricultural and historical institutions, of societies, and of individuals, have thus been obtained.

In nearly all cases, in the first instance, at least, the Smithsonian Institution is called on to furnish lists of suitable foreign recipients for the publications just referred to, or the volumes are sent in bulk, to be addressed here. After the first sending, the exchange is usually more directly between the parties corresponding, the Institution preferring to have the parcels properly addressed before forwarding to Washington. In all cases great care is taken to secure the credit of the donation to the proper party, and to prevent it being supposed to come directly from the Institution.

To facilitate the selection of suitable recipients for donations or exchanges, the Institution publishes once in two years a carefully prepared list of foreign institutions for general distribution. The last one issued contains over 570 names, but manuscript additions bring the number up to about 700. The list of individuals is nearly as large as that of institutions.

To facilitate the selection of recipients for particular works, of which a limited number of copies only may be available for distribution, classified lists of institutions are kept, as of academies of science generally, and of societies devoted to special subjects, as geography, geology, zoology, botany, ethnology, statistics, &c., and these are arranged from No. 1 upwards, in the order of relative importance, or of equable distribution among the centres of learning; thus six copies of any work on hand would be assigned to the first six names on the list of institutions most interested in it.

The parcels, as received from the different portions of North America, are placed, after being addressed, (if not so already,) in their appropriate receptacles, and the list entered specifically in a record book. To facilitate such entry, a detailed invoice of each transmission is required, and the failure to furnish it puts the institution to the great trouble of making it from the books themselves.

When the parcels have all been received, a list of the different donors is printed, together with the titles of the various works which the institution has for distribution at the time. On the day assigned for commencing the labor of making up the packages, the binns are emptied successively, the contents arranged carefully on the counters, so as to bring everything for one address together, the Smithsonian donations are added, and each particular piece is checked off in the printed blank just referred to. This rough invoice is numbered and handed to the packers, who make up the volumes into one or more bundles, and mark them with the number of the invoice, by which means they are easily identified and labelled. When parcels or books are addressed to individuals, these are usually inclosed in the bundles of the societies to which they belong, the number and addresses of such sub-packages being marked on the rough invoices. A correct copy is made of these lists, and forwarded by mail or otherwise to the parties, in which is also stated the nature and time of the transmission. These invoices are finally posted, to the debit of the party addressed, in a large ledger, which shows what each has had, and what return has been made to the Institution. The record of each package is, therefore, made four times.

In sending the invoice of the package for each address, a circular is added explaining the objects of the transmission, and the conditions on which the exchange will be continued.

The time occupied in invoicing and making up the packages varies with the occasion, although a month is usually required to finish the work. After the bundles are all made up, those for each agent are brought into one heap, and they are then packed into boxes, a check list being kept of the numbers placed in each box.

There are three principal agents in Europe who have charge of the Smithsonian exchanges in their respective regions: Dr. Felix Flügel, resident in Leipsic, has charge of continental Europe, with the exception of France, Italy, Spain, and Portugal, (which are supplied by Hector Bossange, of Paris,) and of Greece and Turkey. Henry Stevens, of London, is agent for Great Britain and Ireland. Greece and Turkey are usually reached through the American minister at Constantinople and the consul at Alexandria. Most of the points in Asia and Africa are supplied through the Presbyterian Board of Foreign Missions in New York, and the American Board in Boston, Australia through Mr. I. W. Raymond, of New York, and South America through a variety of channels.

The boxes for the agents above mentioned, containing the different parcels, are then sent from the Institution; those for Dr. Flügel being shipped from Baltimore, through Oelrichs & Lürman, direct to Bremen, thence by railroad to Leipsic. The boxes for Messrs. Bossange and Stevens are shipped by packet from New York.

The governments of Europe to whose ports shipments are made by the Institution have all authorized their admission free of duty, on filing an invoice with the customs authorities some time in advance of the arrival of the boxes. After being received by the agents, these boxes are unpacked, and the different parcels distributed to their destination through the channels selected by the intended recipients, accompanied by circular advices from the agents. In Germany the parcels are usually transmitted through the booksellers of Leipsic, as they may have occasion to send to correspondents in the various towns.

Exchanges from foreign countries for America.—The system of operations in this case is similar in principle to that just described, although the steps take place in inverse order. The packages are sent to the agents of the Institution, who inclose them in boxes, which are forwarded monthly, or oftener. On being received in Washington they are unpacked, an entry made of their contents, and the parcels placed temporarily in the binns assigned to their respective addresses. They are then assorted, those for each party made up into one bundle, and thus forwarded, by express or otherwise, accompanied by a blank receipt, which is to be signed and returned.

MUSEUM.

A.—*Increase of the Museum.*

The collections in natural history received during the year 1857 have been of great extent, and embrace many important additions to the material on hand for extending the knowledge of the animal, vegetable, and mineral productions of America. The specimens received have been from the usual variety of sources; the most important being, as heretofore, those brought in by the different government expeditions, as follows:

1. *Survey of the northwestern boundary line, Archibald Campbell, esq., commissioner.*—The expedition left in April, 1857, for Puget Sound, and during the year had its main camp for the most part at Simeahmoo bay, near the mouth of Frazer's river. Large collections of the animals and plants of the Sound have been made by Dr. Kennerly, surgeon and naturalist of the expedition; and of minerals and fossils by Mr. George Gibbs, the geologist.

2. *Exploration of the Black Hills and Loup Fork, under Lieutenant G. K. Warren, U. S. A.*—Lieutenant Warren made his third visit to the Upper Missouri and Yellowstone region, accompanied, as on previous expeditions, by Dr. Hayden as geologist and naturalist. Very large collections in all branches of natural history were made and brought home, tending, in great measure, to complete our knowledge of the distribution of species over the high plains of the west.

3. *Wagon road to Bridger's Pass, under Lieutenant F. T. Bryan, U. S. A.*—During his second year's work on this road to Utah Territory, Lieutenant Bryan, as before, was accompanied by Mr. Wm. S. Wood, who continued and completed the collections of the preceding year, in securing many species not previously obtained. Dr. Wm. A. Hammond, U. S. A., who accompanied the party as surgeon, also made a separate and independent collection of much interest, not only on the route, but while stationed at Fort Riley. In this he was for a time assisted by Mr. J. Xantus de Vesey.

4. *Wagon road to California via South Pass, under Wm. M. Magraw.*—This party, accompanied by Dr. James G. Cooper, as surgeon and naturalist, aided by C. Drexler, reached Fort Laramie during the autumn. The collections in all departments were large and important, and were accompanied by copious notes on the species observed.

5. *Survey of the southern boundary of Kansas, under Lieutenant Colonel Johnston, U. S. A.*—A valuable collection of specimens in alcohol was made during the survey by J. H. Clark, esq., astronomer of the expedition.

6. *Survey of the Isthmus of Darien, under Lieutenant N. Michler, U. S. A.*—This expedition, accompanied by Mr. A. Schott and Messrs. Wm. S. and Charles Wood, sailed for Carthagena in October, proceeding thence to the isthmus. While at Carthagena a collection of birds and shells was made and sent to Washington, and others are on their way.

Among government expeditions fitted out in 1857, but from which no collections have yet been received, are the following:

7. *Wagon road route to California via El Paso and Fort Yuma, under Colonel Leech.*—This expedition was accompanied by Dr. McCay and Mr. Hays, both of whom were prepared to make collections in natural history.

8. *Exploration of the La Plata and its tributaries, under Captain Page, U. S. N.*—Christopher Wood doing duty as zoological collector.

9. *Artesian well expedition, on the Llano Estacado, under Captain Pope, U. S. A.*—This is the third expedition to the sterile regions of western Texas, conducted by Captain Pope.

10. *Exploration of the Colorado river, under Lieutenant J. C. Ives.*—This expedition started in September, accompanied by Dr. J. S. Newberry, surgeon and geologist, and H. B. Möllhausen, artist and zoologist. Several collections made by these gentlemen about San Diego are on their way, but have not yet been received.

The more important private explorations from which specimens have been received are as follows:

11. *Region around Fort Tejon, California, by J. Xantus de Vesey.*—The collections made by Mr. Vesey will compare favorably with any obtained under government auspices, and embrace complete series of the animals and plants of the vicinity of Fort Tejon, as far as met with; they also include quite a number of new species.

12. *Southern Illinois and Northern Red river, by R. Kennicott.*—Mr. Kennicott, under a commission from the Northwestern University, at Evanston, Illinois, to procure for its museum a collection of specimens of the natural history of the northwest, visited southern Illinois in the spring, and after exploring the vicinity of Cairo and New Madrid for several months, proceeded to the Red river of the North, within the British possessions, and nearly to Lake Winipeg. The collections made cover all branches of zoology.

13. *Coast of Florida, by G. Wurdemann, United States Coast Survey.*—Mr. Wurdemann's collections were in continuation of those of previous years, and included a great variety of species, among them several birds new to the fauna of the United States.

14. *Red river of the North and of Nelson's river, H. B. Territory, by Donald Gunn, esq.*—A large collection of birds and mammals made in these regions by Mr. Gunn, assisted by Mr. John Isbister, have added much to our knowledge of the distribution of species.

A collection of about 150 species of birds of Arctic America, Mexico, and Guatemala, presented by John Gould, esq., of London, has furnished very important data for comparison and determination of species of the United States.

Of the numerous other collections made it is impossible to give an account here. The detailed list of contributions and donations will, however, furnish additional information on the subject.

In conclusion it may be proper to state, that of the government expeditions mentioned above, that under Mr. Campbell was organized by the State Department; those under Lieutenant Warren, Lieutenant Bryan, Colonel Johnston, Captain Pope, and Lieutenant Ives, by the War Department; those under Mr. Magraw and Mr. Leech, by the Department of the Interior; and those under Captain Page and Lieutenant Michler, by the Navy Department.

In the reception of collections from the California coast, the Institution is under great obligations to the California Mail Steamship Line, composed of the United States Mail Steamship Company, the

Panama Railroad Company, and the Pacific Steamship Company, as also to Messrs. Wells, Fargo, Co., for free transportation of very many boxes and packages. The expense of what has been thus received, if charged for at the usual rate, would have been entirely beyond the means of the Institution, and if in an unprecedentedly short time our knowledge of the natural history of California has been carried to a point fully equal to that of any of the older States, it is unquestionably owing in very great measure to the liberality of the companies above mentioned in so generously seconding the efforts of the Institution.

The following table exhibits the additions made to the record books of the museum in 1857, *in continuation of previous years:*

	1851.	1852.	1853.	1854.	1855.	1856.	1857.
Mammals	None.	114	198	351	1,200	2,046	3,200
Birds	--------	--------	--------	4,353	4,425	5,855	8,766
Skeletons and skulls	911	1,074	1,190	1,275	2,050	3,060	3,340
Reptiles	--------	--------	--------	--------	--------	106	239
Fishes	--------	--------	--------	--------	--------	155	613

Present condition of the museum.

The remarks in the last annual report of the Institution in relation to the richness and extent of its collections are strengthened by the additions of the past year, and they are confidently believed to be beyond competition in the field of American zoology. The precise statistics cannot now be given for the different classes and orders, as the cataloguing is not yet completed. In one department, however, some idea of the facts may be realized by the statement, that on the first of July, 1857, the Institution possessed—

	Species.	
Of skins or alcoholic specimens of North American mammals	205	
Of skins or alcoholic specimens of South American mammals	18	
Of skins or alcoholic specimens of European mammals	60	
		283
Of skulls or skeletons of North American mammals	221	
Of skulls or skeletons of South American mammals	17	
Of skulls or skeletons of European mammals	48	
		286

This was entirely exclusive of Cetacea, Pinnipedia, Cheiroptera and Quadrumana, of which there were many species. Since the first of July, the number of species of all orders has received a large increase. The species of North American mammals in the museum of the Institution, not mentioned in the great work of Audubon and Bachman, exceeds 80. Of birds, the North American species are believed to exceed 600; of reptiles, 400; of fishes, probably 800 or more. As all these classes are in process of elaboration, accurate statistics can probably be presented in the next report.

Work done in the museum.

The systematic registration of the Smithsonian collections has been carried on as rapidly as other duties would admit. The number of species labeled and entered during the year amounted to 5,271; most of them in three different series of records, making nearly 15,000 entries. It may be proper to state that all collections, as received, are entered in a general record book, of which the alphabetical list of donations appended to this report is a transcript. The different specimens are next labeled and then entered on the record for the class, or particular order, and from this posted in a ledger consisting of separate sheets, one for each species, systematically arranged, and each sheet containing an enumeration of all the specimens of its species, with the localities, sex, date, measurements and other memoranda, making the third time of writing out the name and statistics. In this way not only can information be obtained of the number of species of each class or order, but also of the separate specimens, with the locality and general character of each one. The posting up is complete for the mammals, birds, and osteological specimens, and well under way for the reptiles and fishes, and some orders of invertebrates.

During the past year the general report on the mammals of the Smithsonian collection has been completed and printed, forming volume VIII of the Report of the Pacific Railroad Survey. That on the birds is far advanced, and will be finished in the course of the ensuing year, which will also, it is hoped, witness the completion of reports on the reptiles and fishes.

Distribution and use of the Smithsonian collections.

As in previous years, the Smithsonian specimens have been freely used by students and investigators in natural history, in preparation of Monographs and other researches. Duplicates have also been distributed to a considerable extent, and as the collections become better arranged and other circumstances allow, it is hoped to make such distribution on a very extensive scale.

List of Donations during the year 1857.

C. Bellmann.—Fishes, &c., in alcohol, from Mississippi.

J. and A. Brakeley.—Fresh deer and otter from Virginia; jar of birds, mammals and reptiles from the Alleghenies of Virginia.

J. Mason Brown.—Cast of the skull of Daniel Boone, taken previous to the re-interment of his remains.

Lieutenant F. T. Bryan, U. S. A.—Three boxes of zoological specimens collected by William S. Wood on the wagon-road expedition from Fort Riley to Bridger's Pass.

Archibald Campbell.—One box of dried skins, and one chest of alcoholic specimens collected on Puget Sound by Dr. Kennerly, on the northwest boundary survey.

J. H. Clark.—Chest with two cans filled with reptiles, fishes and mammals in alcohol; specimens of salt from the salt plains of the Pewsa, on the southern boundary of Kansas.

Mr. Cook.—Copper ores from Arizona.

Dr. J. G. Cooper.—Collections made near Fort Laramie, and thence to Independence; four bottles of Salamanders from New Jersey; one hundred skins of birds from California and Washington Territory.

L. Coulon.—Box of Swiss mammals.

Dr. S. Wylie Crawford, U. S. A.—Thirty-two jars of reptiles and mammals from Texas and New Mexico.

Benjamin Cross.—Golden eagle in the flesh (length 36¼ inches; extent, 86 inches; wing, 25 inches.)

J. P. Cunningham.—Box of Kaolin earth from Virginia.

John Day.—Snake from Virginia.

T. C. Downie.—*Coluber couperi* and *Geomys pinetis*, in alcohol, from Georgia.

C. Drexler.—Skins of six birds and three mammals from near Philadelphia.

Dr. J. Evans.—Ten boxes and one bundle of collections of geological survey of Oregon; skins and skull of *Felis concolor* (panther;) six skulls of Flathead Indians, from Oregon.

James Fairie.—25 skins of *Lepus aquaticus* (marsh hare) and *Sciurus ludovicianus* (Fox squirrel;) birds, reptiles in alcohol, from Louisiana.

A. B. Forbes.—*Viviparous* fish (*Ennichthys megalops*) from California.

Professor C. G. Forshey.—Cast skin of *Scotophis*, and skin of mouse, from Texas; specimens of supposed equine fossil foot-marks; jar of alcoholic specimens; skins of serpents; dried plants; skin of Ocelot and of Raccoons from Fayette county, Texas.

W. H. Gantt, M. D.—Infusorial earth from Texas.

O. E. Garrison.—Six packages Infusorial earth; skins of *Putorius richardsonii* and *Spermophilus 13-lineatus* from Minnesota.

Dr. W. Gesner.—Jar of *Geomys pinetis* and *Arvicola;* mammals and reptiles in alcohol; two jars of mammals from Georgia.

George Gibbs.—Box and barrel containing skeleton of large shark, from Port Townsend, W. T.; keg of fishes, from Puget Sound; keg of fishes from Columbia river.

Dr. J. B. Gilpin.—Skins of mammals from Nova Scotia; fifteen skins of *Putorius* and *Sciurus* from Labrador and Nova Scotia; jar with 12 mammals, in alcohol, from Nova Scotia.

W. R. Goodman.—Diatomaceous earth from Anne Arundel county, Maryland.

John Gould.—160 skins of birds of Mexico and Guatemala; skins of humming birds, (*Campylopterus delattrii; Trochilus heteropogon* and *Eriopus luciani;*) skins of *Apternus hirsutus* and *arcticus.*

Donald Gunn.—Skins of mammals and birds; skeletons; specimens in alcohol from Red river. Skeletons of male and female wolverine from Red river, H. B. T.

Dr. W. A. Hammond, U. S. A.—Box of skins of birds and mammals from Kansas. Chest and two cans of zoological specimens collected during Lieut. Bryan's wagon-road expedition to Bridger's Pass.

Dr. W. A. Hammond and *J. X. de Vesey.*—Skins of twenty-four birds and of two prairie wolves from Kansas.

Dr. E. W. Harker.—Skin of Salamander (*Geomys pinetis?*) from Georgia.

F. V. Hayden.—Six boxes of fossils collected in the Upper Missouri prior to 1856.

C. J. Heistand.—Specimens in alcohol of squirrels, moles, &c., from Pennsylvania.

Dr. E. W. Hilgard.—Specimen of *Carocolla* from Spain.

John S. Hittel.—Human skulls and bones encrusted in stalagmite, from a cave in Calaveras county, Cal.

Col. Hoffman, U. S. A.—Concretions from Cannon-Ball river, Nebraska.

B. A. Hoopes.—Can of *Menobranchus* and small mammals from Lake Superior.

Robert Howell.—Two cans of mammals, in alcohol, from Tioga county, N. Y.

Lieut. J. C. Ives, U. S. A.—Fossil *Dendrechinus excentricus*, Point Lobas, Cal.; miscellaneous fossils from California; fossils from Gatun, N. G.—all collected by Dr. J. S. Newberry.

Dr. R. W. Jeffrey, U. S. N.—Collection of fishes of Norfolk.

Col. E. B. Jewett.—Reptiles from Texas.

Dr. C. B. Kennerly.—Jar of mammals in alcohol, and skins of *Sciurus cinereus*, from Clark county, Va.

Robt. Kennicott.—Six boxes zoological collections made in southern Illinois, and in Minnesota to Lake Winipeg. (Deposited.) Gopher (*Geomys bursarius*) from Illinois; thirty skins of *Arvicola* and *Sorex* from Illinois; two living squirrels, (*Sciurus ludovicianus.*)

Major Jno. Leconte.—*Astacus latimanus* from Georgia.

J. MacMinn.—Skins of five mammals from Pennsylvania.

Wm. M. Magraw.—Box of skins of birds and mammals; plants from Independence; three boxes zoological collections, plants, &c., gathered between Fort Leavenworth and Fort Laramie during the South Pass wagon-road expedition. Collected by Dr. J. G. Cooper.

Geo. P. Marsh.—Minerals from Europe.

C. C. Martin.—Keg of reptiles, fish and mammals, from Pennsylvania and New York.

W. Massenburn.—Collections of serpents and crustacea from Florida.

Maximilian Prinz Von Wied.—Wild boar (*Sus scrofa*) from Germany, and skins of chamois (*Capella rupricapra*) and of female ibex (*Capra ibex*) from Mont Blanc.

Dr. E. Michener.—Mounted original of *Emberiza townsendii.* (Deposited.)

D. Miller, jr.—Thirty small mammals, in alcohol, from Pennsylvania.

Robt. O. Milton.—Box of fossils from Michigan.

H. B. Möllhausen.—Skin of head and skull, with horns, of European stag, (*Cervus elaphus.*)

W. E. Moore.—Skins of monkeys from Bolivia

Henry Moores.—Star fishes from California. (Deposited.)

H. M. Neisler.—Shells, reptiles, fishes, &c., in alcohol, from Georgia.

Dr. J. S. Newberry.—Box of shells, Acapulco; specimens of coals from Ohio.

New Orleans Academy of Sciences.—Skin of pouched rat (*Geomys pinetis*) from Florida.

B. M. Norman.—Three living turtles from New Orleans, (*Emy mobilensis?*)

B. F. Odell.—Mammals and reptiles from near Lake Winnibigoshish, Minnesota.

John Oliphant.—*Falco sparverius*, in flesh, from Maryland.

Capt. T. J. Page, U. S. N.—Two packages of maté and six bottles of water from the Rio Negro and Mato Grosso.

Dr. D. W. C. Peters.—Skins, birds, and mammals; reptiles and fishes, in alcohol, from New Mexico.

Thos. M. Peters.—Bottle of reptiles; skin of *Abastor erythrogrammus* from Alabama.

Prof. Poey.—Two living *Emys decussata;* living boa or maja, (*Epicrates angulifer;*) collection of reptiles, in alcohol, from Cuba.

J. P. Postell.—Two living Gophers, (*Testudo polyphemus;*) skull of *Geomys pinetis;* box of shells, and other invertebrata, from Georgia.

John Potts.—Skins of *Bassaris astuta*, *Putorius frenatus* and *Didelphys californica*, from the city of Mexico.

Francis B. Ray.—Bottle containing *Ophibolus eximius* from Missouri.

E. Raymond.—Fossil wood from Neuse river, North Carolina.

J. W. Raymond.—Skin of white raccoon from North Carolina, and of *Bassaris astuta* from California.

Peter Reid.—Fresh water sponge, in alcohol, from near Lake Champlain.

Rev. Jos. Rowell.—Monkeys and other mammals, fishes, &c., in alcohol.

H. de Saussure.—Four bats, *Sorex alpinus*, *Myoxus glis*, *Mus sylvaticus*, and *musculus*, and *Arvicola nivalis* from the St. Gothard, Switzerland; other small mammals of Switzerland.

S. H. Scudder.—Can of mammals, in alcohol; box of insects from Massachusetts.

Lieut. Semmes, U. S. N.—Syenite from North Greenland.

J. D. Sergeant.—Jar of mammals from Pennsylvania.

James Shoemaker.—Snakes and fishes from Roanoke county, Va.

Col. Wm. B. Slaughter.—Peat from Wisconsin.

J. Stauffer.—Can of mammals, in alcohol, from Pennsylvania.

J. J. Steenstrup, Director of Zoological Museum, Copenhagen.—Six jars of invertebrates from Greenland

J. H. Sternberg.—Four turtles; two boxes of shells, and of reptiles and invertebrates, in alcohol; box of living plants from Isthmus of Panama.

William Stimpson.—Two kegs and numerous jars of marine invertebrates and fishes from Massachusetts; living marine animals for aquarium.

Dr. George Suckley.—Hunters' skin of elk and of mountain goat, *Aplocerus montanus,* from Washington Territory; box of birds from California; skins of mammals, birds; fishes, shells, minerals, and Indian relics, from Washington Territory; box with skins of mammals and birds; plants, &c., from Steilacoom; box of birds, shells, &c., Port Townsend.

A. S. Taylor.—Jar of vertebrates and crabs from California; California minerals.

Mr. Tufts.—Living actinia and other marine animals for aquarium.

Colonel A. Vaughan.—Skins of *Vespertilio noctivagans* and *noveboracensis* from Yellowstone river.

J. X. de Vesey and *Dr. W. A. Hammond, U. S. A.*—Skins of birds and mammals from Kansas.

Dr. D. S. Wall, U. S. A.—Skull of Indian and fragments of pottery from a mound near Fort Capron, Florida; skins of birds; skin of manatee, or sea-cow, and of *Lynx;* also two birds from Florida.

William D. Wallach.—Copper ores and native copper from Bayfield, Wisconsin.

Robert B. Waller.—Bottle of Cyprinodonts from Alabama.

Lieutenant G. K. Warren.—Two boxes fossils from Blackbird Hill, collected by Dr. F. V. Hayden; collections made by Dr. F. V. Hayden during the exploration of the Black hills in 1857, consisting of 5 boxes zoological specimens; 21 boxes fossils and plants, &c.

C. W. Welch.—Troupial (*Icterus vulgaris*) from Laguayra.

D. Welch.—*Menobranchus maculatus* from Lake Champlain.

Samuel Wheat.—Living black snake (*Scotophis allegheniensis*) from Ohio.

Mr. Wheeler.—*Storeria dekayi* from Washington.

Thomas Whelpley —Fossils from Michigan.

Dr. D. D. Whitehurst.—Box of specimens and cask of fishes, &c., in alcohol, from Gulf of Mexico; specimens of fishes (crustacea) from Tortugas.

Dr. S. W. Wilson.—Four living alligators from Georgia; skeleton and skins of otter and deer; skins of *Lepus palustris;* 24 small mammals, in alcohol, from Georgia.

Dr. C. F. Winslow.—Box of lavas from Sandwich Islands; fossil bones from California. (Deposited.)

W. S. Wood.—Bald eagle, *Haliaetus leucocephalus,* mounted; mammals, in alcohol, from Philadelphia.

C. Wright.—Jar mammals and reptiles from Connecticut; fishes from Cuba, said to be viviparous; jars of reptiles, fishes, and invertebrates from Cuba.

G. Würdemann.—Box of invertebrates and skins of birds from Indian Key, Florida; box of bird skins from south Florida; box of birds, crustacea, corals, &c., from Key Biscayne, Florida.

J. E. Younglove.—Bottle of blind fish, (*Amblyopsis,*) taken in a well in Bowling Green, Kentucky.

Unknown.—Box iron ores, St. Louis, Missouri.
Hesperomys cognatus, in alcohol.
Hammerhead shark from Norfolk.
Living raccoon and great horned owl.

LIST OF METEOROLOGICAL STATIONS AND OBSERVERS

FOR THE YEAR 1857.

BRITISH AMERICA.

Name of observer.	Station.	N. lat.	W. long.	Height
		° ′	° ′	*Feet.*
Baker, J. C	Stanbridge, Canada East	45 08	73 00	
Craigie, Dr. W	Hamilton, Canada West	43 15	79 57	
Delany, jr., John	Colonial Building, St. John's, Newfoundland.	47 35	52 38	
Gunn, Donald	Red river Settlement, Hudson's Bay Territory.	50 06	97 00	853
Hall, Dr. Archibald	Montreal, Canada East	45 30	73 36	57
Hensley, Rev. J. M	King's College, Windsor, Nova Scotia.	44 59	64 07	200
Magnetic Observatory	Toronto, Canada West	43 39	79 21	108
Smallwood, Dr. Charles	St. Martin, Isle Jesus, Canada East.	45 32	73 36	118
Steuart, A. P. S	Horton, Nova Scotia	45 06	64 25	95

MAINE.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Bell, John J	Carmel	Penobscot	44 47	69 00	175
Dana, W. D	Perry	Washington	45 00	67 06	100
Gardiner, R. H	Gardiner	Kennebec	44 11	69 46	90
Guptill, G. W	Cornishville	York	43 40	70 44	800
Parker, J. D	Steuben	Washington	44 44	67 58	50
West, Silas	Cornish	York	43 40	70 44	784
Willis, Henry	Portland	Cumberland	43 39	70 15	87
Wilbur, Benj. F	Monson	Piscataquis	43 11	69 35	

NEW HAMPSHIRE.

Bell, Samuel N	Manchester	Hillsborough	42 59	71 28	300
Bixby, A. H.	Francestown	Hillsborough	42 59	71 45	
Brown, B. Gould	Stratford	Coos	44 08	71 34	1,000
Freeman, F. N	Claremont	Sullivan	43 29	72 22	535
Hanscam, R. F	North Barnstead	Belknap	43 38	71 27	
Mack, R. C	Londonderry	Rockingham	42 53	71 20	
Odell, Fletcher	Shelburn	Coos	44 23	71 06	700
Prescott, Dr. Wm	Concord	Merrimack	43 12	71 29	374
Purmort, Nath	West Enfield	Grafton	43 30	72 00	
Root, Dr. Martin N	Francestown	Hillsborough	43 00	71 46	
Sawyer, Henry E	Great Falls	Strafford	43 17	70 52	
	Concord	Merrimack	43 12	71 20	

VERMONT.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Bliss, George	Shelburn	Chittenden	44 23	73 00	150
Bliss, L. W	West Fairlee	Orange	43 55	72 15	
Buckland, David	Brandon	Rutland	43 45	73 00	
Fairbanks, Franklin	St. Johnsbury	Caledonia	44 25	72 00	540
Marsh, Charles	Woodstock	Windsor	43 36	72 35	716
Jackman, A	Norwich	Windsor	43 42	72 20	
Paddock, James A	Craftsbury	Orleans	44 40	72 30	1,100
Parker, Joseph	Rupert	Bennington	43 15	73 11	750
Petty, McK	Burlington	Chittenden	44 29	73 11	346

MASSACHUSETTS.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Bacon, William	Richmond	Berkshire	42 23	73 20	1,190
Bond, Prof. W. C	Cambridge	Middlesex	42 22	71 07	71
Brooks, John	Princeton	Worcester	42 28	71 53	1,113
Darling, L. A	Bridgewater	Plymouth	42 00	71 00	142
Davis, Rev. Emerson	Westfield	Hampden	42 06	72 48	
Ellis, D. H	Canton	Norfolk	42 12	71 08	90
Fallon, John	Lawrence	Essex	42 42	71 11	35
Holcomb, Amasa	Southwick	Hampden	42 02	72 10	265
Lyons, Curtis J MaGee, Irving	Williamstown	Berkshire	42 43	73 13	720
Metcalf, Jno. G., M. D.	Mendon	Worcester	42 06	72 33	
Mitchell, Hon. Wm	Nantucket	Nantucket	41 16	70 06	30
Perkins, Dr. H. C	Newburyport	Essex	42 47	70 52	46
Rice, Henry	North Attleboro'.	Bristol	41 59	71 22	175
Rodman, Samuel	New Bedford	Bristol	41 39	70 56	90
Sargent, John S	Worcester	Worcester	42 16	71 48	536
Schlegel, Albert	Taunton	Bristol	41 49	71 09	
Shaw, Francis	Plainfield	Hampshire	42 30	72 56	
Smith, E L	Boston	Suffolk	42 22	71 03	
Snell, Prof. E. S	Amherst	Hampshire	42 22	72 34	267
Tirrell, Dr. N. Quincy.	Weymouth	Norfolk	42 10	71 00	150
Whitcomb, L. F	Florida	Berkshire	42 42	73 10	2,500

RHODE ISLAND.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Caswell, Prof. A	Providence	Providence	41 49	71 25	120

CONNECTICUT.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Edwards, Rev. T., D.D.	New London	New London	41 21	72 12	90
Harrison, Benj. F	Wallingford	New Haven	41 26	72 50	133
Hull, Aaron B	Georgetown	Fairfield	41 15	73 00	300
Hunt, D	Pomfret	Windham	41 52	72 23	596
Rankin, James	Saybrook	Middlesex	41 18	72 20	10
Scholfield, N	Norwich	New London	41 32	72 03	50
Yeomans, William H	Columbia	Tolland	41 42	72 16	

NEW YORK.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Alba, Dr. E. M.	Angelica.	Alleghany	42 15	78 01	1,500
Arden, Thomas B.	Beverly	Putnam	41 22	72 12	180
Bowman, John	Baldwinsville	Onondaga	43 04	76 41	
Byram, Ephraim N.	Sag Harbor	Suffolk	41 00	72 20	40
Chickering, J. W.	Ovid	Seneca	42 41	76 52	800
Dayton, E. A.	Madrid	St. Lawrence	44 43	75 33	280
Denning, William H.	Fishkill Landing.	Dutchess	41 34	74 18	42
Dewey, Prof. Chester Palmer, F. B.	Rochester	Monroe	43 08	77 51	516
Fellows, Henry B.	Sennett	Cayuga	43 00	76 55	
French, John R	Mexico	Oswego	43 27	76 14	423
Gorton, J. S.	Westfarms	Westchester	40 53	74 01	150
Greene, Prof. Dascom	Troy	Rensselaer	42 44	73 36	58
Guest, W. E.	Ogdensburgh	St. Lawrence	44 43	75 26	
House, J. Carroll	Lowville.	Lewis	43 46	75 38	
House, John C.	Waterford	Saratoga	42 47	73 39	
Howell, R.	Nicholls	Tioga	42 00	76 32	
Ingalls, S. Marshall	Pompey	Onondaga	42 56	76 05	1,745
Johnson, E. W.	Canton	St. Lawrence	44 38	75 15	304
Landon, Anna S.	Eden	Erie	42 30	79 07	700
Lefferts, John	Lodi.	Seneca	42 37	76 53	1,000
Malcolm, Wm. S.	Oswego	Oswego	43 28	77 34	232
Morehouse, A. W.	Spencertown	Columbia	42 19	73 41	800
Morris, Prof. O. W.	New York	New York	40 43	74 05	159
Norton, J. H.	Plainville	Onondaga	43 00	77 15	
Paine, H. N., M. D.	Clinton	Oneida.	43 00	75 20	500
Pernot, Prof. Claudius.	Fordham	Westchester	40 54	74 03	147
Reed, Edward C.	Homer	Cortland	42 38	76 11	1,100
Reid, Peter	Lake	Washington	43 15	73 33	
Riker, Walter H.	Saratoga	Saratoga	43 06	74 00	960
Sanger, Dr. W. W.	Blackwell's Isl'd.	New York	40 45	73 57	29
Sartwell, Dr. H. P.	Penn Yan	Yates	42 42	77 11	740
Sheerar, H. M.	Wellsville	Alleghany	42 07	78 06	1,480
Sias, Prof. Solomon	Fort Edward	Washington	43 13	73 42	
Smith, J. Metcalf	McGrawville	Cortland	42 34	76 11	1,450
Spooner, Stillman	Wampsville	Madison	43 04	75 50	500
Taylor, Jos. W.	Plattsburgh	Clinton	44 40	73 26	156
Titus, Henry Wm.	Bellport	Suffolk	40 44	72 54	
Tourtellot, Dr. L. A.	Utica	Oneida.	43 07	75 15	500
Van Kleek, Rev. R. D.	Flatbush.	Kings	40 37	74 01	54
White, Aaron	Cazenovia	Madison	42 55	75 46	1,260
Williams, Dr. P. O.	Watertown	Jefferson	43 56	75 55	
Wilson, Rev. W. D.	Geneva	Ontario	42 53	77 02	567
Woodward, Lewis	West Concord	Erie	43 00	79 00	2,000
Yale, Walter D.	Houseville	Lewis	43 40	75 32	
Zaepffel, I.	West Morrisania	Westchester	40 53	74 01	150

NEW JERSEY.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Cooke, Robert L.	Bloomfield	Essex	40 49	74 11	120
Schmidt, Dr. E. R.	Burlington	Burlington	40 00	75 12	26
Sergeant, John T.	Sergeantsville	Hunterdon	40 29	75 03	
Simpson, B. F. Willis, O. R.	Freehold	Monmouth	40 15	74 21	
Whitehead, W. A.	Newark	Essex	40 45	74 10	30

PENNSYLVANIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Brown, Samuel	Bedford	Bedford	40 01	78 30	
Baird, John H.	Tarentum	Alleghany	40 37	79 19	950
Brickenstein, H. A.	Nazareth	Northampton	40 43	75 21	
Brugger, Samuel	Fleming	Centre	40 55	77 53	780
Coffin, Selden, J.	Easton	Northampton	40 43	75 16	320
Comly, John	Byberry	Philadelphia	40 06	74 58	
Darlington, Fenelon	Pocopson	Chester	39 54	75 37	218
Edwards, Joseph	Chromedale	Delaware	39 55	75 25	196
Eggert, John	Berwick	Columbia	41 05	76 15	588
Friel, P.	Shamokin	Northumberland.	40 45	76 31	700
Hance, Ebenezer	Morrisville	Bucks	40 12	74 53	30
Heisely, Dr. John	Harrisburg	Dauphin	40 16	76 50	
Hickok, W. O.	Harrisburg	Dauphin	40 16	76 55	
Hoffer, Mary E.	Mount Joy	Lancaster	40 08	76 70	
Jacobs, Rev. M.	Gettysburg	Adams	39 51	77 15	
James, Prof. Charles S.	Lewisburg	Union	40 58	76 58	
Kirkpatrick, Prof. J. A.	Philadelphia	Philadelphia	39 57	75 11	60
Kohler, Edward	North Whitehall	Lehigh	40 40	75 26	250
Martin, William	Pittsburg	Alleghany	40 30	80 00	
Mowry, George	Somerset	Somerset	40 02	79 02	2,180
Ralston, Rev. J. Grier.	Norristown	Montgomery	40 08	75 19	153
Schreiner, Francis	Moss Grove	Crawford	41 40	79 51	
Smith, Prof. Wm.	Canonsburg	Washington	40 25	80 07	936
Smyser, Rev. B. R.	Pottsville	Schuylkill	40 41	76 09	
Stewart, Thos. B.	Murrysville	Westmoreland	40 28	79 35	960
Swift, Dr. Paul	West Haverford.	Delaware	40 00	75 21	
Thickstun, T. F.	Meadville	Crawford	41 39	80 11	1,088
Wilson, Prof. W. C.	Carlisle	Cumberland	40 12	77 11	500
Wilson, W. W.	Pittsburg	Alleghany	40 32	80 02	1,026

DELAWARE.

Craven, Thos. J. Porter, Mrs. E. D.	Newark	New Castle	39 38	75 47	120
Martin, R. A.	Milford	Kent	39 55	75 27	25

MARYLAND.

Baer, Miss H. M.	Shellman Hills	Carroll	39 23	76 57	700
Cofrau, L. R.	Oakland	Alleghany	39 40	79 00	
Goodman, Wm. R.	Annapolis	Anne Arundel	38 58	76 29	20
Hanshew, Henry E.	Frederick	Frederick	39 24	77 18	
Lowndes, Benj. O.	Bladensburg	Prince George	38 57	76 58	
Mayer, Prof. Alfred	Baltimore	Baltimore	39 18	76 37	
Pearce, James A., jr.	Chestertown	Kent	39 14	76 02	
Stagg, T. G.	Ridge	St. Mary's	38 05	76 18	

DISTRICT OF COLUMBIA.

Smithsonian Institution.	Washington	Washington	38 53	77 01	30

VIRGINIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Astrop, Col. R. F	Crichton's Store	Brunswick	36 40	77 46	500
Couch, Samuel	Ashland	Putnam	38 38	81 57	
Dickinson, George C	Rougemont	Albemarle	38 05	78 21	450
Ellis, Col. D. H	Crack Whip	Hardy	39 30	78 31	1,750
Fauntleroy, H. H	Montrose	Westmoreland	38 07	76 54	200
Fraser, James	Mustapha	Wood	39 20	81 41	
Hallowell, Benjamin	Alexandria	Alexandria	38 48	77 01	56
Hoff, Josiah W	Wirt C. H	Wirt	39 05	81 26	
Hotchkiss, Jed	Mossy Creek	Augusta	38 20	79 05	
Johnson, Enoch D	Sisterville	Tyler	39 34	80 56	540
Kendall, James E	Charleston	Jefferson	38 20	81 21	
Kownslar, Miss Ellen	Berryville	Clark	39 09	78 00	575
Marvin, John W	Winchester	Frederick	39 15	78 10	
Offutt, J. J., M. D	Capon Bridge	Hampshire	39 16	78 29	
Patton, Thomas, M. D.	Lewisburg	Greenbrier	38 00	80 00	2,000
Purdie, John R	Smithfield	Isle of Wight	36 50	76 41	100
Ruffin, Julian C	Ruthven	Prince George	37 21	77 33	
Ruffner, David L	Kanawha	Kanawha	38 53	81 25	
Slaven, James	Meadow Dale	Highland	38 23	79 35	
Upshaw, George W	Rose Hill	Essex	38 00	76 57	250
Webster, Prof. N B	Portsmouth	Norfolk	36 50	76 19	34
Wells, J. Carson	Salem	Roanoke	39 20	80 01	1,100
Wickline, Thomas J	Longwood	Rockbridge	37 30	79 31	800

NORTH CAROLINA.

Johnson, Dr. W. M	Warrenton	Warren	36 30	78 15	
McDowell, Rev. A	Murfreesboro'	Hertford	36 30	77 06	
McDowell, W. W	Asheville	Buncombe	35 37	82 29	2,250
Moore, Geo. F., M. D	Gaston	Northampton	36 32	77 45	
Morelle, Daniel	Goldsboro'	Wayne	35 20	77 51	
Phillips, Rev. Jas., D. D	Chapel Hill	Orange	35 54	79 17	

SOUTH CAROLINA.

Cornish, John H	Aiken	Barnwell	33 32	81 34	565
Dawson, John L., M. D.	Charleston	Charleston	32 46	80 00	
Fuller, E. N., M. D	Edisto Island	Colleton	32 34	80 18	23
	Mount Pleasant	Laurens	32 47	79 55	
Glennie, Rev. Alex'r	Waccaman	All Saints	33 40	79 17	20
Johnson, Joseph, M. D	Charleston	Charleston	32 46	80 00	30
Young, J. A., M. D	Camden	Kershaw	34 17	80 33	275

GEORGIA.

Anderson, Jas , M. D	The Rock	Upson	32 52	84 23	833
Arnold, Mrs. J. T	Zebulon	Pike	33 07	84 26	
Easter, Prof. John D	Athens	Clarke	33 58	83 80	850
Gibson, R. T	Whitemarsh Is'd.	Savannah	32 04	81 05	18

GEORGIA—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Glover, Eli S.	Hillsboro'	Jasper	33 13	83 45	566
Haines, William	Augusta	Richmond	33 20	81 54	1,470
Pendleton, E. M., M. D.	Sparta	Hancock	33 17	83 09	550
Posey, John F	Savannah	Chatham	32 05	81 07	42
Reid, James M	Philomath	Oglethorpe	33 45	83 15	
Simpson, F. T.	Factory Mills	Wilkes	33 40	84 46	

FLORIDA.

Bailey, James B.	Gainesville	Alachua	29 35	82 26	184
Baldwin, A. G., M. D.	Jacksonville	Duval	30 30	82 00	13
Batchelder, F. L.	Hibernia	Duval	30 15	81 30	15
Dennis, Wm. C	Salt Ponds	Key West	24 33	81 48	
Fry, Joseph Hester, Lieut. J. W., U. S. N.	Pensacola	Escambia	30 20	87 16	12
Ives, Edward R	Alligator	Columbia	30 12	82 37	174
Mauran, P. B., M. D.	St. Augustine	St. John's	29 48	81 35	8
Steele, Judge Aug	Cedar Keys	Levy	29 07	83 02	12
Whitner, Benj. F.	Belair	Leon	30 24	84 20	70

ALABAMA.

Alison, H. L, M. D.	Carlowville	Dallas	32 10	87 15	300
Barker, Thomas M.	Ashville	St. Clair	33 52	86 20	
Darby, Prof. John	Auburn	Macon	32 37	85 34	821
Tutwiler, Henry	Greene Springs	Greene	32 50	87 46	
Waller, Robert B.	Greensboro'	Greene	32 40	87 34	350

MISSISSIPPI.

Elliott, Prof. J. Boyd	Port Gibson	Claiborne	31 50	91 01	100
Lull, James S.	Columbus	Lowndes	33 30	88 29	227

LOUISIANA.

Barton, Dr. E. H.	New Orleans	Orleans	29 57	90 00	
Kilpatrick, A. R., M. D.	Trinity	Chatahoula	31 30	91 46	108
Merrill, Edward, M. D.	Trinity	Chatahoula	31 37	91 47	68
Taylor, Lewes B.	New Orleans	Orleans	29 57	90 00	

TEXAS.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Brightman, John C.	Goliad	Goliad	28 30	97 15	50
	Helena	Karnes	29 00	97 56	600
Forke, J. L.	New Wied	Comal	29 42	98 15	
Forke, A. Friedrick, Otto	New Braumfels	Comal	29 41	98 15	
Gantt, Dr. Wm. H.	Union Hill	Washington	30 30	96 31	540
Jennings, S. K., M.D. Van Nostrand, J.	Austin	Travis	30 20	97 46	650
Rucker, B. H.	Washington	Washington	30 26	96 15	

TENNESSEE.

Bean, James B.	Walnut Grove	Greene	36 00	82 53	1,350
Stewart, Prof. Wm. M.	Glenwood	Montgomery	36 28	87 13	481
Tuck, W. J., M. D.	Memphis	Shelby	35 08	90 00	262
Wright, Dr. Dan'l F.	Memphis	Shelby	35 08	90 00	262

KENTUCKY.

Beatty, O.	Danville	Boyle	37 40	84 30	950
Ray, L. G., M. D.	Paris	Bourbon	38 16	84 07	810
Savage, Rev. Geo. S.	Millersburg	Bourbon	38 20	84 20	804
Young, Mrs. Lawrence	Springdale	Jefferson	38 07	85 34	570

OHIO.

Abell, B. F.	Welchfield	Geauga	41 23	81 12	1,115
Allen, Prof. Geo. N.	Oberlin	Loraine	41 20	82 15	800
Ammen, J.	Ripley	Brown	38 47	83 31	
Anthony, Newton	Mount Union	Stark	41 20	81 01	
Atkins, Rev. L. S.	Madison	Lake	41 49	81 10	
Benner, J. F.	New Lisbon	Columbiana	40 45	80 46	
Bennett, Henry	Collingwood	Lucas	41 49	83 34	
Binkerd, J. S.	Germantown	Montgomery	39 39	84 11	
Bosworth, Prof. R. S.	College Hill	Hamilton	39 19	84 25	800
Cunningham, Miss A.	Unionville	Lake	41 52	81 00	650
Dayton, Lewis M.	Lancaster	Fairfield	39 40	82 40	
Gilmor, Moses	Jackson	Jackson	39 10	82 32	666
Hannaford, Ebenezer	Cheviot	Hamilton	39 07	84 34	
Harper, George W.	Cincinnati	Hamilton	39 06	84 27	150
Herrick, James D.	Jefferson	Ashtabula	42 00	81 00	
Hollenbeck, F. & D. K.	Perrysburg	Wood	41 39	83 40	
Holston, J. G. F., M. D.	Zanesville	Muskingum	39 58	82 01	700
Hurt, Francis W.	Cincinnati	Hamilton	39 06	84 34	
Hyde, Gustavus A.	Cleveland	Cuyahoga	41 30	81 40	665
Ingram, John, M. D.	Savannah	Ashland	41 12	82 31	
Janes, C. C.	Hillsborough	Highland.			
Luther, S. M.	Hiram	Portage	41 20	81 15	675

OHIO—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Mathews, Joseph McD.	Hillsborough	Highland	39 13	83 30	1,000
McCarty, H. D.	West Bedford	Coshocton	40 18	82 01	876
Peck, W. R., M. D.	Bowling Green	Wood	41 27	83 45	700
Poe, James H.	Portsmouth	Scioto	38 50	82 49	468
Roger, A. P.	Gallipolis	Gallia	39 00	82 01	520
Sanford, Prof. S. N.	Granville	Licking	40 03	82 34	995
Sanford, Smith	Edinburg	Portage	41 20	81 00	520
Schenck, W. L , M. D.	Franklin	Warren	39 30	84 10	
Shaw, Joseph	Bellefontaine	Logan	40 21	83 40	1,031
Shaw, Joseph	Sidney	Shelby	40 21	84 11	
Shields, Robert Smith, John C.	Bellecentre	Logan	40 28	83 45	1,170
Treat, Samuel W.	Windham	Portage	41 10	81 05	
Ward, L. F.	Medina	Medina	41 07	81 47	1,206
Williams, Prof. M. G.	Urbana	Champaign	40 06	83 43	1,015

MICHIGAN.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Allen, James	Port Huron	St. Clair	42 53	82 24	606
Andrews, Seth L., M.D.	Romeo	Macomb	42 44	83 00	730
Campbell, Wm.M.,M.D.	Battle Creek	Calhoun	42 20	85 10	750
Crosby, J. B.	New Buffalo	Berrien	41 45	86 46	600
Currier, Alfred O.	Grand Rapids	Kent	43 00	86 00	752
Streng, L. H.	Grand Rapids	Kent	43 00	86 00	852
Walker, Mrs. Octavia C.	Cooper	Kalamazoo	42 40	85 31	
Whelpley, Miss H	Monroe	Monroe	41 56	83 22	590
White, Peter	Marquette	Marquette	46 32	87 41	630
Whittlesey, Chas. S.	Copper Falls	Houghton	47 25	88 16	1,230
Winchell, Prof. A	Ann Arbor	Washtenaw	42 16	83 44	891
Woodruff, Lum	Ann Arbor	Washtenaw	42 16	83 30	850

INDIANA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Barnes, C.	New Albany	Floyd	38 17	85 45	
Chappellsmith, John	New Harmony	Posey	38 08	87 50	320
Crisp, John F.	Evansville	Vanderburgh	38 08	87 29	390
Lasselle, Charles B.	Logansport	Cass	40 45	86 13	600
Moore, Joseph	Richmond	Wayne	39 47	84 47	800
Smith, Hamilton	Cannelton	Perry	37 58	86 40	450
Woodard, C. S	Michigan City	La Porte	41 41	86 53	622

ILLINOIS.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Babcock, Andrew J.	Aurora	Kane	41 40	88 15	600
Babcock, E.	Riley	McHenry	42 08	88 33	650
Baker, Frank	South Pass	Union	37 28	89 14	
Bowman, Dr. E. H.	Edgington	Rock Island	41 25	90 46	
Brendel, Fred'k, M.D.	Peoria	Peoria	40 36	89 30	
Eldredge, William V.	Brighton	Macoupin	39 00	90 13	

ILLINOIS—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Grant, John	Manchester	Scott	39 33	90 34	683
Hall, Joel	Athens	Menard	39 52	89 56	
Harris, J. O., M. D.	Ottawa	La Salle	41 20	88 47	500
Hiscox, G. D.	Chicago	Cook	41 53	87 41	600
James, Anna	Upper Alton	Madison	39 00	89 36	
Jenkins, J. L.	Granville	Putnam	41 14	89 21	
Mead, S. B, M. D.	Augusta	Hancock	40 12	89 45	200
Mead, Thompson	Batavia	Kane	41 52	88 20	636
Riblet, J. H.	Pekin	Tazewell	40 36	89 45	
Rogers, O. P.	Marengo	McHenry	42 14	88 38	650
Smith, Isaac H.	Fremont Centre	Lake	42 18	88 06	736
Swain, John, M. D.	West Urbana	Champaign	40 09	88 17	550
Titze, Henry A.	West Salem	Edwards	38 30	88 00	
Wallace, Samuel Jacob.	Carthage	Hancock	40 23	90 17	
Whitaker, Benjamin	Warsaw	Hancock	40 20	91 31	

MISSOURI.

Wislizenus, A., M. D.	St. Louis	St. Louis	38 37	90 16	461

IOWA.

Beal, Dexter Beal, Willard W.	Franklin	Buchanan	42 45	87 16	
Beeman, Carlisle D.	Rossville	Allamakee	43 10	91 21	1,400
Fory, John C.	Bellevue	Jackson	42 15	90 25	
Goss, William K.	Border Plains	Webster	42 36	94 05	
Hobart, Edward F.	Maquoketa	Jackson	42 04	90 41	
Horr, Asa, M. D.	Dubuque	Dubuque	42 30	90 52	1,258
McConnell, Townsend.	Pleasant Plain	Jefferson	41 07	91 54	
McCready, Daniel	Fort Madison	Lee	40 37	91 28	
Parker, Nathan H.	Clinton	Clinton	41 48	90 15	
Parvin, T. S.	Muscatine	Muscatine	41 26	91 05	586
Reynolds, W.	Iowa City	Johnson	41 39	91 33	
Saville, Dr. J. J.	Sioux City	Woodbury	42 31	96 25	
Shaffer, J. M., M. D.	Fairfield	Jefferson	41 01	91 57	940
Smith, Prof, B. Wilson	Mount Vernon	Linn	42 00	91 00	

WISCONSIN.

Bean, Prof. S. A. Slye, L. C., M. D.	Waukesha	Waukesha	42 50	88 11	833
Breed, J. Everett	New London	Waupacca	44 21	88 45	
Chandler, Marine T. W.	Falls of St. Croix	Polk	45 30	92 40	660
Durham, W. J.	Racine	Racine	42 49	87 40	
Ellis, Edwin	Bay City	La Pointe	46 33	91 00	658
Gridley, Rev. John	Kenosha	Kenosha	42 35	87 50	600
Hillier, Spencer L.	Prescott	Pierce	44 56	92 40	800
Himoe, John E.	Norway	Racine	42 50	88 10	753

WISCONSIN—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° '	° '	*Feet.*
Lapham, Increase A.	Milwaukie	Milwaukie.	43 03	87 57	593
Lüps, Jacob	Manitowoc	Manitowoc	44 07	87 37	
Mason, Prof. R. Z.	Appleton	Outagamie	44 10	88 35	800
Pickard, J. L., M. D.	Platteville	Grant	42 45	91 00	
Pomeroy, F. C.	Milwaukie	Milwaukie	43 04	87 59	658
Porter, Prof. Wm.	Beloit	Rock	42·30	89 04	750
Schue, A., M. D.	Madison	Dane	43 05	89 25	892
Sterling, Prof. J. W.	Madison	Dane	43 05	89 25	892
Struthers, R. H.	Lind	Waupacca	44 20	89 00	
Underwood, Col. D.	Menasha	Winnebago	44 13	88 18	
Winkler, C., M. D.	Milwaukie	Milwaukie	43 04	87 57	593
Willard, J. F.	Janesville	Rock	42 42	89 91	768

MINNESOTA.

Garrison, O. E.	Princeton	Benton	45 50	93 45	
Hillier, Spencer L.	Wabashaw	Wabashaw	44 30	92 15	850
Odell, Rev. Benj. F.	Lake Winnibigoshish.		47 30	94 40	
Riggs, S. R.	Hazlewood		45	95 30	
Walsh, Stephen	Buchanan		47 33	92 00	
Wright, E. M.	Lapham	Pembina	46 10	96 00	850

NEBRASKA.

Byers, Wm. N.	Omaha	Douglas	41 15	96 10	
Hamilton, William	Bellevue	Sarpy	41 08	95 50	

KANSAS.

Brown, G. W.	Lawrence	Douglas	38 58	95 12	800
Fish, Edmund	Council City	Shawnee	38 42	95 50	
Goodnow, Isaac T.	Manhattan	Riley	39 13	96 45	
Himoe, S. O., M. D.	Mapleton	Bourbon	38 04	94 51	
McCarty, H. D.	Leavenworth City	Leavenworth	39 20	94 33	1,342

UTAH.

Phelps, Henry E.	Great Salt Lake City.		40 45	111 26	4,250

CALIFORNIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Ayres, W. O., M. D.	San Francisco	San Francisco	37 48	122 23	115
Belcher, W. C.	Marysville	Yuba	39 12	121 42	
Logan, Thos. M., M.D.	Sacramento	Sacramento	38 35	121 40	49

GUATEMALA.

CANUDUS, ANTONIO COLLEGE.

SOUTH AMERICA.

Name of Observer.	Station.	Lat.	Lon.	Height.
		° ′	° ′	*Feet.*
Fendler, A.	Colonia Tovar, Venezuela	10 26	67 20	6,500
Geological Surveyors	Port of Spain, Trinidad	10 39	61 34	16
Hering, C. J.	Plantation, Catharina Sophia, Colony of Surinam, Dutch Guiana	5 48	56 47	
Uricoschea, Dr. E.	Bogota, New Granada	4 36	74 14	8,863

BERMUDA.

Arnold, James B.	Shelby Bay	32 28	64 32	
Royal Gazette				

AZORES.

Dabney, S. W	Honta, Fayal Island	38 30	28 42	80

REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee respectfully submit to the Board of Regents the following report of the receipts and expenditures of the Smithsonian Institution during the year 1857, with estimates for the year 1858:

RECEIPTS.

The whole amount of Smithson's bequest deposited in the treasury of the United States is $515,169, from which an annual income, at 6 per cent., is derived, of		$30,910 14
Extra fund from unexpended income invested as follows:		
In $75,000 Indiana 5 per cent. bonds, yielding	$3,750 00	
In $53,000 Virginia 6 per cent. bonds, yielding	3,210 00	
In $7,000 Tennessee 6 per cent. bonds, yielding	420 00	
In $500 Georgia 6 per cent. bonds, yielding	30 00	
In $100 Washington 6 per cent. bonds, yielding	6 00	
		7,416 00
		38,326 14
Balance in hands of Treasurer January 1, 1857		7,164 32
Total receipts		$45,490 46

GENERAL STATEMENT OF EXPENDITURES.

For building, furniture, and fixtures	$4,062 65	
For items common to the different objects of the Institution	13,035 18	
For publications, researches, and lectures	11,051 52	
For library, museum, and gallery of art	6,999 81	
		$35,149 16
Balance in the hands of the Treasurer January 1, 1858, of which $5,000 belongs to the extra fund		10,341 30

Statement in detail of the expenditures during 1857:

BUILDING, FURNITURE, FIXTURES, ETC.

Repairs, &c., incident to building	$3,305 12	
Furniture and fixtures for uses in common	373 61	
Furniture and fixtures for library	163 50	
Furniture and fixtures for museum	150 80	
Magnetic observatory	49 62	
Grounds	20 00	
		$4,062 65

GENERAL EXPENSES.

Meetings of Board and Committees	$281 00	
Lighting and heating	1,244 33	
Postage	524 02	
Transportation and exchange	2,264 74	
Stationery	347 94	
General printing	236 50	
Apparatus	191 66	
Laboratory	341 38	
Salary of the Secretary	3,499 92	
Chief clerk	1,200 00	
Book-keeper	200 00	
Janitor	400 97	
Watchmen	534 65	
Laborers	794 00	
Messenger	128 00	
Extra clerk hire	222 00	
Incidentals, general	624 07	
		13,035 18

PUBLICATIONS, RESEARCHES, AND LECTURES.

Smithsonian Contributions	$6,230 02	
Reports on progress of knowledge	342 00	
Other publications	649 90	
Meteorology	2,465 24	
Investigations, computations, and researches	250 00	
Pay of lecturers	980 00	
Incidentals to lectures	134 36	
		11,051 52

LIBRARY, MUSEUM, AND GALLERY OF ART.

Cost of books	$2,019 83	
Pay of assistants	1,194 12	
Transportation for library	200 00	
Museum—salary	1,999 92	

Explorations	$57 52	
Collections	49 78	
Alcohol, jars, and museum incidentals	445 77	
Transportation for museum	450 00	
Assistance and labor in museum	500 00	
Gallery of art	82 87	
		$6,999 81
Total expenditure		$35,149 16

The estimated income for the year 1857 was $38,290 14, exclusive of the balance in the hands of the Treasurer; the *actual* income exclusive of this balance was $38,326 14.

The estimated expenditure amounted to $34,000, the actual expenditure to $35,149 16. The excess is due to unexpected repairs, necessary to the building in consequence of a very severe hail storm, which broke several thousand panes of glass, and otherwise injured the edifice; and to the payment of the last unsettled account contracted by the architect for the gas pipes and fixtures.

The expenditures, however, are less than the income for the year, leaving a total balance now in the hands of the Treasurer of $10,341 30. Of this sum, $5,000 are the remainder of the extra fund, ($125,000,) intended to be permanently invested, and the whole is at present required for carrying on the operations of the Institution, until the receipt of the next semi-annual income.

During the past year, the stocks purchased by the Institution temporarily declined in commercial value, but they are now selling at about the same prices as those at which they were bought. Fluctuations, however, of this character do not affect the income of the Institution, since the amount of interest continues permanently the same.

The committee respectfully submit the following estimate of the receipts and expenditures for the year 1858:

Receipts.

Balance in the hands of the Treasurer January 1, 1858, (exclusive of $5,000 belonging to the extra fund)	$5,341 30
Interest on the original fund for 1858	30,910 14
Interest on the extra fund invested in State stocks	7,416 00
	$43,667 44

Expenditures.

BUILDING, FURNITURE AND FIXTURES, ETC.

Repairs and incidentals	$1,500 00	
Furniture and fixtures in common	500 00	
" " for library	150 00	
" " for museum	150 00	
Magnetic observatory	50 00	
		$2,350 00

GENERAL EXPENSES.

Meetings of Board and committees	$300 00	
Lighting and heating	600 00	
Postage	500 00	
Transportation and exchange	2,500 00	
Stationery	350 00	
General printing	350 00	
Apparatus	250 00	
Laboratory	400 00	
Incidentals, general	650 00	
Salaries.—Secretary	3,500 00	
Chief clerk	1,400 00	
Book-keeper	200 00	
Janitor	400 00	
Watchman	500 00	
Laborers	800 00	
Extra clerk hire	300 00	
		$13,000 00

PUBLICATIONS, RESEARCHES AND LECTURES.

Smithsonian Contributions to Knowledge	$6,500 00	
Reports	1,500 00	
Other publications	1,000 00	
Meteorology	3,000 00	
Investigations, computations, and researches	250 00	
Lectures	1,000 00	
		13,250 00

LIBRARY, MUSEUM AND GALLERY OF ART.

Cost of books	$3,000 00	
Pay of assistants in library	1,200 00	
Transportation for library	400 00	
Incidentals for library	150 00	
Museum—salary	2,000 00	
Explorations	50 00	
Collections	50 00	
Incidentals, museum, jars, alcohol, &c	300 00	
Transportation, museum	550 00	
Assistants and labor, museum	600 00	
Gallery of art	100 00	
		8,400 00
		$37,000 00

It is impossible to make a very definite estimate of the expenditures on account of the museum, during the year 1858, because the collection at the Patent Office is to be transferred to the keeping of the Institution, and the amount of expenditures under this head will depend upon the appropriation made by Congress for this purpose.

In conclusion, the committee report that they have examined the books, and each account for the past year, separately, and find them all correct.

Respectfully submitted.

J. A. PEARCE,
A. D. BACHE,
JOS. G. TOTTEN,
Executive Committee.

REPORT OF THE BUILDING COMMITTEE.

The building of the Smithsonian Institution having been completed, the special object of the Building Committee for which it was originally appointed, might be considered accomplished, and therefore an annual report no longer necessary; but as a large portion of the edifice remained unfinished, and since repairs are required which will probably be very expensive, it is thought proper that the committee should be continued.

At the last session of Congress an appropriation of fifteen thousand dollars was made for cases for the accommodation of the collections belonging to government. These are now finished and form a beautiful addition to the large hall, and are apparently well adapted to the purpose for which they are intended. With strict economy the appropriation of Congress has been found sufficient to provide accommodations for the present reception of the articles, though in the course of time additional cases will be required.

The west wing of the building, devoted to the library, has been furnished with alcoves and a gallery extending around three sides of the large room. This arrangement, which will serve very much to increase the accommodation and security of the books, produces a very pleasing architectural effect.

The large cisterns in the grounds near the building, which were directed to be arched over at the last session of the Board, have been properly secured, and one of them converted into an ice-house.

The balance of a bill for gas fixtures, which had been contracted by the architect, and which remained unsettled, on account of a disagreement as to certain charges, has been finally paid, after a reduction of $352 99.

The peculiar style of architecture of the building, and the large amount of surface it exposes to the weather, renders constant repairs necessary. During the past year almost the whole time of two workmen has been occupied in this service.

Respectfully submitted.

RICHARD RUSH,
WM. H. ENGLISH,
JOSEPH HENRY,
Building Committee.

JOURNAL OF PROCEEDINGS

OF THE

BOARD OF REGENTS

OF

THE SMITHSONIAN INSTITUTION.

MONDAY, MARCH 16, 1857.

A meeting of the Board of Regents was held this day at 11 o'clock a. m.

Present: Hon. R. B. Taney, Chancellor, Hon. John C. Breckinridge, James M. Mason, S. A. Douglas, Gen. Jos. G. Totten, Prof. A. D. Bache, Wm. B. Magruder, and the Secretary.

The minutes of the last meeting were read and approved.

The Chancellor, Chief Justice Taney, then presented the following communication:

WASHINGTON, *March* 16, 1857.

GENTLEMEN: When the Board of Regents was originally organized it was deemed proper that the Vice President of the United States for the time being should be elected as the Chancellor. The Institution exists under the authority of Congress, and they have made certain officers of the government *ex officio* Regents. The Vice President is the highest in rank of the officers thus designated; and it would seem to be peculiarly proper that the one who presides over the deliberations of one branch of the national legislature should also preside over the deliberations of a scientific institution which the nation has brought into existence and fosters.

Unfortunate events have for some time past left the government without a Vice President elected by the people. And when that office was vacant the Regents conferred on me the office which had always before been filled by the Vice President. And when I accepted it I regarded the appointment as a temporary one. The reason for the appointment has now happily ceased, and I desire to give the Regents an opportunity of restoring the original plan of organization, in which I fully concurred when it was adopted.

I therefore resign the office of Chancellor of the Institution, and at the same time return my thanks for the honor which the Regents bestowed upon me in electing me to that office.

But my resignation will not lessen the interest I feel in the Institution. On the contrary, every year's experience has more and more convinced me of its usefulness and efficiency in promoting the objects of its founder, and I shall always be ready to offer my humble aid if I can be useful in advancing its prosperity and success.

I have the honor to be, with the highest respect, your obedient servant,

R. B. TANEY.

To the REGENTS OF THE SMITHSONIAN INSTITUTION.

Mr. Breckinridge, Vice President of the United States, moved that the present Chancellor, Chief Justice Taney, be re-elected to that office, expressing his unwillingness to assume the position which had been so long and so ably filled by its present occupant.

The motion was adopted unanimously, whereupon Judge Taney remarked that he was anxious to serve the Institution to the best of his ability, and he could not decline this expression of the confidence of the Board if they insisted on his retaining the office of Chancellor.

The Secretary announced that, by joint resolution of the Senate and House of Representatives, Hon. Richard Rush, of Pennsylvania, and Gen. Joseph G. Totten, of the city of Washington, had been re-elected Regents for six years; also that the President of the Senate had reappointed Hon. James A. Pearce and Hon. James M. Mason, Regents for the same period of time.

The Secretary announced to the Board that, since its last meeting, three distinguished men of science, correspondents of the Institution, had deceased, namely: Prof. J. W. BAILEY, Dr. E. K. KANE, and Mr. W. C. REDFIELD.

On this announcement Prof. Bache offered a series of appropriate remarks, referring to their eminent services in the promotion of science.

Gen. Totten offered the following resolutions, which were adopted:

Resolved, That the Regents of the Smithsonian Institution have heard with regret the announcement of the death of Prof. JACOB W. BAILEY, whose communications to the Smithsonian Contributions have attracted the notice and won the approval of naturalists throughout the world.

Resolved, That the Regents offer to the family of Prof. Bailey their condolence on the loss which they have sustained.

Mr. Douglas offered the following resolutions, which were adopted:

Resolved, That the Regents of the Smithsonian Institution, in common with the whole country, have heard with deep regret of the death of one of their esteemed collaborators, Dr. E. K. KANE, to whom was committed by this Institution a set of philosophical instruments for the purpose of research in the polar regions, which he used, and carefully returned at the hazard of his life, with a series of observations of great value to science.

Resolved, That the Regents offer to the family of Dr. Kane their condolence on the loss which they have sustained.

Prof. Bache offered the following resolution, which was adopted:

Resolved, That the Regents of the Smithsonian Institution have heard with regret of the decease of their valued correspondent, WILLIAM C. REDFIELD, of New York, whose labors in meteorology have rendered his name familiar to men of science in every part of the civilized world, and offer to his family their condolence on the loss which they have sustained.

A communication from Dr. Robert Hare was read, relative to the practical construction of minute weights and measures.

On motion of Dr. Magruder, the following resolutions were adopted:

Resolved, That a copy of the communication of Dr. Hare be transmitted to the Secretary of the Treasury, with the recommendation of the Board of Regents that the instrument offered by Dr. Hare be received by the government, and placed in the Office of Weights and Measures.

Resolved, That the communication of Dr. Hare be inserted in the appendix to the report of the Regents to Congress.

A communication from J. A. Johnson, esq., of Maryland, relative to an "International Geographic and Scientific Commission" was read and referred to the Executive Committee and the Secretary.

The Secretary made a communication to the Board, relative to an article which had been published by Prof. S. F. B. Morse, containing charges against his moral character and his scientific reputation.

The Chancellor made a few remarks, confirming Prof. Henry's statement as to the advice he had given him respecting this attack.

On motion of Mr. Mason, the following resolution was adopted:

Resolved, That the communication of the Secretary and accompanying documents be referred to a committee, to examine and report upon it at the next session of the Board of Regents.

Whereupon the Chancellor appointed Messrs. Mason, Pearce, Felton, and Douglas as the committee.

The Board then adjourned *sine die.*

WASHINGTON, *January* 20, 1858.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of the beginning of their annual meeting on the third Wednesday of January of each year, the Board met this day in the Regents' room.

No quorum being present, the Board adjourned to meet on Thursday, January 28, 1858.

THURSDAY, JANUARY 28, 1858.

A meeting of the Board of Regents was held this day at 10 a. m., in the Smithsonian Institution.

Present: Hon. John C. Breckinridge, Vice President of the United States, Hon. J. M. Mason, Hon. S. A. Douglas, Hon. George E. Badger, Prof. A. D. Bache, Prof. C. C. Felton, Mr. Seaton, Treasurer, and the Secretary.

In the absence of the Chancellor the Vice President was called to the chair.

The minutes of the last meeting were read and approved.

The Secretary stated that, since the last meeting of the Board, the Speaker of the House of Representatives had appointed Hon. William H. English, of Indiana, Hon. Benjamin Stanton, of Ohio, and Hon. L. J. Gartrell, of Georgia, as Regents for the term of their service as members of the House.

The Treasurer presented a statement of the receipts and expenditures during the year 1857, and also a general statement of the funds; which were referred to the Executive Committee.

The following communication was presented:

WASHINGTON, *January* 23, 1858.

GENTLEMEN: The undersigned offers for sale, and respectfully suggests to your honorable Board the propriety of purchasing, the *gallery* of *Indian portraits* now, and for some years past, in the Smithsonian Institution.

He proposes to sell the whole collection described in the catalogue published by the Institution, one hundred and fifty-two in number, for the sum of twelve thousand dollars—one-third of the same cash and the remainder at two equal annual instalments; or, if it should be preferred, one-fourth down and the residue in three equal annual instalments.

The undersigned commenced his labors in this work in 1842, and devoted the best years of his life in travelling through the region of our country peopled principally by the red man—through the wilds of Oregon and what is now Washington Territory. All of the portraits are accurate likenesses of prominent chiefs and braves, and readily recognized by men who have had intercourse with the various tribes of Indians.

Since 1852 he has cherished the hope (but has not been able to realize it) that Congress would authorize the purchase of this collection. He has, up to this time, made sacrifices—such as one believing in the merit of his own work, and whose zeal in persevering through arduous and unremitting toil to accomplish it, alone would make—to keep this collection together. He will not affect the modesty of refraining from expressing his belief that no other gallery (aside from what artistic merit the public may award it) possesses the interest, in a national point of view, that this does. Some of the chiefs represented are no longer living; and, to the little we know of their history it will be some satisfaction to add the perpetuation of their features. These were taken from life and in the character they themselves preferred to be handed down to the gaze of future generations.

The price at which he offers this collection will not more than cover the outlay in cost of material, transportation, insurance, travelling expenses, &c., and will not afford him any compensation for his time and labor. Taking, as he humbly conceives, the intrinsic value of these Indian portraits into consideration, he will receive no pecuniary profit by their disposal on the terms named.

His ardent desire that they should be preserved, as a national work, in some place at the capital of our country; his failure heretofore to induce Congress to agree to their purchase, and the more pressing reasons of *liabilities* now maturing, impel him to make this proposition. Your honorable Board are again requested to consider it and communicate your answer at as early a day as is convenient. If the purchase of the portraits is not authorized by you, he will be compelled to expose them at public auction in time to have the proceeds available by the 1st of May next.

The undersigned will take this occasion to tender his acknowledgments to the Board and Professor Henry for the use of the hall in the Institution where the gallery now is, and for other courtesies, which he will always appreciate.

I am, very respectfully, your obedient servant,

J. M. STANLEY.

The Hon. BOARD OF REGENTS *of the Smithsonian Institution.*

On motion, this communication was referred to a special committee, and Messrs. Felton, Douglas, and Badger were appointed.

The Secretary laid before the Board a present from Miss Contaxaki, of Greece, consisting of a volume of drawings, &c., illustrating the celebrated works of art in her own land, together with the following letters:

WASHINGTON, *November* 23, 1857.

SIR: During my last trip to the east I was charged by Miss Elizabeth B. Contaxaki, a native of the isle of Crete, with an "ornamental album," which she desired me to present, through you, to the Smithsonian Institution. In forming the work, this lady designed it as a contribution to the Universal Exhibition at Paris, in 1855, worthy of the classic renown of the ancient city of Athens. So ardent is her admiration of the United States and its institutions that she wishes it to be permanently placed in this country, and having a high appreciation of you as an American statesman, and your reputation as a classical scholar, she desired that I would request you to offer it in her name to the Smithsonian Institution.

The "Classical Bouquet," as it is entitled, consists of illustrations of the principal monuments and places in the kingdom of Greece, to which are added a few from her native isle of Crete, not yet emancipated from the Moslem yoke. These illustrations are explained by quotations from the ancient Greek authors in the original language, beautifully illuminated; whilst many of the pages are adorned with flowers culled from the spots which the drawings represent.

Miss Contaxaki is the sole originator and authoress of it, assisted in its execution by native artists of Greece. The beauty of the finish, and the faithfulness and accuracy of the quotations from Hesiod, Homer, Xenophon, Plato, and others, show that the present sons and daughters of the renowned ancient city of Minerva are not insensible of the glory that was once attached to her name, nor incapable of appreciating those monuments of art, science, and literature which still survive.

Feeling assured that, as an eminent classical scholar, you will fully appreciate the worth of the Classical Bouquet, I beg to present it, through you, to the Smithsonian Institution, in her name.

With sentiments of the highest respect, I remain your obedient servant,

CHAS. S. SPENCE.

Hon. LEWIS CASS,
Secretary of State.

WASHINGTON CITY, *November* 25, 1857.

SIR: I send you herewith a splendid album, together with a letter from Mr. Spence, explanatory of the circumstances of its execution and transmission to this country. I perform the duty of presenting it to the Smithsonian Institution with great pleasure, for it is a finished specimen of taste and art, worthy of a prominent place in your interesting collection. Mr. Spence has so well described it that any further reference to it on my part is unnecessary.

I am, dear sir, respectfully yours,

LEWIS CASS.

Prof. HENRY,
Smithsonian Institution, Washington City.

On motion, the work was referred to Professor Felton, to report a resolution expressive of the high appreciation of the gift on the part of the Board, and a letter of acknowledgment to Miss Contaxaki.

A letter was read from Sir George Simpson, expressing the desire and intention of the agents of the Hudson's Bay Company to co-operate with the Smithsonian Institution in procuring specimens of natural history, and in the prosecution of scientific researches.

The Board then adjourned to meet on Saturday, 30th instant, at 11 o'clock, a. m.

SATURDAY, JANUARY 30, 1858.

The Board of Regents met this day in the hall of the Institution at 11 o'clock a. m.

Present: Hon. J. C. Breckinridge, Vice President of the United States, Hon. J. A. Pearce, Hon. J. M. Mason, Hon. S. A. Douglas, Hon. W. H. English, Professor A. D. Bache, Professor C. C. Felton, Mr. Seaton, Treasurer, and the Secretary.

The Vice President took the chair.

The minutes were then read and approved.

The minutes of the last meeting of the "Establishment" were read for information, according to the by-laws of that body.

The Secretary stated to the Board the action of Congress at its last session relative to the construction of cases in the Smithsonian building for the government collections, and also the decision of the Attorney General respecting the law.

The Secretary then presented the annual report of the operations, expenditures, and condition of the Institution during the year 1857; which was read.

The Board then visited the rooms of the building, the collections, &c., and adjourned.

WASHINGTON, *April* 10, 1858.

The Board of Regents met this day at 11 o'clock a. m.

Present: Hon. J. M. Mason, Hon. S. A. Douglas, Hon. George E. Badger, Hon. Benj. Stanton, Hon. L. J. Gartrell.

Mr. Mason was called to the chair.

The minutes were read and approved.

The report of the Building Committee for the year 1857 was read and accepted.

The report of the Executive Committee was presented, together with the estimates for the year 1858.

Communications relative to the care of the government collections, the Wynn estate, the publications, investigations, and other operations of the Institution, were read.

On motion of Mr. Badger, the Secretary was directed to have the windows and other parts of the east wing of the building put in good order.

The following report from Professor Felton was presented:

REPORT ON THE PRESENT OF MISS CONTAXAKI.

The Secretary laid before the Board a volume received from Greece, and sent as a gift to the Smithsonian Institution, together with the letter of the Hon. Mr. Spence, late United States minister to Constantinople, to the Secretary of State, and the letter of the Hon. Lewis Cass, the Secretary of State, to Professor Henry, the Secretary of the Institution. The volume and the correspondence were referred to Professor Felton.

The volume was transmitted from Athens, Greece, through Mr.

Spence. It was designed and executed by a Greek lady of rare literary accomplishments, Miss Elizabeth B. Contaxaki, assisted by six Greek gentlemen, resident in Athens. It contains sketches of the principal ruins in that city, and views of the most famous historical places there and in other parts of Greece, correctly drawn and delicately colored, together with the passage, from the classic authors, in which the objects and places are described or referred to, translations of the passages, and extracts from English and French writers on the same subjects. The book is adorned with exquisitely drawn vignettes, and emblematic devices, and with specimens of the wild flowers which grow in the places described, carefully preserved, pressed, and attached to the leaves. The volume is bound in blue velvet, and tastefully decorated with silver. It is put in an elegantly and richly carved case, made of olive wood, from the olive groves near Athens, where stood, in ancient times, the academic groves of Plato's school. The body of the case is made of the trunk of the tree, and the ornamental portions, of the root, which is of darker and richer color. This beautiful gift, therefore, combines a great variety of objects, possessing, from their associations with the loftiest achievements of Hellenic genius, a deep and singular interest, and forming a most appropriate memorial of the country from which European art, education, philosophy, and letters took their rise.

Miss Contaxaki, the tasteful designer of this memorial, is a native of the island of Crete. At the time of the outbreak of the Greek revolution, her father was a landed proprietor there, and, in common with the great body of the Hellenic race, lost most of his property by the rapacity and tyranny of the Turks. His family was dispersed, and his daughter Elizabeth became an inmate in the family of the Rev. Dr. John H. Hill, the American missionary, who established himself in Athens, at the close of the war, for the benevolent and enlightened purpose of aiding the Greeks to reconstruct the shattered edifice of civilization, by establishing the school, which still continues to dispense the blessings of education among the children of its first pupils in that illustrious capital. Residing with Dr. Hill for many years, and educated chiefly under his superintendence and care, Elizabeth became known to many American travellers in the East, by whom she has often been mentioned with a cordial appreciation of her accomplishments and merits. Their personal relations have naturally inspired her with a warm interest in the United States, heightened by the sympathies of the citizens of America in the regeneration of her country, and the substantial aid furnished by them to Greece in the hour of her utmost need. Recently Miss Contaxaki, after a visit to Constantinople, where she was received with distinction, has returned to her native island, which is under the government of the Pacha of Egypt, and, by her learning and ability, has succeeded in recovering, through the Moslem tribunal, a portion of her paternal estate.

The volume now presented to the Smithsonian Institution was sent to the great Paris Exhibition of 1855, where it excited much admiration, and gained a diploma for its accomplished author. She has now transmitted it for permanent deposit among the treasures of the Smithsonian Institution in the United States.

The Regents of the Institution accept the gift with great pleasure, not only on account of its rare beauty, its intrinsic value, and the many interesting associations it suggests with that famous city, called by Milton "the eye of Greece, mother of art and arms," but also as an expressive symbol of the hearty good will for the American republic, cherished by the enlightened spirit of a nation which has so honorably vindicated its right to the glories of an illustrious descent by re-establishing the institutions of freedom and learning on the soil where, in ancient times, they earliest flourished, and with unexampled splendor.

The committee recommends the adoption of the following resolutions by the Board:

Resolved, That the regents of the Smithsonian Institution accept, with gratitude, the splendid memorial volume presented by Miss Elizabeth B. Contaxaki, and that they recognize, in the beauty, taste, and art displayed in its general execution and style of its embellishment, a pleasing indication that the genius which placed the ancient Greeks at the head of the civilization of the world still survives in their descendants.

Resolved, That a copy of the above report, and of these resolutions, be transmitted, with a letter of acknowledgment from the Smithsonian Institution, to Miss Contaxaki, the accomplished donor.

On motion, the report was accepted and the resolutions adopted.

The Board then adjourned.

WEDNESDAY, MAY 19, 1858.

The Board met this day in the Vice President's room, United States Capitol, at 9½ o'clock.

Present: The Chancellor, Hon. Roger B. Taney, Hon. John C. Breckinridge, Vice President of the United States, Hon. J. M. Mason, Hon. J. A. Pearce, Hon. S. A. Douglas, Hon. W. H. English, Hon. Benjamin Stanton, Prof. A. D. Bache, and the Secretary.

The minutes were read and approved.

Mr. Pearce explained the report of the Executive Committee and the estimates for the year 1858, and, on motion, they were adopted.

The following report was presented from Prof. Felton, of the committee to whom was referred the communication of Mr. J. M. Stanley:

REPORT ON THE PROPOSITION TO PURCHASE THE INDIAN GALLERY.

The Secretary laid before the Board a letter from Mr. J. M. Stanley, painter of the gallery of Indian portraits, now on deposit with the Smithsonian Institution, proposing to sell them to the Institution for the sum of twelve thousand dollars.

The committee appointed to consider and report upon the subject respectfully represent that, while they are fully sensible of the great historical and ethnological value of this collection of portraits, and of their characteristic excellence, they are yet of opinion that it would be inexpedient to withdraw the sum mentioned from the funds necessary to carry on the scheme of active operations, which has been so ably inaugurated and, thus far, so successfully executed. The income of the Smithsonian fund should not be scattered among different and disconnected objects, and the sum necessary for the purchase of the gallery cannot be spared, without crippling for a time, at least, the regular operations of the Institution.

Among the Contributions to Knowledge several important works relating to the aboriginal inhabitants of America have been published by the Institution and circulated over the civilized world.

Grammars and dictionaries of the Indian languages may be mentioned as of special interest, and of great value to the science of comparative philology. Their language will probably pass away, and the races speaking them disappear; but the works to which we allude will preserve, for future investigators of the science of philology, the characteristic form in which their thoughts were expressed, and will have an important bearing, not only on general ethnological inquiries, but on the philosophy of the human mind. These volumes have been eagerly sought and studied by the most eminent comparative philologists of Europe, and have, by universal consent, contributed materially to the increase and diffusion of knowledge among men in that department of science.

But though your committee are of opinion that the purchase of this gallery would interfere with the present plan of operations, and that it would not so directly tend to the increase and diffusion of knowledge, they would earnestly express the opinion that, in a national point of view, the value of these portraits can hardly be overestimated.

They represent forty-three different tribes, and are taken from the leading personages in them. The artist has studied carefully the peculiarities of the tribes, the characteristic expressions of the individuals, their natural attitudes and actions, their several styles of costume and ornament, and has reproduced, with artistic skill, all these particulars. To this interesting enterprise he has given ten of the best years of his life, having traversed, with great labor and inconvenience, the principal regions inhabited by the subjects of his pencil. The number of portraits, including that of the artist, enumerated in the catalogue, is one hundred and fifty-two. The price for which they are offered is much below their real value, being less than $80 a piece. At the proposed rate the artist will receive no compensation for his time and labor, and barely enough to defray the cost of material, transportation, travelling expenses and insurance.

The number of the tribes represented so faithfully in this gallery, and the prominence of the individuals, render the collection very complete and satisfactory, as presenting a general view of the characteristic features of the red man. These circumstances make it important that the gallery should be preserved entire. Its peculiar value consists in its comprehensive character no less than in the fidelity of the individual details. Centuries hence, when most all of the tribes here represented shall have disappeared, as the New England tribes, for example, have nearly disappeared, this gallery will be an object of the profoundest interest to the student of man, the historian, the philosopher, and the statesman.

The relations between the government of the United States and the Indian tribes form one of the most delicate and important subjects of national legislation. The government has not only endeavored to deal with the red men in a liberal and paternal spirit, but has done much towards illustrating their character and condition by the publication of costly works embodying the observations and researches of investigators who have devoted themselves to Indian studies. It appears to your committee that to purchase this collection, and to place it in some secure situation easy of access to visitors at the capital, would be an act worthy of the enlightened liberality of Congress. The cost would be insignificant, and the value of the collection would increase in all future time. No place is so suitable for its permanent deposit as the city of Washington, and no guardianship so appropriate as that of the government of the United States.

Your committee recommend to the Board that the subject of the purchase of Mr. Stanley's Indian gallery be brought respectfully to the attention of Congress, as a measure eminently deserving a favorable consideration in its bearings upon the history of the aboriginal tribes of America, and as a monument of deep and lasting interest to the people of the United States.

The report was accepted, and laid on the table for the present.

The Secretary stated that Mr. Putnam having resigned the agency of the Smithsonian publications in New York, Messrs. D. Appleton & Co. had been appointed his successors.

The Secretary announced that since the last meeting of the Board the death of Dr. ROBERT HARE, of Philadelphia, had occurred, who was one of the principal benefactors of the Institution, and its first honorary member.

Professor Bache gave an account of the life, character, and scientific researches of Dr. Hare, and offered the following resolutions:

Resolved, That the Regents of the Smithsonian Institution have learned with deep regret the decease of one of the earliest and most venerated honorary members of the establishment, Robert Hare, M.D., of Philadelphia, late professor of chemistry in the University of Pennsylvania.

Resolved, That the activity and power of mind of Dr. Hare, shown through a long and successful career of physical research, the great fertility of invention, the happy adaptations to matters of practical life, and the successful grappling with questions of high theory in physical science, have placed him among the first in his country of the great contributors to knowledge, *clarum et venerabile nomen.*

Resolved, That while we deplore the loss of this great and good man, who has done so much to keep alive the flame of science in our country in past days, we especially mourn the generous patron of our Institution, the sympathizing friend of the youth of some of us, and the warm-hearted colleague of our manhood.

Resolved, That we offer to the bereaved family of Dr. Hare our sincere condolence in the loss which they have sustained by his death.

The resolutions were adopted.

The report of the Secretary for 1857 was then accepted.

Professor Felton, in behalf of the special committee to whom the following communication of Professor Henry of March 16, 1857, together with accompanying documents, &c., were referred, presented a report.

COMMUNICATION FROM PROF. HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION, RELATIVE TO A PUBLICATION BY PROF. MORSE.

Gentlemen: In the discharge of the important and responsible duties which devolve upon me as Secretary of the Smithsonian Institution, I have found myself exposed, like other men in public positions, to unprovoked attack and injurious misrepresentation. Many instances of this, it may be remembered, occurred about two years ago, during the discussions relative to the organic policy of the Institution; but, though very unjust, they were suffered to pass unnoticed, and generally made, I presume, no lasting impression on the public mind.

During the same controversy, however, there was one attack made upon me of such a nature, so elaborately prepared and widely circulated, by my opponents, that, though I have not yet publicly noticed it, I have from the first thought it my duty not to allow it to go unanswered. I allude to an article in a periodical entitled "Shaffner's Telegraph Companion," from the pen of Prof. S. F. B. Morse, the celebrated inventor of the American electro-magnetic telegraph. In this, not my scientific reputation merely, but my moral character was pointedly assailed; indeed, nothing less was attempted than to prove that in the testimony which I had given in a case where I was at most but a reluctant witness, I had consciously and wilfully deviated from the truth, and this, too, from unworthy and dishonorable motives.

Such a charge, coming from such a quarter, appeared to me then, as it appears now, of too grave a character and too serious a consequence to be withheld from the notice of the Board of Regents. I, therefore, presented the matter unofficially to the Chancellor of the Institution, Chief Justice Taney, and was advised by him to allow the matter to rest until the then existing excitement with respect to the organization of the Institution should subside, and that in the meantime the materials for a refutation of the charge might be collected and prepared, to be brought forward at the proper time, if I should think it necessary.

The article of Mr. Morse was published in 1855, but at the session of the Board in 1856 I was not prepared to present the case properly to your consideration, and I now (1857) embrace the first opportunity of bringing the subject officially to your notice, and asking from you an investigation into the justice of the charges alleged against me. And this I do most earnestly, with the desire that when we shall all have passed from this stage of being, no imputation of having attempted to evade in silence so grave a charge shall rest on *me*, nor on *you*, of having continued to devolve upon me duties of the highest responsibility, after that was known to some of you individually, which, if true, should render me entirely unworthy of your confidence. Duty to the Board of Regents, as well as regard to my own memory, to my family, and to the truth of history, demands that I should lay this matter before you, and place in your hands the documents necessary to establish the veracity of my testimony, so falsely impeached, and the integrity of my motives, so wantonly assailed.

My life, as is known to you, has been principally devoted to science, and my investigations in different branches of physics have given me some reputation in the line of original discovery. I have sought, however, no patent for inventions, and solicited no remuneration for my labors, but have freely given their results to the world, expecting only, in return, to enjoy the consciousness of having added, by my investigations, to the sum of human knowledge, and to receive the credit to which they might justly entitle me.

I commenced my scientific career about the year 1828, with a series of experiments in electricity, which were continued at intervals up to the period of my being honored by election to the office of Secretary of this Institution. The object of my researches was the advancement of science, without any special or immediate reference to its application to the wants of life or useful purposes in the arts. It is true, nevertheless, that some of my earlier investigations had an important bearing on the electro-magnetic telegraph, and brought the science to that point of development at which it was immediately applicable to Mr. Morse's particular invention.

In 1831 I published a brief account of these researches, in which I drew attention to the fact of their applicability to the telegraph; and in 1832, and subsequently, exhibited experiments illustrative of the application of the electro-magnet to the transmission of power to a distance, for producing telegraphic and other effects. The results I had published were communicated to Mr. Morse, by his scientific assistant, Dr. Gale, as will be shown on the evidence of the latter; and the facts which I had discovered were promptly applied in rendering effective the operation of his machine.

In the latter part of 1837 I became personally acquainted with Mr. Morse, and at that time, and afterwards, freely gave him information in regard to the scientific principles which had been the subject of my investigations. After his return from Europe, in 1839, our intercourse was renewed, and continued uninterrupted till 1845. In that year, Mr. Vail, a partner and assistant of Mr. Morse, published a work purporting to be a history of the Telegraph, in which I conceived manifest injustice was done me. I complained of this to a mutual friend, and subsequently received an assurance from Mr. Morse that if another edition were published, all just ground of complaint should be removed. A new emission of the work, however, shortly afterwards appeared, without change in this respect, or further reference to my labors. Still I made no public complaint, and set up no claims on account of the telegraph. I was content that my published researches should remain as material for the history of science, and be pronounced upon, according to their true value, by the scientific world.

After this, a series of controversies and lawsuits having arisen between rival claimants for telegraphic patents, I was repeatedly appealed to, to act as expert and witness in such cases. This I uniformly declined to do, not wishing to be in any manner involved in these litigations, but was finally compelled, under legal process, to return to Boston from Maine, whither I had gone on a visit, and to give evidence on the subject. My testimony was given with the statement that I was not a willing witness, and that I labored under the disadvantage of not having access to my notes and papers, which were in Washington. That testimony, however, I now reaffirm to be true in every essential particular. It was unimpeached before the court, and exercised an influence on the final decision of the question at issue.

I was called upon on that occasion to state, not only what I had published, but what I had done, and what I had shown to others in regard to the telegraph. It was my wish, in every statement, to render Mr. Morse full and scrupulous justice. While I was constrained, therefore, to state that he had made no discoveries in science, I distinctly declared that he was entitled to the merit of combining and applying the discoveries of others, in the invention of the best practical form of the magnetic telegraph. My testimony tended to establish the fact that, though not entitled to the exclusive use of the electro-magnet for telegraphic purposes, he was entitled to his particular machine, register, alphabet, &c. As this, however, did not meet the full requirements of Mr. Morse's comprehensive claim, I could not but be aware that, while aiming to depose nothing but truth and the whole truth, and while so doing being obliged to speak of my own discoveries, and to allude to the omissions in Mr. Vail's book, I might expose myself to the possible, and, as it has proved, the actual, danger of having my motives misconstrued and my testimony misrepresented. But I can truly aver, in accordance with the statement of the counsel, Mr. Chase, (now governor of Ohio,) that I had no desire to arrogate to myself undue merit, or to detract from the just claims of Mr. Morse.

I have the honor to be your obedient servant,

JOSEPH HENRY.

To the Board of Regents.

The Chancellor, Chief Justice Taney, corroborated Prof. Henry's statement as to his advising a delay in noticing the publication referred to until the public mind should be more settled in regard to the policy of the Institution, and the discussions which had arisen in Congress in reference to it should be ended.

He stated that it would be seen by the report of the decision of the Supreme Court, in the case in which Professor Henry was a witness, that, in the opinion of the court, Professor Morse had produced no testimony that could invalidate the testimony of Professor Henry, or impair in any degree its weight, and gave full credit to it in the udgment it pronounced.

REPORT OF THE SPECIAL COMMITTEE OF THE BOARD OF REGENTS ON THE COMMUNICATION OF PROFESSOR HENRY.

Professor Henry laid before the Board of Regents of the Smithsonian Institution a communication relative to an article in Shaffner's Telegraph Companion, bearing the signature of Samuel F. B. Morse, the inventor of the American electro-magnetic telegraph. In this article serious charges are brought against Professor Henry, bearing upon his scientific reputation and his moral character. The whole matter having been referred to a committee of the Board, with instructions to report on the same, the committee have attended to the duty assigned to them, and now submit the following brief report, with resolutions accompanying it.

The committee have carefully examined the documents relating to the subject, and especially the article to which the communication of Professor Henry refers. This article occupies over ninety pages, filling an entire number of Shaffner's Journal, and purports to be "a defence against the injurious deductions drawn from the deposition of Professor Joseph Henry, (in the several telegraph suits,) with a critical review of said deposition, and an examination of Professor Henry's alleged discoveries bearing upon the electro-magnetic telegraph."

The first thing which strikes the reader of this article is, that its title is a misnomer. It is simply an assault upon Professor Henry; an attempt to disparage his character; to deprive him of his honors as a scientific discoverer; to impeach his credibility as a witness and his integrity as a man. It is a disingenuous piece of sophistical argument, such as an unscrupulous advocate might employ to pervert the truth, misrepresent the facts, and misinterpret the language in which the facts belonging to the other side of the case are stated.

Mr. Morse charges that the deposition of Professor Henry "contains imputations against his (Morse's) personal character," which it does not, and assumes it as a duty "to expose the utter non-reliability of Professor Henry's testimony;" that testimony being supported by the most competent authorities, and by the history of scientific discovery. He asserts that he "is not indebted to him (Professor Henry) for any discovery in science bearing on the telegraph," he having himself acknowledged such indebtedness in the most unequivocal manner, and the fact being independently substantiated by the testimony of SEARS C. WALKER, and the statement of Mr. Morse's own associate, Dr. GALE. Mr. Morse further maintains, that all discoveries bearing upon the telegraph were made, not by Professor Henry, but by others, and prior to any experiments of Professor Henry in the science of electro-magnetism; contradicting in this proposition the facts in the history of scientific discovery perfectly established and recognized throughout the scientific world.

The essence of the charges against Prof. Henry is, that he gave false testimony in his deposition in the telegraph cases, and that he has claimed the credit of discoveries in the sciences bearing upon the electro-magnetic telegraph which were made by previous investigators; in other words, that he has falsely claimed what does not belong to him, but *does* belong to others.

Professor Henry, as a private man, might safely have allowed such charges to pass in silence. But standing in the important position which he occupies, as the chief executive officer of the Smithsonian Institution; and regarding the charges as undoubtedly containing an impeachment of his moral character, as well as of his scientific reputation; and justly sensitive, not only for his own honor, but for the honor of the Institution, he has a right to ask this Board to consider the subject, and to make their conclusions a matter of record, which may be appealed to hereafter should any question arise with regard to his conduct in the premises.

Your committee do not conceive it to be necessary to follow Mr. Morse through all the details of his elaborate attack. Fortunately, a plain statement of a few leading facts will be sufficient to place the essential points of the case in a clear light.

The deposition already referred to was reluctantly given, and under the compulsion of legal process, by Prof. Henry, before the Hon. Geo. S. Hillard, United States commissioner, on the 7th of September, 1849.

The following is the statement of the Hon. S. P. CHASE, (now governor of Ohio,) one of the counsel in the telegraph cases, in a letter to Professor Henry, dated Columbus, Ohio, November 26, 1856:

> In the year 1849, I was professionally employed in the defence of certain gentlemen engaged in the business of telegraphing between Louisville and New Orleans, against whom a bill of complaint had been filed in the Circuit Court of the United States for the district of Kentucky. The object of the bill was to restrain the defendants, my clients, from the use in telegraphing of a certain instrument called the Columbian Telegraph, on the ground that it was an infringement upon the rights of the complainants under the patents granted to Professor Morse. It therefore became my duty, in the preparation of their defence, to ascertain the precise nature and extent of their rights. With this view I called upon you, in August or September of that year, for your deposition. It was taken before George S. Hillard, esq., a United States commissioner for the district of Massachusetts, in Boston. I remember very well that you were unwilling to be involved in the controversy, even as a witness, and that you only submitted to be examined in compliance with the requirements of law. Not one of your statements was volunteered. They were all called out by questions propounded either verbally or in writing. I was not sufficiently familiar at the time with the precise merits of the case to know what would or would not be important, and therefore insisted on a full statement, not merely of the general history of electro-magnetism as applied to telegraphing, but of all your own discoveries in that science having relation to the same art, and of all that had passed between yourself and Professor Morse connected with these discoveries or with the telegraph. You could not have refused to respond to the questions propounded, without subjecting yourself to judicial animadversion and constraint. Nothing in what you testified, or your manner of testifying, suggested to me the idea that you were animated by any desire to arrogate undue merit to yourself, or to detract from the just claims of Professor Morse.
>
> S. P. CHASE.

Previous to this deposition, Mr. Morse, as appears from his own letters and statements, entertained for Prof. Henry the warmest feelings of personal regard, and the highest esteem for his character as a scientific man. In a letter, dated April 24, 1839, he thanks Prof. Henry for a copy of his "valuable contributions," and says, "I perceive many things (in the contributions) of great interest to me in my telegraphic enterprise." Again, in the same letter, speaking of an intended visit to the Professor at Princeton, he says: "I should come as a learner, and could bring no 'contributions' to your stock of experiments of any value." And still further: "I think that you have pursued an original course of experiments, and discovered facts more immediately bearing upon my invention than any that have been published abroad."

It appears, from Mr. Morse's own statement, that he had at least two interviews with Prof. Henry—one in May, 1839, when he passed the afternoon and night with him, at Princeton; and another in February, 1844—both of them for the purpose of conferring with him on subjects relating to the telegraph, and evidently with the conviction, on Mr. Morse's part, that Prof. Henry's investigations were of great importance to the success of the telegraph.

As late as 1846, after Mr. Morse had learned that some dissatisfaction existed in Prof. Henry's mind in regard to the manner in which his researches in electricity had been passed over by Mr. Vail, an assistant of Mr. Morse, and the author of a history of the American magnetic telegraph, Mr. Morse, in an interview with Prof. Henry, at Washington, said, according to his own account, "Well, Prof. Henry, I will take the earliest opportunity that is afforded me in anything I may publish to have justice done to your labors; for I do not think that justice has been done you, either in Europe or this country."

Again, in 1848, when Prof. Walker, of the Coast Survey, made his report on the theory of Morse's electro-magnetic telegraph, in which the expression occurred, "the helix of a soft iron magnet, prepared after the manner first pointed out by Prof. Henry," Mr. Morse, to whom the report was submitted, said: "I have now the long wished for opportunity to do justice publicly to Henry's discovery bearing on the telegraph." And in a note prepared by him, and intended to be printed with Prof. Walker's report, he says: "The allusion you make to the helix of a soft iron magnet, prepared after the manner first pointed out by Prof. Henry, gives me an opportunity, of which I gladly avail myself, to say that I think that justice has not yet been done to Prof. Henry, either in Europe or in this country, for the discovery of a scientific fact, which, in its bearing on telegraphs, whether of the magnetic needle or electro-magnet order, is of the greatest importance."

He then proceeds to give a historical synopsis, showing that, although suggestions had been made and plans devised by Soemmering, in 1811, and by Ampère, in 1820, yet that the experiments of Barlow, in 1824, had led that investigator to pronounce "the idea of an electric telegraph to be chimerical"—an opinion that was, for the time, acquiesced in by scientific men. He shows that, in the interval between 1824 and 1829, no further suggestions were made on the subject of electric telegraphs. But he proceeds—"In 1830, Prof. Henry, assisted by Dr. Ten Eyck, while engaged in experiments on the application of the principle of the galvanic multiplier to the development of great magnetic power in soft iron, made the important discovery that a battery of intensity overcame that resistance in a long wire which Barlow had announced as an insuperable bar to the construction of electric telegraphs. Thus was opened the way for fresh efforts in devising a practicable electric telegraph; and Baron Schilling, in 1832, and Professors Gauss and Weber, in 1833, had ample opportunity to learn of Henry's discovery, and avail themselves of it, before they constructed their needle telegraphs." And, while claiming for himself that he was "the first to propose the use of the electro-magnet for telegraphic purposes, and the first to construct a telegraph on the basis of the electro-magnet," yet he adds, "*to Professor Henry is unquestionably due the honor of the discovery of a principle which proves the practicability of exciting magnetism through a long coil, or at a distance, either to deflect a needle or to magnetize soft iron.*"

What Mr. Morse here describes as "a principle," the discovery of which is unquestionably due to Professor Henry, is the law which first made it possible to work the telegraphic machine invented by Mr. Morse, and for the knowledge of which Mr. Morse was indebted to Professor Henry, as is positively asserted by his associate, Dr. GALE. This gentleman, in a letter, dated Washington, April 7, 1856, makes the following conclusive statement:

WASHINGTON, D. C., *April* 7, 1856.

SIR: In reply to your note of the 3d instant, respecting the Morse telegraph, asking me to state definitely the condition of the invention when I first saw the apparatus in the winter of 1836, I answer: This apparatus was Morse's original instrument, usually known as the type apparatus, in which the types, set up in a composing stick, were run through a circuit breaker, and in which the battery was the cylinder battery, with a single pair of plates. This arrangement also had another peculiarity, namely, it was the electro-magnet used by Moll, and shown in drawings of the older works on that subject, having only a few turns of wire in the coil which surrounded the poles or arms of the magnet. The sparseness of the wires in the magnet coils and the use of the single cup battery were to me, on the first look at the instrument, obvious marks of defect, and I accordingly suggested to the Professor, without giving my reasons for so doing, that a battery of many pairs should be substituted for that of a single pair, and that the coil on each arm of the magnet should be increased to many hundred turns each; which experiment, if I remember aright, was made on the same day with a battery and wire on hand, furnished I believe by myself, and it was found that while the original arrangement would only send the electric current through a few feet of wire, say 15 to 40, the modified arrangement would send it through as many hundred. Although I gave no reasons at the time to Professor Morse for the suggestions I had proposed in modifying the arrangement of the machine, I did so afterwards, and referred in my explanations to the paper of Professor Henry, in the 19th volume of the American Journal of Science, page 400 and onward. It was to these suggestions of mine that Professor Morse alludes in his testimony before the circuit court for the eastern district of Pennsylvania, in the trial of B. B. French and others *vs.* Rogers and others.—See printed copy of Complainant's Evidence, page 168, beginning with the words "Early in 1836 I procured 40 feet of wire," &c., and page 169, where Professor Morse alludes to myself and compensation for services rendered to him, &c.

At the time I gave the suggestions above named, Professor Morse was not familiar with the then existing state of the science of electromagnetism. Had he been so, or had he read and appreciated the paper of Henry, the suggestions made by me would naturally have occurred to his mind as they did to my own. But the principal part of Morse's great invention lay in the mechanical adaptation of a power to produce motion, and to increase or relax at will. It was only necessary for him to know that such a power existed for him to adapt mechanism to direct and control it.

My suggestions were made to Professor Morse from inferences drawn by reading Professor Henry's paper above alluded to. Professor Morse professed great surprise at the contents of the paper when I showed it to him, but especially at the remarks on Dr. Barlow's results respecting telegraphing, which were new to him, and he stated at the time that he was not aware that any one had even conceived the idea of using the magnet for such purposes.

With sentiments of esteem, I remain yours truly,

L. D. GALE.

Prof. Jos. Henry,
Secretary of the Smithsonian Institution.

It further appears, that principally for the information thus communicated Mr. Morse assigned to Dr. Gale an interest in the telegraph, which he afterwards purchased back for $15,000, as appears from the following letter of Dr. Gale:

Patent Office, *August* 5, 1857.

Dear Sir: In reply to yours of this date, respecting the interest I once possessed in Morse's telegraph patent, secured to me by the said Morse, as alluded to by him in his statement to the Commissioner of

Patents, I would simply state that the part I owned when I entered the service of the government in this office was orginally given me by the said Morse for services rendered him in making his invention practically effective in sending currents through long distances, &c., and that the said interest was retransferred to the said Morse for the sum of fifteen thousand dollars.

Respectfully,

L. D. GALE.

Professor HENRY,
Secretary Smithsonian Institution.

It thus appears, both from Mr. Morse's own admission down to 1848, and from the testimony of others most familiar with the facts, that Professor Henry discovered the law, or "principle," as Mr. Morse designates it, which was necessary to make the practical working of the electro-magnetic telegraph at considerable distances possible; that Mr. Morse was first informed of this discovery by Dr. Gale; that he availed himself of it at once, and that it never occurred to Mr. Morse to deny this fact until after 1848. He had steadily and fully acknowledged the merits and genius of Mr. Henry, as the discoverer of facts and laws in science of the highest importance to the success of his long-cherished invention of a magnetic telegraph. Mr. Henry was the discoverer of a principle, Mr. Morse was the inventor of a machine, the object of which was to record characters at a distance, to convey intelligence, in other words, to carry into execution the idea of an electric telegraph. But there were obstacles in the way which he could not overcome until he learned the discoveries of Professor Henry, and applied them to his machine. These facts are undeniable. They constitute a part of the history of science and invention. They were true in 1848, they were equally true in 1855, when Professor Morse's article was published. We give a passage here from the deposition of SEARS C. WALKER, in the case of French *vs.* Rogers, Respondent's Evidence, page 199, bearing upon this whole subject:

"In consequence of some statements made by me in my official reports relative to the invention of the receiving magnet, a question arose between Mr. Morse and myself as to the origin of this invention. It was amicably discussed by Mr. Morse, Professor Henry, Dr. Gale, and myself, with Professor Henry's article, alluded to in answer to the second question before us. The result of the interview was conclusive to my mind that Professor Henry was the sole discoverer of the law on which the intensity magnet depends for its power of sending the galvanic current through a long circuit. I was also led to conclude that Mr. Morse, in the course of his own researches and experiments before he had read Professor Henry's article, before alluded to, had encountered the same difficulty Mr. Barlow and those who preceded him had encountered, that is, the impossibility of forcing the galvanic current through a long telegraph line. His own personal researches had not overcome this obstacle. They were made in the laboratory of the New York University. I also learned at the same time, by the conversations above stated, that he only overcame this obstacle by constructing a magnet on the principle invented by Professor Henry, and described in his article in Silliman's Journal. His attention was directed to it by Dr. Gale."

What changed Mr. Morse's opinion of Professor Henry, not only as a scientific investigator, but as a man of integrity, after the admissions of his indebtedness to his researches, and the oft repeated expressions of warm personal regard? It appears that Mr. Morse was involved in a number of lawsuits, growing out of contested claims to the right of using electricity for telegraphic purposes. The circumstances under which Professor Henry, as a well known investigator in this department of physics, was summoned by one of the parties to testify have already been stated. The testimony of Mr. Henry, while supporting the claims of Mr. Morse as the inventor of an admirable invention, denied to him the additional merit of being a discoverer of new facts or laws of nature, and to this extent, perhaps, was considered unfavorable to some part of the claim of Mr. Morse to an *exclusive* right to employ the electro-magnet for telegraphic purposes. Professor Henry's deposition consists of a series of answers to verbal, as well as written, interrogatories propounded to him, which were not limited to his published writings, or the subject of electricity, but extended to investigations and discoveries in general having a bearing upon the electric telegraph. He gave his testimony at a distance from his notes and manuscripts, and it would not have been surprising if inaccuracies had occurred in some parts of his statement; but all the material points in it are sustained by independent testimony, and that portion which relates directly to Mr. Morse agrees entirely with the statement of his own assistant, Dr. Gale. Had his deposition been objectionable, it ought to have been impeached before the Court; but this was not attempted; and the following tribute to Professor Henry by the judge, in delivering the opinion of the Supreme Court of the United States, indicates the impression made upon the Court itself by all the testimony in the case: "It is due to him to say that no one has contributed more to enlarge the knowledge of electro-magnetism, and to lay the foundations of the great invention of which we are speaking, than the Professor himself."

Professor Henry's answers to the first and second interrogatories present a condensed history of the progress of the science of electro-magnetism, as connected with telegraphic communication, embracing an account of the discoveries of Oersted, Arago, Davy, Ampère; of the investigations by Barlow and Sturgeon; of his own researches, commenced in 1828, and continued in 1829, 1830, and subsequently. The details of his experiments and their results, though brief, are very precise. There is abundant evidence to show that Professor Henry's experiments and illustrations at Albany, and subsequently at Princeton, proved, and were declared at the time by him to prove, that the electric telegraph was now practicable; that the electro-magnet might be used to produce mechanical effects at a distance adequate to making signals of various kinds, such as ringing bells, which he practically illustrated. In proof of this, we quote a letter to Professor Henry, from Professor JAMES HALL, of Albany, late president of the American Association for the Advancement of Science:

JANUARY 19, 1856.

DEAR SIR: While a student of the Rensselaer School, in Troy, New York, in August, 1832, I visited Albany with a friend, having a letter of introduction to you from Professor Eaton. Our principal object was to see your electro-magnetic apparatus, of which we had heard much, and at the same time the library and collections of the Albany Institute.

You showed us your laboratory in a lower story or basement of the building, and in a larger room in an upper story some electric and galvanic apparatus, with various philosophical instruments. In this room, and extending around the same, was a circuit of wire stretched along the wall, and at one termination of this, in the recess of a window, a bell was fixed, while the other extremity was connected with a galvanic apparatus.

You showed us the manner in which the bell could be made to ring by a current of electricity, transmitted through this wire, and you remarked that this method might be adopted for giving signals, by the ringing of a bell at the distance of many miles from the point of its connexion with the galvanic apparatus.

All the circumstances attending this visit to Albany are fresh in my recollection, and during the past years, while so much has been said respecting the invention of electric telegraphs, I have often had occasion to mention the exhibition of your electric telegraph in the Albany Academy, in 1832.

If at any time or under any circumstances this statement can be of service to you in substantiating your claim to such a discovery at the period named, you are at liberty to use it in any manner you please, and I shall be ready at all times to repeat and sustain what I have here stated, with many other attendant circumstances, should they prove of any importance.

I remain very sincerely and respectfully yours,

JAMES HALL.

Professor JOSEPH HENRY.

In his deposition, Prof. Henry's statements are within what he might fairly have claimed. But he is a man of science, looking for no other reward than the consciousness of having done something for its promotion, and the reputation which the successful prosecution of scientific investigations and discoveries may justly be expected to give. In his public lectures and published writings he has often pointed out incidentally the possibility of applying the facts and laws of nature discovered by him to practical purposes; he has freely communicated information to those who have sought it from him, among whom has been Mr. Morse himself, as appears by his own acknowledgments. But he has never applied his scientific discoveries to practical ends for his own pecuniary benefit. It was natural, therefore, that he should feel a repugnance to taking any part in the litigation between rival inventors, and it was inevitable that, when forced to give his testimony, he should distinctly point out what was so clear in his own mind and is so fundamental a fact in the history of human progress, the distinctive functions of the discoverer and the inventor who applies discoveries to practical purposes in the business of life.

Mr. Henry has always done full justice to the invention of Mr. Morse. While he could not sanction the claim of Mr. Morse to the *exclusive* use of the electro-magnet, he has given him full credit for the mechanical contrivances adapted to the application of his invention. In proof of this we refer to his deposition, and present also the following statement of Hon. Charles Mason, Commissioner of Patents, taken from a letter addressed by him to Prof. Henry, dated March 31, 1856:

U. S. Patent Office, *March* 31, 1856.

Sir: Agreeably to your request I now make the following statement:

Some two years since, when an application was made for an extension of Prof. Morse's patent, I was for some time in doubt as to the propriety of making that extension. Under these circumstances I consulted with several persons, and among others with yourself, with a view particularly to ascertain the amount of invention fairly due to Prof. Morse.

The result of my inquiries was such as to induce me to grant the extension. I will further say that this was in accordance with your express recommendation, and that I was probably more influenced by this recommendation, and the information I obtained from you, than by any other circumstance, in coming to that conclusion.

I am, sir, yours very respectfully,

CHARLES MASON.

Prof. J. Henry.

To sum up the results of the preceding investigation in a few words

We have shown that Mr. Morse himself has acknowledged the value of the discoveries of Prof. Henry to his electric telegraph; that his associate and scientific assistant, Dr. Gale, has distinctly affirmed that these discoveries were applied to his telegraph, and that previous to such application it was impossible for Mr. Morse to operate his instrument at a distance; that Prof. Henry's experiments were witnessed by Prof. Hall and others in 1832, and that these experiments showed the possibility of transmitting to a distance a force capable of producing mechanical effects adequate to making telegraphic signals; that Mr. Henry's deposition of 1849, which evidently furnished the motive for Mr. Morse's attack upon him, is strictly correct in all the historical details, and that, so far as it relates to Mr. Henry's own claim as a discoverer, is within what he might have claimed with entire justice; that he gave the deposition reluctantly, and in no spirit of hostility to Mr. Morse; that on that and other occasions he fully admitted the merit of Mr. Morse as an inventor; and that Mr. Morse's patent was extended through the influence of the favorable opinion expressed by Professor Henry.

Your committee come unhesitatingly to the conclusion that Mr. Morse has failed to substantiate any one of the charges he has made against Prof. Henry, although the burden of proof lay upon him; and that all the evidence, including the unbiased admissions of Mr. Morse himself, is on the other side. Mr. Morse's charges not only remain unproved but they are positively disproved.

Your committee recommend the adoption of the following resolutions:

Resolved, That Professor Morse has not succeeded in refuting the statements of Professor Henry in the deposition given by the latter in 1849; that he has not proved any one of the accusations against Prof. Henry made in the article in Shaffner's Telegraph Companion in 1855, and that he has not disproved any one of his own admissions in regard to Prof. Henry's discoveries in electro-magnetism, and their importance to his own invention of the electro-magnetic telegraph.

Resolved, That there is nothing in Professor Morse's article that diminishes, in the least, the confidence of this Board in the integrity of Prof. Henry, or in the value of those great discoveries which have placed his name among those of the most distinguished cultivators of science, and have done much to exalt the scientific reputation of the country.

Resolved, That this report, with the resolutions, be recorded in the Proceedings of the Board of Regents of the Institution.

The report was accepted and the resolutions were unanimously adopted. The Board then adjourned *sine die.*

APPENDIX TO THE REPORT OF THE COMMITTEE.

STATEMENT OF PROFESSOR HENRY IN RELATION TO THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.

In the beginning of my deposition I was requested to give a sketch of the history of electro-magnetism having a bearing on the telegraph, and the account I then gave from memory I have since critically examined and find it fully corroborated by reference to the original authorities. My sketch, which was the substance of what I had been in the habit of giving in my lectures, was necessarily very concise, and almost exclusively confined to one class of facts, namely, those having a direct bearing on Mr. Morse's invention, and my paper in Silliman's Journal was likewise very brief and intended merely for scientific men. In order, therefore, to set forth more clearly in what my own improvements consisted it may be proper to give a few additional particulars respecting some points in the progress of discovery, illustrated by wood cuts.

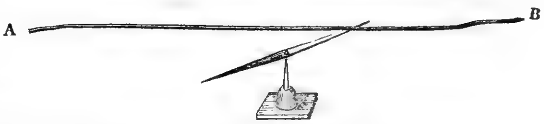
There are several forms of the electrical telegraph: first, that in which frictional electricity has been proposed to produce sparks and motion of pith balls at a distance.

Second, that in which galvanism has been employed to produce signals by means of bubbles of gas from the decomposition of water.

Third, that in which electro-magnetism is the motive power to produce motion at a distance; and again, of the latter there are two kinds of telegraph, those in which the intelligence is indicated by the motion of a magnetic needle, and those in which sounds and permanent signs are made by the attraction of an electro-magnet. The latter is the class to which Mr. Morse's invention belongs. The following is a brief exposition of the several steps which led to this form of the telegraph.

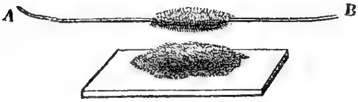
The first essential fact, as I stated in my testimony, which rendered the electro-magnetic telegraph possible was discovered by Oersted, in the winter of 1819–'20. It is illustrated by figure 1, in which the magnetic needle is deflected by the action of a current of galvanism transmitted through the wire A B. (See Annals of Philosophy, vol. 16, page 273.)

Fig. 1.



The second fact of importance, discovered in 1820, by Arago and Davy, is illustrated in figure 2. It consists in this, that while a current of galvanism is passing through a copper wire A B, it is magnetic, it attracts iron filings and not those of copper or brass, and is capable of developing magnetism in soft iron. (See Annales de Chimie, vol. 15, page 94.)

Fig. 2.



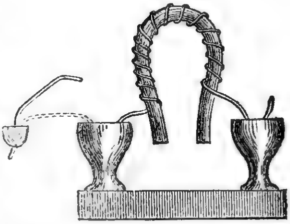
The next important discovery, also made in 1820, by Ampère, was that two wires through which galvanic currents are passing in the same direction attract, and in opposite direction repel, each other. On this fact Ampère founded his celebrated theory, that magnetism consists merely in the attraction of electrical currents revolving at right angles to the line joining the two poles of the magnet. The magnetisation of a bar of steel or iron, according to this theory, consists in establishing within the metal by induction a series of electrical currents, all revolving in the same direction at right angles to the axis or length of the bar. (See Annales de Chimie, vol. 15, page 69.)

It was this theory which led Arago, as he states, to adopt the method of magnetizing sewing needles and pieces of steel wire, shown in figure 3. This method consists in transmitting a current of electricity through a helix surrounding the needle or wire to be magnetized. For the purpose of insulation the needle was inclosed in a glass tube, and the several turns of the helix were at a distance from each other to insure the passage of electricity, through the whole length of the wire, or, in other words, to prevent it from seeking a shorter passage by cutting across from one spire to another. The helix employed by Arago obviously approximates the arrangement required by the theory of Ampère, in order to develop by induction the magnetism of the iron. By an attentive perusal of the original account of the experiments of Arago, given in the Annales de Chimie et Physique, vol. XV, 1820, page 93, it will be seen that, properly speaking, he made no electro-magnet, as has been asserted by Morse and others; his experiments were confined to the magnetism of iron filings, to sewing needles and pieces of steel wire of the diameter of a millimetre, or of about the thickness of a small knitting needle. (See Annales de Chimie, vol. 15, page 95.)

Fig. 3.

Mr. Sturgeon, in 1825, made an important step in advance of the experiments of Arago, and produced what is properly known as the electro-magnet. He bent a piece of iron *wire* into the form of a horseshoe, covered it with varnish to insulate it, and surrounded it with a helix, of which the spires were at a distance. When a current of galvanism was passed through the helix from a small battery of a single cup the iron wire became magnetic, and continued so during the passage of the current. When the current was interrupted the magnetism disappeared, and thus was produced the first temporary soft iron magnet.

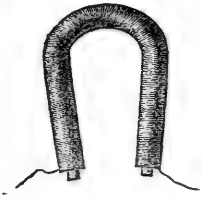
Fig. 4.



The electro-magnet of Sturgeon is shown in figure 4, which is an exact copy from the drawing in the Transactions of the Society for the Encouragement of Arts, &c., vol. XLIII. By comparing figures 3 and 4 it will be seen that the helix employed by Sturgeon was of the same kind as that used by Arago; instead, however, of a straight steel wire inclosed in a tube of glass, the former employed a bent wire of soft iron. The difference in the arrangement at first sight might appear to be small, but the difference in the results produced was important, since the temporary magnetism developed in the arrangement of Sturgeon was sufficient to support a weight of several pounds, and an instrument was thus produced of value in future research.

The next improvement was made by myself. After reading an account of the galvanometer of Schweigger, the idea occurred to me that a much nearer approximation to the requirements of the theory of Ampère could be attained by insulating the conducting wire itself, instead of the rod to be magnetized, and by covering the whole surface of the iron with a series of coils in close contact. This was effected by insulating a long wire with silk thread, and winding this around the rod of iron in close coils from one end to the other. The same principle was extended by employing a still longer insulated wire, and winding several strata of this over the first, care being taken to insure the insulation between each stratum by a covering of silk ribbon. By this arrangement the rod was surrounded by a compound helix formed of a long wire of many coils, instead of a single helix of a few coils, (figure 5.)

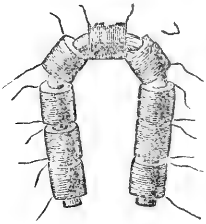
Fig. 5.



In the arrangement of Arago and Sturgeon the several turns of wire were not precisely at right angles to the axis of the rod, as they should be, to produce the effect required by the theory, but slightly oblique, and therefore each tended to develop a separate magnetism not coincident with the axis of the bar. But in winding the wire over itself the obliquity of the several turns compensated each other, and the resultant action was at right angles to the bar. The arrangement then introduced by myself was superior to those of Arago and Sturgeon, first in the greater multiplicity of turns of wire, and second in the better application of these turns to the development of magnetism. The power of the instrument, with the same amount of galvanic force, was by this arrangement several times increased.

The maximum effect, however, with this arrangement and a single battery was not yet obtained. After a certain length of wire had been coiled upon the iron the power diminished with a further increase of the number of turns. This was due to the increased resistance which the longer wire offered to the conduction of electricity. Two methods of improvement therefore suggested themselves. The first consisted, not in increasing the length of the coil, but in using a number of separate coils on the same piece of iron. By this arrangement the resistance to the conduction of the electricity was diminished and a greater quantity made to circulate around the iron from the same battery. The second method of producing a similar result consisted in increasing the number of elements of the battery, or, in other words, the projectile force of the electricity, which enabled it to pass through an increased number of turns of wire, and thus, by increasing the length of the wire, to develop the maximum power of the iron.

Fig. 6.



To test these principles on a larger scale the experimental magnet was constructed, which is shown in figure 6. In this a number of compound helices were placed on the same bar, their ends left projecting, and so numbered that they could be all united into one long helix, or variously combined in sets of lessser length.

From a series of experiments with this and other magnets it was proved that, in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used then one long wire must be employed, making many turns around the iron, the length of wire and consequently the number of turns being commensurate with the projectile power of the battery.

In describing the results of my experiments the terms *intensity* and *quantity* magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the *intensity* magnet I designated a piece of soft iron, so surrounded with wire that its magnetic power could be called into operation by an *intensity* battery, and by a *quantity* magnet, a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a *quantity* battery.

I was the first to point out this connexion of the two kinds of the battery with the two forms of the magnet in my paper in Silliman's Journal, January 1831, and clearly to state that when magnetism was to be developed by means of a compound battery, one long coil was to be employed, and when the maximum effect was to be produced by a single battery, a number of single strands were to be used.

These steps in the advance of electro-magnetism though small, were such as to interest and astonish the scientific world. With the same battery used by Mr. Sturgeon, at least a hundred times more magnetism was produced than could have been obtained by his experiment. The developments were considered at the time of much importance in a scientific point of view, and they subsequently furnished the means by which magneto-electricity, the phenomena of dia-magnetism, and the magnetic effects on polarized light were discovered. They gave rise to the various forms of electro-magnetic machines which have since exercised the ingenuity of inventors in every part of the world, and were of immediate applicability in the introduction of the magnet to telegraphic purposes. Neither the electro-magnet of Sturgeon nor any electro-magnet ever made previous to my investigations was applicable to transmitting power to a distance.

The principles I have developed were properly appreciated by the scientific mind of Dr. Gale, and applied by him to operate Mr. Morse's machine at a distance.

Previous to my investigations the means of developing magnetism in soft iron were imperfectly understood. The electro-magnet made by Sturgeon, and copied by Dana, of New York, was an imperfect quantity magnet, the feeble power of which was developed by a single battery. It was entirely inapplicable to a long circuit with an intensity battery, and no person possessing the requisite scientific knowledge would have attempted to use it in that connexion after reading my paper.

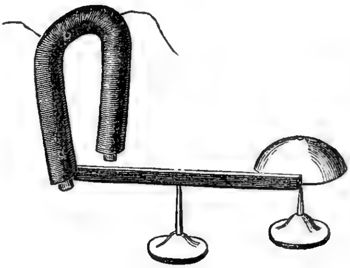
In sending a message to a distance two circuits are employed, the first a long circuit through which the electricity is sent to the distant station to bring into action the second, a short one, in which is the local battery and magnet for working the machine. In order to give projectile force sufficient to send the power to a distance, it is necessary to use an intensity battery in the long circuit, and in connexion with this, at the distant station, a magnet surrounded with many turns of one long wire must be employed to receive and multiply the effect of the current enfeebled by its transmission through the long conductor. In the local or short circuit either an intensity or a quantity magnet may be employed. If the first be used, then with it a compound battery will be required; and, therefore, on account of the increased resistance due to the greater quantity of acid, a less amount of work will be performed by a given amount of material; and, consequently, though this arrangement is practicable it is by no means economical. In my original paper I state that the advantages of a greater conducting power, from using several wires in the quantity magnet, may, in a less degree, be obtained by substituting for them one large wire; but in this case, on account of the greater obliquity of the spires and other causes, the magnetic effect would be less. In accordance with these principles, the receiving magnet, or that which is introduced into the long circuit, consists of a horse-shoe magnet surrounded with many hundred turns of a single long wire, and is operated with a battery of from 12 to 24 elements or more, while in the local circuit it is customary to employ a battery of one or two elements with a much thicker wire and fewer turns.

It will, I think, be evident to the impartial reader that these were improvements in the electro-magnet which first rendered it adequate to the transmission of mechanical power to a distance; and had I omitted all allusion to the telegraph in my paper, the conscientious historian of science would have awarded me some credit, however small might have been the advance which I made. Arago and Sturgeon, in the accounts of their experiments, make no mention of the telegraph, and yet their names always have been and will be associated with the invention. I briefly, however, called attention to the fact of the applicability of my experiments to the construction of the telegraph; but not being familiar with the history of the attempts made in regard to this invention, I called it "Barlow's project," while I ought to have stated that Mr. Barlow's investigation merely tended to disprove the possibility of a telegraph.

I did not refer exclusively to the needle telegraph when, in my paper, I stated that the *magnetic* action of a current from a trough is at least not sensibly diminished by passing through a long wire. This is evident from the fact that the immediate experiment from which this deduction was made was by means of an electro-magnet and not by means of a needle galvanometer.

At the conclusion of the series of experiments which I described in Silliman's Journal, there were two applications of the electro-magnet in my mind: one the production of a machine to be moved by electro-magnetism, and the other the transmission of or calling into action power at a distance. The first was carried into execution in the construction of the machine described in Silliman's Journal, vol. 20, 1831, and for the purpose of experimenting in regard to the second, I arranged around one of the upper rooms in the Albany Academy a wire of more than a mile in length, through which I was enabled to make signals by sounding a bell, (fig. 7.) The mechanical arrangement for affecting this object was simply a steel bar, permanently magnetized, of about ten inches in length, supported on a pivot and placed with its north end between the two arms of a horse-shoe magnet. When the latter was excited by the current, the end of the bar thus placed was attracted by one arm of the horse-shoe, and repelled by the other, and was thus caused to move in a horizontal plane and its further extremity to strike a bell suitably adjusted.

Fig. 7.



This arrangement is that which is alluded to in Professor Hall's letter* as having been exhibited to him in 1832 It was not, however, at that time connected with the long wire above mentioned, but with a shorter one put up around the room for exhibition.

At the time of giving my testimony, I was uncertain as to when I had first exhibited this contrivance, but have since definitely settled the fact by the testimony of Hall and others that it was before I left Albany, and abundant evidence can be brought to show that previous to my going to Princeton in November, 1832, my mind was much occupied with the subject of the telegraph, and that I introduced it in my course of instruction to the senior class in the Academy. I should

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* See the Report of the Committee, page 96, and Proceedings of the Albany Institute, anuary, 1858.

state, however, that the arrangement that I have described was merely a temporary one, and that I had no idea at the time of abandoning my researches for the practical application of the telegraph. Indeed, my experiments on the transmission of power to a distance were superseded by the investigation of the remarkable phenomena, which I had discovered in the course of these experiments, of the induction of a current in a long wire on itself, and of which I made the first mention in a paper in Silliman's Journal in 1832, vol. 22.

I also devised a method of breaking a circuit, and thereby causing a large weight to fall. It was intended to illustrate the practicability of calling into action a great power at a distance capable of producing mechanical effects; but as a description of this was not printed, I do not place it in the same category with the experiments of which I published an account, or the facts which could be immediately deduced from my papers in Silliman's Journal.

From a careful investigation of the history of electro-magnetism in its connexion with the telegraph, the following facts may be established:

1. Previous to my investigations the means of developing magnetism in soft iron were imperfectly understood, and the electro-magnet which then existed was inapplicable to the transmission of power to a distance.

2. I was the first to prove by actual experiment that, in order to develop magnetic power at a distance, a galvanic battery of intensity must be employed to project the current through the long conductor, and that a magnet surrounded by many turns of one long wire must be used to receive this current.

3 I was the first actually to magnetize a piece of iron at a distance, and to call attention to the fact of the applicability of my experiments to the telegraph.

4. I was the first to actually sound a bell at a distance by means of the electro-magnet.

5. The principles I had developed were applied by Dr. Gale to render Morse's machine effective at a distance.

The results here given were among my earliest experiments; in a scientific point of view I considered them of much less importance than what I subsequently accomplished; and had I not been called upon to give my testimony in regard to them, I would have suffered them to remain without calling public attention to them, a part of the history of science to be judged of by scientific men who are the best qualified to pronounce upon their merits.

DEPOSITION OF JOSEPH HENRY, IN THE CASE OF MORSE *vs.* O'REILLY,

TAKEN AT BOSTON, SEPTEMBER, 1849.

[*From the Record of the Supreme Court of the United States.*]

1. Please state your place of residence and your occupation; also, what attention, if any, you have given to the subjects of electricity, magnetism, and electro-magnetism.

Answer.—I begin this deposition with the express statement that I do not voluntarily give my testimony; but that I appear on legal summons, and in submission to law. I am Secretary to the Smithsonian Institution, established in the city of Washington, where I now reside. The principal direction of the Institution is confided to me. As I do not expect to return to Washington until some time in October, I have been called upon to give my testimony here in Boston; on this account I labor under the disadvantage of being obliged to testify without my notes and papers, which are now in Washington.

I commenced the study of electro-magnetism in 1827; and since then have, at different times, [until] within the last two and a half years, when I became Secretary of the Smithsonian Institution, made original investigations in this and kindred branches of physical science. I know no person in our country who has paid more attention to the study of the principles of electro-magnetism than myself.

2. Please give a general account of the progress of the science of electro magnetism, as connected with telegraphic communication; and of any inventions or discoveries in electro-magnetism applicable to the telegraph, made by yourself.

Answer.—I consider an electro-magnetic telegraph as one which operates by the combined influence of electricity and magnetism. Prior to the winter of 1819–'20, no form of the electro-magnetic telegraph was possible; the scientific principles on which it is founded were then unknown. The first fact of electro-magnetism was discovered by Oersted, of Copenhagen, during that winter. It is this: A wire being placed close above, or below, and parallel to a magnetic needle, and a galvanic current being transmitted through the wire, the needle will tend to place itself at right angles to it. This fact was widely published, and the account was everywhere received with interest.

The second fact of importance was discovered independently, and about the same time, by Arago, at Paris, and Davy, at London. It is this: During the transmission of a galvanic current through a wire of copper, or any other metal, the wire exhibits magnetic properties, attracting iron, but not copper filings, and having the power of inducing permanent magnetism in steel needles. The next important fact was discovered by Ampère, of Paris, one of the most sagacious and successful cultivators of physical science in the present century. It is this: Two parallel wires through which galvanic currents are passing in the same direction, attract each other; but if the currents pass in opposite directions, they repel each other. On this fact Ampère founded his ingenious theory of magnetism and electro-magnetism. According to this theory, all magnetic phenomena result from the attraction or repulsion of electric currents, supposed to exist in the iron at right angles to the length of the bar; and that all the phenomena of magnetism and electro magnetism are thus referred to one principle, namely, the action of electrical currents on each other.

Ampère deduced from this theory many interesting results, which were afterwards verified by experiment. He also proposed to the French Academy a plan for the application of electro-magnetism to the transmission of intelligence to a distance; this consisted in deflecting a number of needles at the place of receiving intelligence, by galvanic currents transmitted through long wires. This transmission was to be effected by completing a galvanic circuit. When completed, the needle was deflected. When interrupted, it returned to its ordinary position, under the influence of the attraction of the earth. This project of Ampère was never reduced to practice. All these discoveries and results were prior to 1823.

The next investigations relating to the magnetic telegraph were published in 1825; they were by Mr. Barlow, of the Royal Military Academy of Woolwich, England. He found that there was great diminution in the power of the galvanic current to produce effects with an increase of distance; a diminution so great in a distance of two hundred feet was observed, as to convince him of the impracticability of the scheme of the electro-magnetic telegraph. His experiments led him to conclude that the power was inversely as the square root of the length of the wire. The publication of these results put at rest, for a time, all attempts to construct an electro-magnetic telegraph.

The next investigations, in the order of time, bearing on the telegraph, were made by Mr. Sturgeon, of England. He bent a piece of iron wire into the form of a horse-shoe, and put loosely around it a coil of copper wire, with wide intervals between the turns or spires to prevent them touching each other, and through this coil he transmitted a current of galvanism. The iron, under the influence of this current, became magnetic, and thus was produced the first electro-magnetic magnet, sometimes called simply the electro-magnet. An account of this experiment was first published in November, 1825, in the Transactions of the Society for the Encouragement of the Arts in England; and was made known in this country through the Annals of Philosophy for November, 1826.

Nothing further was done pertaining to the telegraph until my own researches in electro-magnetism, which were commenced in 1828, and continued in 1829, 1830, and subsequently; Barlow's results, as I before observed, had prevented all attempts to construct a magnetic telegraph on the plan of Ampère, and our own knowledge of the development of magnetism in soft iron, as left by Sturgeon, was not such as to be applicable to telegraphic purposes. The electro-magnet of Sturgeon could not be made to act by a current through a long wire, as will be apparent hereafter in this deposition.

After repeating the experiments of Oersted, Ampère, and others, and publishing an account in 1828 of various modifications of electro-magnetic apparatus, I commenced in that year the investigation of the laws of the development of magnetism in soft iron, by means of the electrical current. The first idea that occurred to me in accordance with the theory of Ampère, with reference to increasing the power of the electro-magnet, was that of using a longer wire than had before been employed. A wire of sixty feet in length, covered with silk, was wound round a whole length of an iron bar, either straight or in the form of a U, so as to cover its whole length with several thicknesses of the wire.

The results of this arrangement were such as I had anticipated, and electro-magnets of this kind, exhibited to the Albany Institute in March, 1829, possessed magnetic power superior to that of any before known.

The idea afterwards occurred to me that the quantity of galvanism, supplied by a small galvanic battery, might be applied to develop a still greater amount of magnetic power in a large bar of iron. On experiment, I found this idea correct. A battery of two and a half square inches of zinc, developed magnetism in a large bar sufficient to lift fourteen pounds.

The next suggestion which occurred to me was that of using a number of wires of the same length around the same bar, so as to lessen the resistance which the galvanic current experienced in passing from the zinc to the copper through the coil. To bring this to the test of experiment, a second wire, equal in length to the first, was wound around the last mentioned magnet, and its ends soldered to the plates of the same battery.

The magnet with this additional wire lifted twenty-eight pounds, or, in other words, its power was doubled.

A series of experiments was afterwards made, to determine the resistance to conduction of wires of different lengths and diameters, and the proper lengths and number of wires for producing, with different kinds of galvanic batteries, the maximum of amount of magnetic development with a given quantity of zinc surface. For this purpose a bar of soft iron, two inches square and twenty inches long, weighing twenty-one pounds, and much larger than any before used, was bent in the form of a horse-shoe. Around this were wound nine strands of copper wire, each sixty feet long, the ends left projecting so that one or more coils could be used at once, either connected with a battery or with each other, thus forming several coils with several battery connexions, or one long coil with single battery connexions. The greatest effect obtained with this magnet, using a battery of a single pair, with a zinc plate of two-fifths of a square foot of surface, and all the wire arranged as separate coils, was to lift a weight of six hundred and fifty pounds; with a large battery the effect was increased to seven hundred and fifty pounds. In a subsequent series of experiments, not published with the preceding, the same magnet was made to sustain one thousand pounds. When a compound battery was employed of a number of pairs, it was found that the greatest effect was produced when all the wires were arranged as a single long coil. I subsequently constructed electro-magnets on the same plan, which supported much greater weights. One of these, now in the cabinet of Princeton, will sustain three thousand six hundred pounds with a battery occupying about a cubic foot of space. It consists of thirty strands of wire, each about forty feet in length.

The abovementioned experiments exhibit the important fact that when a galvanic battery of intensity (that is to say, a battery consisting of a number of pairs) is employed, the electro-magnet connected with it must be wound with one long wire, in order to produce the greatest effect; and that when a battery of quantity, (that is, one of a single pair,) is employed, the proper form of the magnet connected with it is that in which several shorter wires are wound around the iron. The first of these magnets, which is the one now employed in the long or main circuit of the telegraph, may be called an intensity magnet; and the second, which is used in the local circuit, may be denominated the quantity.

The quantity of electricity which can be passed through a long circuit of ordinary-sized wire is, under the most favorable circumstances, exceedingly small, and in order that this may develop magnetism in a bar of iron, it was necessary that it should be made to revolve many times around the iron, that its effects may be multiplied; and this is effected by using a long single coil. Hence it will be seen that the electro-magnet of Mr. Sturgeon was not applicable to telegraphic purposes in a long circuit.

Previous to making the last experiments above mentioned, in order to guide myself, I instituted a series of preliminary experiments on the conduction of wires of different lengths and diameters, with different batteries. In these experiments a galvanometer, or an instrument consisting of a magnetic needle freely suspended within a coil of wire, was first employed to denote, by the deflection of its needle, the power of the current. The result from a number of experiments, with a battery of a single pair, was the same as that obtained by Barlow, namely, that the power diminished rapidly with the increase of distance With the same battery, and a larger wire, the diminution was less. The galvanometer was next removed, and a small electro-magnet substituted in its place. With a single battery, the same result was again obtained—a great diminution of lifting power with the increase of distance. After this the battery of a single pair was removed and its place supplied by one of intensity, consisting of twenty-five pairs. With this the important fact was observed, that no perceptible diminution of the lifting power took place, when the current was transmitted through an intervening wire between the battery and the magnet of upwards of one thousand feet.

This was the first discovery of the fact that a galvanic current could be transmitted to a great distance with so little a diminution of force as to produce mechanical effects, and of the means by which the transmission could be accomplished. I saw that the electric telegraph was now practicable; and, in publishing my experiments and their results, I stated that the fact just mentioned was applicable to Barlow's project of such a telegraph. I had not the paper of Barlow before me, and erred in attributing to him a project of a telegraph, as he only disproved, as he thought, the practicability of one. But the intention of the statement was to show that I had established the fact that a mechanical effect could be produced by the galvanic current at a great distance, operating upon a magnet or needle, and that the telegraph was therefore possible. In arriving at these results, and announcing their applicability to the telegraph, I had not in mind any particular form of telegraph, but referred only to the general fact that it was now demonstrated that a galvanic current could be transmitted to great distances with sufficient power to produce mechanical effects adequate to the desired object.

The investigations above mentioned were all devised and originated, and the experiments planned, by myself. In conducting the latter, however, I was assisted by Dr. Philip Ten Eyck, of Albany. An account of the whole was published in the 19th volume of Silliman's Journal, in 1831, with the exception of the account of the large magnet afterwards constructed at Princeton in 1833, and the experiment mentioned of lifting a thousand pounds with one of my first magnets. While I was engaged in these researches, Prof. Moll, of the University of Utrecht, was pursuing investigations somewhat similar, and succeeded in making powerful electro-magnets, but made no discovery as to the distinction between the two kinds of magnets, or the transmissibility of the galvanic current to a great distance with power to produce mechanical effects. In fact, his experiments were but a repetition on a large scale of those of Sturgeon.

After completing the investigations abovementioned, I commenced a series of experiments on another branch of electricity closely connected with this subject. Among other things, I applied the principles above mentioned to the construction of an electro-magnetic machine, which has since excited much attention in reference to the application of electro-magnetism as a motive power in the arts.

In 1832 I was called to the chair of natural philosophy in the College of New Jersey, at Princeton, and in my first course of lectures in that institution, in 1833, and in every subsequent year during my connexion with that institution, I mentioned the project of the electro-magnetic telegraph, and explained how the electro-magnet might be used to produce mechanical effects at a distance adequate to making signals of various kinds. I never myself attempted to reduce these principles to practice, or to apply any of my discoveries to processes in the arts. My whole attention, exclusive of my duties to the college, was devoted to original scientific investigations, and I left to others what I considered in a scientific view of subordinate importance the application of my discoveries to useful purposes in the arts. Besides this, I partook of the feeling common to men of science, which disinclines them to secure to themselves the advantages of their discoveries by a patent.

In February, 1837, I went to Europe; and early in April of that year Prof. Wheatstone, of London, in the course of a visit to him in King's College, London, with Prof. Bache, now of the Coast Survey, explained to us his plans of an electro-magnetic telegraph; and, among other things, exhibited to us his method of bringing into action a second galvanic circuit. This consisted in closing the second circuit by the deflection of a needle, so placed that the two ends projecting upwards, *of* the open circuit, would be united by the contact of the end of the needle when deflected, and on opening or breaking of the circuit so closed by opening the first circuit, and thus interrupting the current, when the needle would resume its ordinary position under the influence of the magnetism of the earth. I informed him that I had devised another method of producing effects somewhat similar. This consisted in opening the circuit of my large quantity magnet at Princeton, when loaded with many hundred pounds weight, by attracting upward a small piece of moveable wire, with a small intensity magnet, connected with a long wire circuit. When the circuit of the large battery was thus broken by an action from a distance, the weights would fall, and great mechanical effect could thus be produced, such as the ringing of church bells at a distance of a hundred miles or more, an illustration which I had previously given to my class at Princeton. My impression is strong, that I had explained the precise process to my class before I went to Europe, but testifying now without the opportunity of reference to my notes, I cannot speak positively. I am, however, certain of having mentioned in my lectures every year previously, at Princeton, the project of ringing bells at a distance, by the use of the electro-magnet, and of having frequently illustrated the principle of transmitting power to a distance to my class, by causing in some cases a thousand pounds to fall on the floor, by merely lifting a piece of wire from two cups of mercury closing the circuit.

The object of Prof. Wheatstone, as I understood it, in bringing into action a second circuit, was to provide a remedy for the diminution of force in a long circuit. My object, in the process described by me, was to bring into operation a large quantity magnet, connected with a quantity battery in a local circuit, by means of a small intensity magnet, and an intensity battery at a distance.

The only other scientific facts of importance to the practical operation of the telegraph not already mentioned are the discovery by Steinheil, in 1837, in Germany, of the practicability of completing a galvanic circuit, by using the earth for completing the circuit, and the construction of the constant battery in 1836, or about that time, by Professor Daniell, of King's College, London. I believe that I was the first to repeat the experiments of Steinheil and Daniell in this country. I stretched a wire from my study to my laboratory, through a distance in the air of several hundred yards, and used the earth as a return conductor, with a very minute battery, the negative element of which was a common pin, such as is used in dress, and the positive element the point of a zinc wire immersed in a single drop of acid. With this arrangement, a needle was deflected in my laboratory before my class. I afterwards transmitted currents in various directions through the college grounds at Princeton. The exact date of these experiments I am unable to give without reference to my notes. They were previous, however, to the unsuccessful attempt of Mr. Morse to transmit currents of electricity through wires buried in the earth between Washington and Baltimore, and before he attempted to use the earth as a part of the circuit. Previous to this time, and after the abovementioned experiments, Mr. Morse visited me at Princeton, to consult me on the arrangement of his conductors. During this visit, we conversed freely on the subject of insulation and conduction of wires. I urged him to put his wires on poles, and stated to him my experiments and their results.

In the course of the years 1836 and 1837, various plans of more or less merit, were devised, and more or less fully carried into effect, for applying the principles already discovered to the construction of electro-magnetic telegraphs in different parts of the world, but of these I do not undertake to give any particular account. I would say, however, that of these plans that for which Mr. Morse subsequently obtained a patent was, in my judgment, the best.

3. Please state whether or not you are acquainted with the electro-magnetic telegraph for which S. F. B. Morse obtained a patent in 1846. If you are, please state whether any, and if any, which of the principles or plans which you have described as discovered, or announced by yourself or others are used in the construction or operation of it. State also what principles used in the telegraph are, so far as you know, original with Professor Morse.

Answer.—I am acquainted with the principles and general mode of operation of the telegraph and improvement referred to. The telegraph is based upon the facts discovered by myself and others, of which I have already given an account.

The plan which was first described to me in the autumn of 1837 by Mr. Morse, or by Professor Gale, who was associated with him in the construction of the telegraph, was to employ a single entire circuit of wire, with an intensity battery to excite the current, and an intensity magnet to receive it and produce a mechanical action, which would work the recording apparatus. Mr. Morse afterwards employed the intensity battery in a long circuit, and an intensity magnet to receive its current at a distant point, and produce the mechanical effect of closing a secondary circuit. The secondary circuit may be either employed to transmit a second current to a distant point and there close a third circuit, and thus continue the line, or for working a recording apparatus in the secondary circuit, or it may be employed without reference to the continuation of the line, as a short local circuit to work a local magnet. In the first case, there must be in the secondary circuit an intensity battery and intensity magnet; in the last case, a quantity magnet and quantity battery are required.

I heard nothing of the secondary circuit as a part of Mr. Morse's plan until after his return from Europe, whither he went in 1838. It was not till long after this that Mr. Morse used the earth as a part of the circuit in accordance with the discovery of Steinheil.

I am not aware that Mr. Morse ever made a single original discovery, in electricity, magnetism, or electro-magnetism, applicable to the invention of the telegraph. I have always considered his merit to consist in combining and applying the discoveries of others in the invention of a particular instrument and process for telegraphic purposes. I have no means of determining how far this invention is original with himself, or how much is due to those associated with him.

4. Please state when you first became acquainted with Mr. Morse, and what knowledge he possessed of electricity, magnetism, and

electro-magnetism, and what information you or others communicated to him relating to the telegraph. State, also, all you know of the attempts of himself, and others associated with him, to construct an electro-magnetic telegraph, either from your own observation or from statements made by himself or by others in your presence. State particularly any conversation, if any, you may have had with him in reference to your own discoveries applied to the telegraph.

Answer.—Shortly after my return from Europe, in the autumn of 1837, I learned that Mr. Morse was about to petition Congress for assistance in constructing the electro-magnetic telegraph. Some of my friends in Princeton, knowing what I had done in developing the principles of the telegraph, urged me to make the representations to Congress, which I expressed some thought of doing, namely: that the principles of the electro-magnetic telegraph belonged to the science of the world, and that any appropriation which might be made by Congress should be a premium for the best plan, and the means of testing the same, which the ingenuity of the country might offer. Shortly after this I visited New York, and there accidentally made the personal acquaintance of Mr. Morse;* he appeared to be an unassuming and prepossessing gentleman, with very little knowledge of the general principles of electricity, magnetism, or electro-magnetism. He made no claims, in conversation with me to any scientific discovery, or to anything beyond his particular machine and process of applying known principles to telegraphic purposes. He explained to me his plan of a telegraph with which he had recently made a successful experiment; I thought this plan better than any with which I had been made acquainted in Europe; I became interested in him, and instead of interfering in his application to Congress, I [subsequently†] gave him a certificate, in the form of a letter, stating my confidence in the practicability of the electro-magnetic telegraph and my belief that the form proposed by himself was the best which had been published.

Mr. Morse subsequently visited Princeton several times to confer with me on the principles of electricity and magnetism which might be applicable to the telegraph. I freely gave him any information I possessed.

I learned in 1837, or thereabouts, that Professor Gale and Dr. Fisher were the scientific assistants of Mr. Morse in preparing the telegraph. Mr. Vail was also employed, but I know not in what capacity, and I am not personally acquainted with him. With Professor Gale I have been intimately acquainted for several years; he had been a pupil in chemistry of my friend Dr. Torrey, and had studied my papers on electro-magnetism, and, as he informed me, had applied them in the arrangement of the apparatus for the construction of Morse's telegraph.

My researches had been given to the world several years before the attempt was made to reduce the magnetic telegraph to practice. Mr.

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* This meeting took place in the chemical store of Mr. Chilton, Broadway, New York, and the place and time are both indelibly impressed upon my mind.

† The word subsequently was accidentally omitted in giving my testimony. The omission, however, is of little importance.

Chilton, of New York, informed me that he had referred Mr. Morse to them previous to his experiments in the New York University. I was therefore much surprised on the publication, in 1845, of a work purporting to give a history of the telegraph, and of the principles on which it was founded, by Mr. Vail, then principal assistant of Mr. Morse, and one of the proprietors of his patent, to find all my published researches relating to the telegraph passed over with little more than the remark that Dr. Moll and myself had made large electro-magnetic magnets. Presuming that this publication was authorized by Mr. Morse and the proprietors of the telegraph, I complained to some of his friends of the injustice, and after his return from Europe, (for he was absent at the time the book was issued,) I received a letter, copied and signed by Mr. Vail, but written by Mr. Morse, as the latter afterwards informed me, excusing the publication, on the ground that he (Mr. Vail) was ignorant of what I had done, and asking me for an account of my researches. This letter was addressed to me after the book had been stereotyped and widely circulated. It has been translated into French, and, I believe, published in Paris. To the letter I did not think fit to make any reply. I afterwards received a letter from Mr. Morse, in his own name, on the same subject, to which I gave a verbal reply in January, 1847, in Washington. In this interview Mr. Morse acknowledged that injustice had been done me, but said that proper reparation would be made. Another issue of the same work was made, bearing date 1847, in which there is no change in the statement relative to my researches.

About the beginning of 1848 Mr. Walker, of the Coast Survey, in a report on the application of the telegraph to the determination of differences of longitude, alluded to my researches. A copy of this was sent to Mr. Morse, which led to an interview between Mr. Walker, Professor Gale, Mr. Morse, and myself. At this meeting, which took place at my office in Washington, Mr. Morse stated that he had not known until reading my paper in January, 1847, that I had two years before his first conception in 1832, settled the point of practicability of the telegraph, and shown how mechanical effects could be produced at a distance, both in the deflection of a needle and in the action of an electro-magnet; that he did not know, at the time of his experiments in 1837 that there had been any doubts of the action of a current at a distance, and that in the confidence of the persuasion that the effect could be produced, he had devised the proper apparatus by which his telegraph was put in operation. Professor Gale, being then referred to, stated that Mr. Morse had forgotten the precise state of the case; that he, (Mr. Morse,) previous to his, (Dr. Gale's,) connexion with him, had not succeeded in producing effects at a distance; that, when he was first called in he found Mr. Morse attempting to make an electro-magnet act through a circuit of a few yards of copper wire suspended around a room in the University of New York, and that he could not succeed in producing the desired effect even in *this* that circuit; that he (Dr. Gale) asked him if he had studied Prof. Henry's paper on the subject, and that the answer was "no;" that he then informed Mr. Morse that he would find the principles necessary to success explained in that paper; that instead of the battery of a single element, he should employ one of a number of pairs; and that, in place of the magnet with a short single wire, he should use one with a long coil. Dr. Gale further stated that his apparatus was in the same building, and that having articles of the kind he had mentioned, he procured them, and that with these the action was produced through a circuit of half a mile of wire.* To this statement Mr. Morse made no reply. The interview then terminated, and I have since had no further communication with him on the subject.

5. Please state whether or not you ever constructed any machine for producing motion by magnetic attraction and repulsion; if yea, what was it, and what led to the making of it.

Answer.—After developing the great magnetic power of the electro-magnet as already described, the thought occurred to me that this power might be applied to give motion to a machine. The simplest arrangement which suggested itself to my mind was one already referred to, namely, causing a movable bar, supported on a horizontal axis like a scale beam, to be attracted and repelled by two permanent magnets. This could be readily effected by transmitting through a coil of wire around the suspended bar a current of galvanism, first in one direction, and then in the opposite direction, the alternations of the current being produced by dipping the ends of wires projecting from the coils into cups of mercury connected with batteries, one on either side. An account of this was published in Silliman's Journal, for 1831, vol. xx., p. 340. It was the first successful attempt to produce a mechanical motion which might apparently be employed in the arts as a motive power. This little machine attracted much attention at home and abroad, and various modifications of it were made by myself and others. I never, however, regarded it as practically applicable in the arts, because of the great expense of producing power by this means, except, perhaps, in particular cases where expense of power is of little consequence.

6. Please look at the drawings of the Columbian telegraph, now shown you, marked G. W. B. and N. B. C., and certified by G. S. Hillard, Commissioner. Describe generally the apparatus represented and its mode of operation, and state in what respects, if any, it differs from the telegraphic apparatus patented by Mr. Morse.

Answer.—I have looked at the drawings, and I find, on examination, that it will be impossible for me to give a definite answer to the question, unless I have more time than is now at my disposal, and the means of examining and comparing the operations of the machines.

7. Please state, if you can, how many original experiments you have made in the course of your investigations in electricity, magnetism, and electro-magnetism.

Answer.—The experiments I have mentioned in this deposition form but a small part of my original investigations. Besides many

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* See Dr. ale's letter of April 7, 1856, page 93.

that I made in Albany, which I have not mentioned, since my removal to Princeton, I have made several thousands on electricity, magnetism, and electro-magnetism, particularly the former, which have more or less bearing on practical applications of this branch of science, brief minutes of which fill several hundred folio pages. Many of these have not been published in detail. They have cost me years of labor and much expense.

The only reward I ever expected was the consciousness of advancing science, the pleasure of discovering new truths, and the scientific reputation to which these labors would entitle me.

JOSEPH HENRY.

Sworn to before me, September 7, 1849.

GEO. S. HILLARD,
Commissioner.

GENERAL APPENDIX TO THE REPORT FOR 1857.

The object of this Appendix is to illustrate the operations of the Institution by the reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

LECTURES ON COAL.

BY PROFESSOR JOSEPH LE CONTE.

Nature is a book in which are revealed the divine character and mind. Science is the human interpretation of this divine book, human attempts to understand the thoughts and plans of Deity. The book being divine, it is evident that all parts are equally sacred. The subjects of all sciences may be said to be equally, because they are all infinitely, noble. To the scientific mind the organization of an insect, a polyp, or an infusorial animalcule is no less dignified a subject of human inquiry than the organization of the solar system. Yet, as in the Sacred Scriptures, while all parts are equally sacred, because all are divine, some are cherished with peculiar reverence, as giving nobler conceptions of divine character, or clearer views of human duty. So also in science there are some branches which, by a certain magnitude in the objects with which they deal, strike the imagination and kindle the enthusiasm in a peculiar degree. From a purely abstract or intellectual point of view they may be all equal, but as human studies, as means of elevating the mind and ennobling the soul, they differ very much among themselves.

In this, the noblest function of science, there are two departments which stand out beyond all others, viz: astronomy and geology. We are all accustomed to look upon astronomy as the most magnificent of sciences, as more than all others extending the bounds of human intellectual vision; but I am perfectly confident that when the age has grasped as firmly and apprehended as clearly the fundamental idea of geology as it has already done that of astronomy, all will agree with me in thinking that the former is not one whit behind the latter in the overwhelming grandeur of its conceptions. Let us, then, compare these two noble sciences. Let us attempt to vindicate the claims of geology to stand beside astronomy in the very first rank of sciences as twin sisters, distinguished from all others by superior beauty and dignity.

There are two conditions of material existence, viz: *space* and *time*. We cannot conceive of material existence except under these two conditions. Now, the peculiar province of astronomy is space, as that of geology is time. Other sciences may have to do with space, limited space, a portion of space, but it belongs to astronomy alone to deal with infinite space. So also there are other sciences which necessarily deal with limited time, but it is the peculiar prerogative of geology to deal with infinite time.* As astromy is *limited in time* to the present epoch, or, in fact, to about two thousand years, but unlimited in space, so also geology is *limited in space* to the surface of the earth, but *unlimited in time*. As astronomy measures her distances by billions of

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* We use the term "*infinite*" with reference to time, as with reference to space, as synonymous with *inconceivably great*, illimitable by human conception.

miles, or millions of earth radii, so geology her epochs by millions of years, *i. e.*, earth revolutions. As the astronomer takes the radius of the earth as a *base line* wherewith to measure the dimensions of the solar system, so the geologist takes the present geological epoch, and "causes now in operation," as a *time measuring rod*, with which to estimate the length of the tertiary period. As the astronomer, becoming more bold as he ascends, takes the diameter of the earth's orbit as a line wherewith to calculate the distances of the fixed stars, or even dares to estimate the probable distance of the remotest nebula, so the geologist, no less daring, takes the tertiary as a rod wherewith to measure approximatively the almost inconceivable lapse of time represented by the secondary rocks, or even dares to cast his telescopic glance back into the dim nebulosity of the remotest palæozoic period. Finally, as the astronomer, when telescopic vision fails, still speculates, though filled with awe, concerning the infinite, unknown abyss of space beyond, so also the geologist, when mile-stones are no longer visible, when fossils and stratified rocks fail, still vainly peers with wondering gaze backward, and strives to pierce the darkness beyond, still believes that all he sees, or can ever hope to see, is but a fragment of the infinite abyss of time beyond. Overwhelmed, appalled, he shrinks back within himself, and remembers that his own mind, so daring, so arrogant, so apparently limitless, is also but a fragment of the infinite intelligence.

Thus, while astronomy fills the regions of the *universe* with objects, geology fills the regions of *infinite duration* with events. As astronomy carries us upwards by the relations of geometry, geology carries us backwards by the relations of cause and effect. As astronomy steps from point to point of the universe by a chain of triangles, so geology steps from epoch to epoch of the earth's history by a chain of mechanical and organical laws. If one depend on the axioms of geometry, the other depends upon the axioms of causation. In a word, the realm of astronomy is the universe of space, that of geology the universe of time. The one peoples her universe with *space-worlds*, the other her's with creations—*time-worlds*.

The great object of all science is to establish the universality of law; harmony in the midst of apparent confusion; unity in the midst of diversity; unity of force amidst diversity of phenomena, physical science; unity of plan in the midst of diversity of expression, natural science. Now, it is the peculiar province of astronomy to establish this universality of law throughout all space, as it is of geology throughout all time. Astronomy shows that the same force which controls the falling of a stone governs the motions of the heavenly bodies; so also geology shows that the changes through which each animal passes in its embryonic development are similar to those through which the whole earth and its inhabitants have passed in the course of its geological history; that the same mind which now conducts the one has presided through all time over the other. If astronomy, more than all other sciences, illustrates that sublime attribute of Deity, His omnipresence or unchangeableness in space, geology, more than all other sciences, illustrates that other sublime attribute of Deity, His immutability or unchangeableness in time.

There are in the history of science two eras which, more than all others, strike the imagination and fill the mind with admiration. Or rather, I should say, two moments, the greatest in the intellectual history of the human race. They are those in which were born in the mind of man the fundamental ideas of astronomy and geology—the ideas of infinite space and infinite time, containing other worlds and other creations. You have all, probably, thought of the sublimity of that moment when the idea of infinite space, peopled with worlds like our own, was first thoroughly realized by the mind of man. You have all, probably, shared in imagination the exstacy of Galileo as gazing with awe through the first telescope, the phases of Venus and the satellites of Jupiter suddenly revealed to him the existence of other worlds besides his own. Before that pregnant moment our own was *alone* in the universe. Sun, moon, and stars were but satellites to the earth. Astronomy was but the geometry of the heavens; the geometry of the curious lines which these "*wandering fires*" traced upon the crystalline concave of the skies. In an instant the great fundamental idea of modern astronomy was born in the mind of Galileo. In an instant man's intellectual vision is infinitely extended, but his own world, before so great, has shrunk into an atom in the midst of infinite space; has become a younger sister, a comparatively insignificant member in a great family of worlds.

We have all been accustomed to look upon this as the grandest moment in the intellectual history of man. But there is another moment less known, or if known, less thought of, because less understood and less appreciated, but not less grand. It is that in which was born in the mind of man the fundamental idea of geology; in which the idea of other time-worlds besides our own entered the mind of the aged Buffon.

For many years, indeed centuries, it had been observed that organic remains, particularly marine shells, might be found far inland, and even high up the slopes of mountains. There was much speculation among scientific men as to the origin of these shells. They were attributed by some to the deluge, by others more truly to gradual and permanent changes in the relative level of sea and land. But no one for a moment supposed that they belonged to any period anterior to the present epoch. Some may have supposed that they were extending the known limits of the present epoch, that they were discovering new *continents* in the *ocean* of time, but never dreamed that these were the evidences of a *new world* in the *infinite abyss* of time. Buffon himself had taken active part in these discussions. Finally, near the end of the last century, and in the evening of his great and long life, a large number of these remains, both marine shells and mammalian vertebrates, larger than he had ever examined before, were placed at his disposal and subject to his inspection. To his astonishment he found them entirely different from species now inhabiting the earth. In that moment, in the mind of the venerable Buffon, suddenly, like Minerva from the head of Jove, was born the idea of infinite time containing successive creations. In an instant man's intellectual vision was again infinitely extended; but his own world again dwindled into a single day in the geological history of the earth.

The whole future of geology was seen in the vision of that moment. Filled with awe, the old man, then over 80 years of age, published his discovery. In a kind of sacred phrenzy he spoke of the magnificence of the prospect, and prophesied of the future glories of this new science, which he was, alas, too old to pursue. Thus, to the last, his dying hand pointed the way, and his dying voice kindled the enthusiasm of those whom he could no longer lead.

Picture for a moment to yourself the aged Buffon thus gazing in rapture, silent and alone, upon this new world suddenly opened to his intellectual vision. I cannot help comparing him to Moses of old on the top of Pisgah. Like Moses, he had reached the extreme verge of mortal life; like him, he stood upon a mount, raised far above the rest of the world by the eminence of his intellectual position; like him, he gazed with sacred solemn joy, mingled with sadness, upon a new world, a promised land, which he was forbidden to enter; and, like him, also, he died there upon the mount, prophesying of the future glories of the new land, and calling upon his followers to enter in and take possession.

One more comparison between these two noble sciences: In comparing modern with ancient or even mediæval civilization, nothing is more striking or more significant than the difference in the manner in which nature is viewed in relation to man. The spirit of the older civilization tended to exalt man in his own estimation and to degrade nature, while that of modern civilization tends to humiliate by insisting upon his insignificance in comparison with the greatness of nature. In art this is seen in the gradual but constant increase in the contemplation of nature, both in painting and poetry. An increasing love of wilderness and mountain, of rock and crag, of cloud and sky. In science it is still more distinctly seen in the amazing progress of the physical and natural sciences. The mind of man has gradually passed from the study and contemplation of itself to the study and contemplation of nature. We believe this was a necessary, but cannot believe that it is a final change. When, by the study of external nature, a true and solid foundation is laid for philosophy, the human mind will again return to the study and contemplation of *itself*, as the greatest of nature's works.

Now, it has already been seen, that among the most efficient agents in bringing about this great and necessary change have been the sciences of astronomy and geology. Nothing has tended so much to humiliate the pride of man as the recognition of the astounding fact that *his* habitation, *his world*, is but an atom among millions of similar atoms in the boundless realms of space; and that *his* time, the life of his race, is but a day in the immeasurable cycle of geological changes. But there is this great difference between the two sciences, that while astronomy leaves man thus humiliated, prostrate, and hopeless, geology lifts him up and restores him to his dignity. While astronomy gives no evidence of the superiority of the earth to other heavenly bodies, or of man above other possible material intelligences—gives no hint of the superior dignity of our world among other space-worlds—geology most distinctly declares the superior dignity of our time-world, and of our race, among all other time-worlds and their races. She teaches unmistakeably that there has been a gradual course of preparation for the present epoch; that there is an unity of plan in the whole system of time-worlds; that, in a certain sense, they are all satellites to *ours;* that they are all bound together by a force; that force the plans of the Almighty, and its centre the present epoch. Thus man becomes the centre of the universe of time. Thus, also, by analogy we are led to suspect that there may be a similar unity in the system of space-worlds also, and that ours may, and probably does, enjoy a superiority, if not in size at least in organization, and therefore in the intelligence of its inhabitants. Thus man's dignity is restored, or rather, I should say, dignity is given in place of pride. "Pride goeth before a fall," but dignity comes after.

But it will no doubt be objected by many that the position of a science depends not only upon the dignity of its subjects, but also, in no small degree, upon the certainty of its conclusions, and that, in this respect, astronomy is far superior. But even this is a mistake, the result of misconception. Even here the superiority of astronomy has been very much exaggerated. Astronomy has its hypotheses and uncertainties as well as geology; and, on the other hand, geology has its certainties as well as astronomy; only it has happened, in this as well as in many other cases, that the wisdom of age has given false dignity to its errors and follies, while the wildness of youth has discredited its wisdom. The certainties of astronomy have given an appearance of truth to its wildest hypotheses, while the hypotheses of geology have unjustly thrown some discredit upon her truest theories and most certain facts. The certainties of astronomy are the form, size, weight, distance, and relative position of her space-worlds. Her uncertainties are their physical geography, climate, and, more than all, their inhabitants, animal and vegetable. The certainties of geology are the physical geography, climate, and, more than all, the inhabitants, animal and vegetable, of her time-worlds, while her uncertainties are their relative size and distance. It is seen, then, that the certainties of the one are precisely the uncertainties of the other. Which, then, are the nobler—the certainties of astronomy or those of geology? Is it more noble to know the relative size and position of worlds in space and time or to be acquainted with the beings which form their crowning glory? It would carry me too far to pursue this train of thought. Suffice it to say that, in either case, that which was most important to know has been rendered most certain; while, also, in both cases, that which is most uncertain is also least important to know.

I have thought this long introduction necessary, because geology is so constantly misunderstood. She is looked upon by some with suspicion, as wild in her speculations and uncertain in her conclusions; by others with indifference, as a mass of dry and unattractive detail; and by still others with positive dread, as tending to infidelity. I deemed it necessary, therefore, to say a few words in vindication of her high rank among the inductive sciences, both in respect to the certainty of her conclusions, and, still more, the nobleness of her conceptions and the absorbing interest of her subjects. I might have gone still further, and vindicated her claim to be considered the chief handmaid of religion among the sciences. But this would have led me much too far. Thirty years later, and all I have thus far said would have been unnecessary. One generation more and geology will need no defender; both her dignity and her religious tendency will be universally acknowledged. But for this purpose one more generation must first pass away.

Perhaps it may seem to some of you as a startling paradox, but it is nevertheless a fact, that the shortness of human life is one of the most powerful elements of human progress. It would seem as if the human mind grows and develops, the philosophy and opinions which govern the conduct of life continue to be modified and moulded, until about the age of twenty-five or thirty, when the character becomes unchangeable, opinions become prejudices, and the whole mind, as it were, petrified. Further progress would be impossible, but that another generation, with minds still plastic, comes forward, takes up and carries on the work a few steps, and becomes petrified in its turn. There are certainly some noble exceptions to this rule—instances of minds which with their maturity retain the plasticity of youth—but the very rarity of the exception only proves the rule.

You doubtless recollect that the children of Israel wandered forty years in the wilderness before they were fit to enter the promised land. The marks of Egyptian bondage were upon their souls as well as upon their necks. One generation must fall in the wilderness, and a new generation, free from Egyptian prejudices, must arise. We are apt to look upon this as an isolated fact in history, and entirely characteristic of this peculiar people. On the contrary, it is a fact of deepest significance in the philosophy of human progress, and intended for the instruction of us all. To this day it seems to be impossible that any great step should be made in the intellectual progress of our race, except by the sacrifice of at least one generation. We are even now in the midst of such a great change, brought about by the revelations of geology. One more generation dropped in the wilderness and we are fairly in the promised land. Do not misunderstand me, however, as quarrelling with this *conservative spirit;* on the contrary, this brake upon the wheels of the car of progress seems absolutely necessary for its steady motion.

But I find I am again digressing, and therefore hasten to return to my subject.

I have said that the field of geology is the universe of time. It is one of these time-worlds of which I wish to draw a true, though necessarily an outline, picture in the next two or three lectures. I shall not attempt more than an outline, for this would only tire you with a multitude of details, but shall seize, if possible, the most striking features, make a comparison between this and other subsequent time-worlds, particularly our own, and endeavor to find the law which binds the whole into one system.

Among the many time-worlds of which geology tells us I select but one, viz: the COAL PERIOD. Its position is far back in the palæozoic times. Measuring time by space it is in the region of the fixed stars, although one of the brightest in the firmament of time. If I could transport you in imagination to the surface of Sirius; if I could draw a picture of its physical geography, climate, and, more than all, of its inhabitants, who in this audience would remain unmoved? Shall the interest be less because the separation from us is by time instead of space; because the place is our own earth, and the materials of the picture beneath our very feet?

The coal period is a world distinctly separated from those which precede and those which follow it. As in the geographical distribution of fauna and flora upon the surface of the earth at the present time, we find in some cases contiguous fauna and flora seem to interpenetrate or pass by insensible gradations into one another; the species on the confines of each dying out in number but not in specific character, insensibly *replaced* but not *transmuted.* So also in the distribution of fauna and flora in time we find some (as, for instance, those of the tertiary) which pass by insensible gradations into one another, or interlock with the preceding and succeeding, although only by gradual replacement, not by transmutation. But as in geographical distribution we also find many fauna and flora completely isolated by physical barriers, mountain chains, oceans, or deserts, from contiguous fauna and flora, so also in geological distribution we find creations are often distinctly separated from other creations contiguous in time, by physical barriers in the form of convulsions of the earth, and marked by broken, dislocated, and upturned strata. In the history of the earth there seems to have been many such successive creations completely destroyed by convulsions; in other words, the time-worlds are apparently separated by blank spaces, whose dimensions we have no means of estimating. Such a distinct world is the coal period, with its fauna and flora distinctly separated from the old red sandstone which precedes, and still more so from the new red sandstone which succeeds. A *distinct world*—completely circumscribed in time—having its own poles and equator.

Now, in geology, history is recorded upon *tablets of stone*—stratified rocks. Time is represented by their thickness; remarkable events by their dislocation; the fauna and flora by the contained fossils. Let us, then, examine the strata which represent this period.

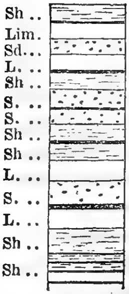
They are called the "carboniferous strata," and the period the "carboniferous period," from the remarkable fact that they contain almost all the coal which is found in the world. The deposit of carbonaceous matter is not indeed confined to this period, for it has occurred in every period of the earth's history, as evidenced by the fact that thin seams of coal are found in all the strata. Similar deposits are still going on in peat bogs and deltas of the present day. But the accumulations of carbon in the strata of which we are speaking are so enormous, in comparison to those found elsewhere, that the name carboniferous, as applied to these strata and this period, becomes entirely appropriate. With the single exception of the oolite strata, which belong to the secondary period, and in which coal is profitably mined in Virginia and in England, all known coal mines belong to the carboniferous strata. The knowledge of this simple fact would have saved the useless expenditure of millions of dollars, both in this country and in England. It is worse than useless to expend money and labor in following up signs of coal, unless we are sure we are in the region of the carboniferous strata.

The carboniferous strata are subdivided into two very distinct groups, representing, of course, distinct subdivisions of the carboniferous period. These are called lower and upper carboniferous, or the mountain limestone, and the "coal measures." The former are mostly limestone, the latter mostly shales and sandstone; the one mostly of marine origin, the other mostly fresh water; the fossils of the one are mostly marine animals, of the other terrestrial vegetation. I shall confine myself entirely to the latter, or the true "*coal measures*," as they are called, from the fact that ninety-nine hundredths of all the coal in the world are found in them.

You will observe, then, that I have taken for my subject one-half of the carboniferous period. The carboniferous is itself but one of the four great subdivisions of the palæzoic period, and the palæzoic period, in its turn, only one of the four great epochs, exclusive of the present, into which the history of our earth is divided. You see, then, that the period of which I wish to give you a rapid sketch is less than one-thirtieth part of the *recorded* history of the earth; yet the average thickness of these strata is about 3,000 or 4,000 feet. In Wales they are 12,000 feet thick, and in Nova Scotia nearly 15,000. If, then, thickness of strata represent length of time, how great must be the lapse of time represented by the coal measures.

Such being the enormous thickness of the *coal measures*, it necessarily follows that but a very small proportion of the mass consists of coal. The coal strata consist of thick beds of limestone, sandstone, ironstone, and shale, containing thin seams of *coal*, and this alternation sometimes many times repeated in the same locality; the whole forming a series like the sheets of a ream of paper, arranged in no discoverable rational order, but indiscriminately alternating. The seam of coal will sometimes be covered with a stratum of limestone, sometimes of standstone, and sometimes of shale; although it rarely happens that the sandstone or limestone comes directly in contact with the coal; but is generally separated by a stratum, sometimes very thin, of shale or slate. In fact a stratum of clay or fine mud rock both underlies and overlies each seam. Below it forms the "fire clay," and above the black slate of the miners.

Fig. 1.



I have said that the order is various in different parts of the same alternating series; but in every part of the same coal field the alternation is the same for the same part of the series. In other words, each stratum is generally horizontally extended over the whole coal field in a continuous sheet, so that each seam is accompanied by the same strata above and below. This is a fact of great importance, as it affords the readiest means of determining the identity of individual coal seams.

Coal strata, like all other sedimentary deposits, were at the time of formation horizontal, or nearly so. Sometimes they are found nearly in this their original position, as in many of the coal fields of our own country. More generally this original horizontality has been disturbed by igneous agency, and the coal strata are found in the form of basins. Sometimes the strata are so folded as to give rise to series of basins belonging to the same original field. Whether, however, the strata retain their original horizontality, or are thrown into basins by igneous agency, seldom or never do we find the whole of the original mass deposited. A large portion has been carried away by aqueous agency. From this cause a large coal field, covering many thousands of square miles, may exist only in the form of isolated mountains or detached basins of coal strata, as in the accompanying figures, where all the mass represented by the dotted lines has been carried away by denuding agencies. Thus, for instance, nearly the whole of Illinois was originally occupied by a vast coal field, but little disturbed by igneous agency, but by far the larger portion of the coal strata of this immense field was carried away by denuding agencies.

Fig. 2.

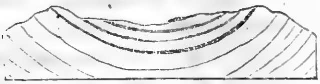


Fig. 3.

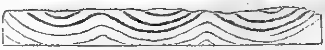


Fig. 4.

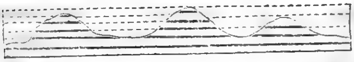


Fig. 5.

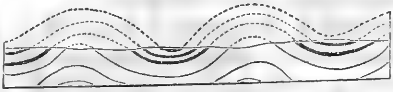
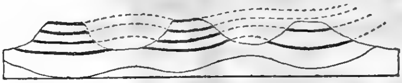


Fig. 6.



You will observe, then, the striking difference in mode of occurrence between metallic ores and coal. The former are associated with rocks of every age, except, perhaps, the tertiary; the latter almost exclusively confined to those of a particular age. The former exist in the form of veins intersecting the strata, the latter in the form of seams parallel with the strata. The former extend indefinitely downwards, the latter horizontally. The former are the result of igneous agency, the latter of sedimentary deposit. Ignorance of this simple but radical difference has been the cause of much pecuniary loss, and seems not yet entirely eradicated. When, for instance, some years ago it was rumored in the streets of Philadelphia that the bottom of the Mauch Chunk Summit mine was reached, there was an universal panic, and stocks in coal mines went down enormously, not knowing that the continuation of coal seams was to be looked for horizontally rather than vertically.

This simple rule, when taken in connexion with the one previously enunciated, viz: that a coal seam throughout its whole extent is attended both above and below by the same strata, would render the identification of coal seams, and the tracing of them across valleys from hillside to hillside, a matter of little difficulty, were it not for dislocation of the strata, producing what are called faults, slips, or troubles. In the accompanying figures, for instance, the strata have been displaced by the elevation of one part of the field more than another. This is not conspicuous on the surface, because all has been cut down to one level by aqueous agencies. The supposed configuration of surface immediately after such unequal elevation is represented by the dotted outline; the strong line represents the present configuration of surface. All between these, therefore, represents the amount of matter carried away by denuding agencies. These faults occur very often in coal fields, and are a source of serious annoyance to the miner.

Fig. 7.

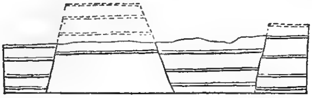
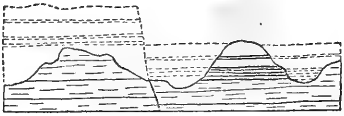


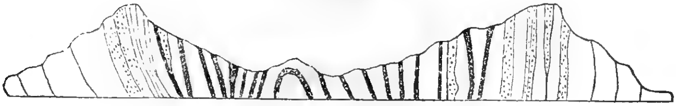
Fig. 8.



I have taken here the simplest case of dislocation. The difficulty becomes very much greater when, instead of being horizontal, the strata are highly and variously inclined. In such cases the skill and knowledge of the geologist is often tasked to the utmost.

I have said that while metallic veins extend indefinitely downwards, coal seams for the most part are extended horizontally, or nearly so. Sometimes, however, coal seams may appear, like metallic veins, to extend downwards. This is the case in highly inclined and particularly in vertical strata, as in the accompanying sketch of the anthracite coal field of Pennsylvania. In such cases, however, as well as in every other, it will be observed that the seams are strictly parallel with the strata, that the strata have been elevated to a vertical position by igneous agency, and the included coal seams have been raised with them, still maintaining their relative position.

Fig. 9.

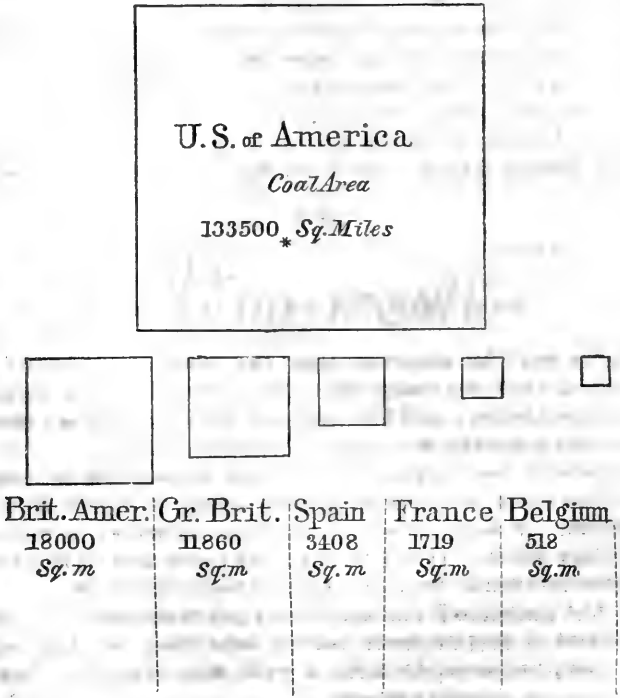


The *thickness* of coal seams varies from a few lines to many feet; sometimes they exist as sheets as thin as paper, in others in masses 30 or 40 feet thick. A single seam of pure coal, however, is seldom more than 6 or 8 feet thick. It is true that in France and in the anthracite region of Pennsylvania they are said to occur 60 or 70 feet thick, or even more, but upon close examination such mammoth seams will be found to consist of two or more seams, separated by thin laminæ of slate; too thin, however, to form a roof, and, therefore, the several seams are wrought together as one.

The *number* of seams occurring in one locality and separated by interstratified sandstone and shale is sometimes as great as one hundred, and their aggregate thickness one hundred and fifty feet. Enormous as is this mass of carbonaceous matter, it is but a small fraction of the entire mass of the coal strata. The thickest and purest seams are generally near the middle of this series; as if the conditions necessary for the formation of coal had gradually come into existence and as gradually disappeared; that there were two poles and an equator belonging to this time-world—a morn, noon, and evening to this geological day.

We have spoken thus far only of the thickness of coal strata and of coal seams; but it is impossible to form a correct idea of the amount of matter contained in these strata or in these seams without taking into account also their horizontal extent. Coal is very widely distributed over the world, although some countries are more favored than others. England, France, Spain, Portugal, Belgium, Sweden, Poland, and Russia have their beds of coal. It is also found abundantly in Asia, Africa, and South America; but no where is the coal formation more extensively displayed than in the United States, and no where are its beds of greater thickness, more convenient for working, or of more valuable quality. There are within the limits of the United States no less than four coal fields of enormous dimensions. One of these, the Appalachian coal field, commences on the north, in Pennsylvania and Ohio, sweeping south through western Virginia and eastern Kentucky, Tennessee, extends even into Alabama. Its area is estimated at about 60,000 square miles. A second occupies the greater portion of Illinois and Indiana; in extent almost equal to

Fig. 10.



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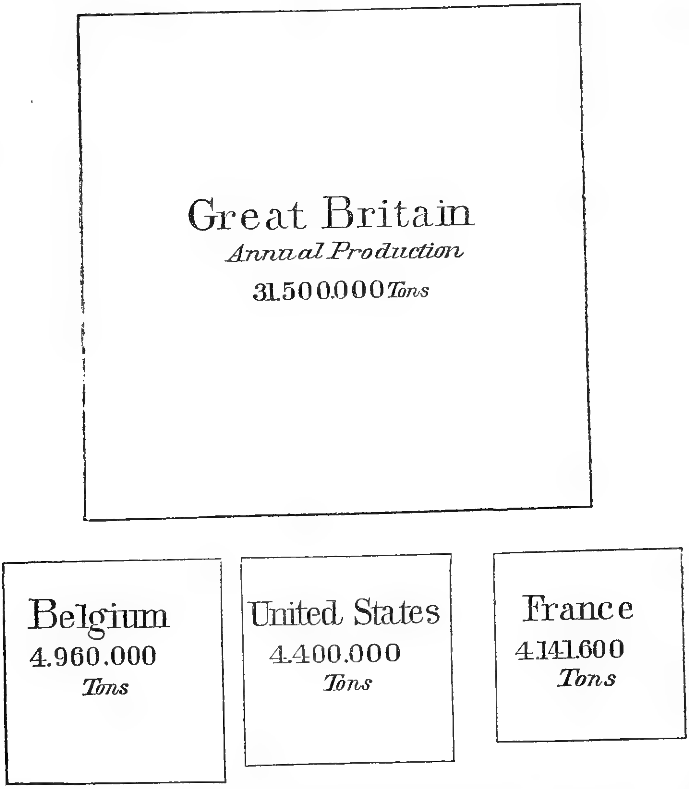
[*] Recent estimates by Marcou and by H. D. Rodgers make the coal area of the United States near 200,000 square miles.

the Appalachian. A third covers the greater portion of Missouri, while a fourth occupies the greater portion of Michigan. Just out of the limits of the United States, in New Brunswick and Nova Scotia, there is still a fifth, occupying, according to Mr. Lyell, an area of 36,000 square miles. Besides these there are several others of less extent.

If we now compare the relative coal areas of the principal coal producing countries, the superiority of our own will be still conspicuous. The following diagrams represent these relative areas in a more intelligible form than could be done by mere figures.

But if, on the other hand, we compare in the same manner the relative annual production of the same countries, we will find the order very different.

Fig. 11.



It will be seen that the annual production of coal in Great Britain is more than seven times that of the United States, although her coal area is so much less. It is estimated that even at this enormous rate of production the coal fields of Great Britain will yet last for 500 years. There is little danger, then, that ours will fail us shortly.

Now industry, as the basis of the organization of society, forms the distinguishing feature of modern civilization. Coal is the very aliment of industry. The material prosperity of any country may therefore be tolerably accurately estimated by the amount of coal consumed.

According to this method of estimation, Great Britain is superior to all other countries in actual material civilization. But if the consumption of coal is a measure of the *actual* civilization of a country, the *amount of coal area* represents its *potential* civilization. How far are we superior to all other countries in this respect! What a glorious destiny awaits us in the future—a destiny already predetermined in the earliest geological history of the earth.

One more remark and I am done. It is certain that, as manufacturing and productive industry take root and flourish almost exclusively in cool and temperate climates, so also in them do the coal formations prevail in the greatest abundance. Our scientific maps and investigations confirm the one, and national statistics the other. Almost all the true coal of the world is found in the north temperate zone. Thus the climates which are most congenial to laborious occupations, the latitudes best adapted to the vigorous growth of industrial civilization, are precisely those where, fortunately, have been placed the materials of labor, the aliment of industry. Fortunately did I say? No; this has not been the result of blind chance, but of deliberate providential design. We have here a sublime illustration of that all-comprehensive foreknowledge which foresees and designs the end from the beginning; of that immutability which changes not, but only unfolds its eternal plans; of that unity in the system of time-worlds of which I have already spoken, our own epoch being the sun and centre.

THEORIES OF THE COAL.

There is no point connected with the coal which has been the subject of so much discussion as the manner of its accumulation. At first view, existing nature seems to offer no analogy to guide us in our attempts to account for such enormous accumulations of carbonaceous matter. It is admitted, however, I believe, on all hands, that the deposit must have taken place in water. The perfect preservation of the carbon of the plants, and often of their external forms and structure, which must have suffered complete oxydation and disintegration if exposed to the air, the fact that the plants were most or all of them swamp plants, and, more than all, the alternation of coal seams with sedimentary deposits of clay and sand, all seem to point unmistakably to water as the preserving agent. There is still another evidence which I think has generally been overlooked. In the midst of the more structureless bituminous matter of the coal are often found imbedded wedge-shaped masses of vascular tissue called native carbon. No one who attentively examines these wedges can fail to perceive that they are the wooden wedges of exogens separated by the decomposition of the softer cellular tissue of the intervening medullary rays, while they floated as logs upon the water and finally became imbedded in the carbonaceous mud below.

Thus far I believe all theorists agree. But from this point opinions diverge; some geologists holding that the coal was deposited on the spot where the plants grew, others that the plants were drifted in the form of rafts to great distances and deposited at the mouths of rivers; the former, that a coal basin is the site of an ancient peat bog, the latter, that it is the position of an ancient estuary or delta. The former opinion is called the "*peat bog theory*," the latter the "*estuary theory*."

Peat bog theory.—It is well known that in many countries, particularly in moist, cool climates, and damp, low grounds, certain plants, such as ferns, mosses, &c., as well as trees which delight in moist places, if allowed to grow undisturbed from generation to generation will, by their decay, accumulate enormous masses of carbonaceous matter. Such a spot is called a *peat bog*. The theory of this accumulation is as follows: Plants derive all their carbon from the atmosphere. In the annual fall of leaf, and finally their own death, they return to the earth the whole of the matter thus silently extracted from the air. Undisturbed vegetation, therefore, constantly enriches the soil by adding to it what has been taken from the air. Thus worn out lands improve by lying fallow. Thus the rich black vegetable mould found covering the ground in forests continues to increase from year to year. In all ordinary cases, however, there is a limit beyond which this accumulation will not go. By decomposition the organic matter is again returned to the atmosphere as fast as it accumulates. But if by any means this decomposition is prevented the organic matter accumulates indefinitely. This is precisely what takes place in peat bogs. The presence of water in a great measure prevents the oxydation of the carbon. The growth of plants now continually takes carbon from the atmosphere, their death as continually deposits it upon the earth. Each generation rises, phœnix-like, from the ashes of the last, to become in its turn soil for the next. Thus the ancestral accumulation continues to increase, the funeral pile continues to rise, until pure carbonaceous matter may in time accumulate to the depth of thirty or forty feet. Such a mass of carbonaceous matter deprived of its water and compressed to the density of coal, would make a seam of perhaps three or four feet in thickness. Now, according to the peat bog theory, it is under such circumstances that the carbon of a coal seam has been accumulated.

The arguments in favor of this theory are: 1st. *The purity of the coal.* It is true that coal is often found largely mixed with earthy matter or mud. As we have already shown, every stage of gradation may be traced between pure coal and pure shale. But by far the larger portion of coal seems to be entirely free from foreign matter. The amount of ash is not greater than five to ten per cent.; that is, not greater than might arise from the earthy matter of the plants from which the coal was derived. This purity of the coal indicates complete absence of sediment in the water in which the coal was originally laid down. Now the water of peat swamps, though discolored by organic matter in solution, is always entirely free from sediment. In fact, this seems a necessary condition of the growth of peat plants—an incursion of water containing mud is fatal to such plants. If, then, a coal seam is the result of carbonaceous matter slowly accumulated at the bottom of ancient peat swamps, the purity of the coal is completely accounted for. But if, on the contrary, it is formed by the accumulation of timber carried down to the mouths of great rivers during freshets, it should always be largely mixed with mud.

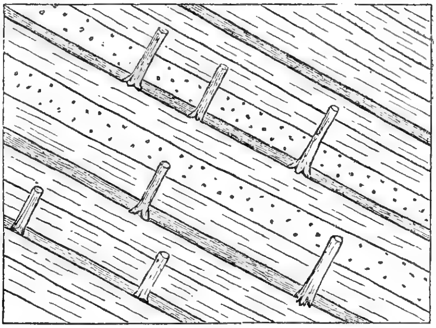
2d. The fine preservation of the tenderest and most delicate parts of plants. We have already spoken of the profusion of finely-preserved leaves and entire fronds of ferns in the black slate overlying a coal seam. So perfect is this preservation that large and complex fronds are often entirely unbroken, and even the minutest variation of the leaves as distinct as in the living fern. This fine preservation of tender parts seems strongly to indicate that these leaves had fallen gently from the parent stem, and been preserved on the spot where they fell. It seems utterly inconsistent with the violent action of currents bearing rafts to great distances.

3d. The position of the finely-preserved leaves, &c., always on the upper surface of the coal seam, (roof of the coal mine.) Precisely the same is observed in every peat swamp. The perfect leaves are to be found only on top, for the plain reason that these are the last fallen, and therefore not yet disorganized. But in the case of accumulations of vegetable matter at the mouths of rivers, there seems to be no reason why leaves should not be entangled in all parts alike.

4th. Coal, like peat, is composed of completely disorganized carbonaceous matter, containing fragments in which vegetable structure is more distinct. This is not inconsistent with what I have already said in my last lecture of the vegetable origin of even the most structureless coal being detectable by the microscope. Plants are composed entirely of cells. Both in peat and in coal these cells are generally separated from one another. The vegetable structure is completely disorganized, but the separate cells still bear unmistakable marks of their origin; the organic structure is gone, but the organic origin is still visible. But if a coal seam was an imbedded raft, it should be composed almost entirely of fragments of trunks, branches, &c., instead of a structureless mass containing only a few such fragments.

5th. It will be recollected that a seam of coal is overlaid by black slate and underlaid by fire-clay. In the black slate, as already said, are found the finest impressions of leaves and other tender parts; *in the fire-clay*, which underlies the coal seam, are found imbedded in the greatest abundance the roots of plants, and not unfrequently the stumps of trees with the roots attached, precisely as they grow. And, what is still more remarkable and significant, trunks of trees are not unfrequently found almost entire, standing erect, with their roots still bedded in the fire-clay, their trunks passing through the seam, and far into the overlying strata of shale and limestone. By means of evidence of this kind Lyell and Dawson have been able to make out distinctly nearly 60 planes of successive vegetation in the coal field of Nova Scotia. In many of these, viz: about 20, the trees are still in the position in which they grew, as shown in figure 12; of the rest the evidence consisted in the imbedded stigmaria or roots of sigillaria.

Fig. 12.



In the cases in which these trunks and roots, *in situ*, are found, (and they are by no means uncommon,) the evidence is conclusive that the coal was formed on the spot where the trees grew; in other words, that the growth of the trees and the deposit of the coal took place simultaneously on the same spot. This is clearly impossible in an estuary, but is known to take place in every peat swamp.

To recapitulate the whole argument: If we examine a peat bog which has been for many years thickly overgrown with ferns, mosses, and water plants of various kinds, and shaded by many large trees, we find the soil composed entirely of black carbonaceous matter, wholly destitute of structure but revealing its vegetable origin to the microscope, containing fragments of trunks and branches of trees lying in all possible positions, some prostrate, some inclined at all angles, many, both living and dead, still erect, their roots firmly fixed in the clay at the bottom of the bog, below the peaty matter which has slowly gathered about their lower parts, and over the whole lie thickly strewn the freshly fallen leaves. Now suppose such a peat bog to be deeply buried beneath the surface of water and overwhelmed with sediment of clay and sand, and again, after ages, elevated and exposed by section to the scrutiny of the geologist, and we shall have a complete reproduction of the phenomena of a coal seam.

The great, and almost the only, objection which has been urged against this theory is to be found, not in the phenomena of an individual coal seam, but rather in the general phenomena of coal basins, in the repeated alternation in the same locality of coal seams with marine and fresh water strata. We have already seen that there are in the same coal basin sometimes as many as an hundred coal seams, one above the other; now, according to this theory, when the coal seam was forming the spot must have been above the surface of the sea, but when the interstratified limestones and shales were being deposited the same spot must have been beneath the sea-level. Thus, argues the objector, we are driven to the enormous assumption that the same spot has been successively upheaved above and depressed beneath the sea-level one hundred times during the carboniferous period, and, what is still more remarkable, that every time it rose above the sea it became a peat swamp; or if the intervening strata are fresh water instead of marine, the difficulty seems only to be increased.

Estuary theory.—It is to meet this very difficulty, to account for this remarkable alternation of strata, that the rival theory has been proposed. An estuary is the wide open mouth of a river emptying into a tidal sea; it is occupied sometimes by fresh and sometimes by salt water. The deposit at the bottom of an estuary, in suitable positions, is, therefore, an alternation of fresh water and marine strata. In seasons of freshets the river water, loaded with sediment and perhaps bearing rafts of drift timber, forces back the sea water, occupies the estuary, and makes its deposit of clay and sand, containing fragments of such drift timber; in seasons of low water the ocean returns and makes its deposit, perhaps of limestone, and so on alternately. A coal field is supposed by these theorists to be the position of an ancient estuary; the limestone strata are the marine deposit, the shale and sandstone the river deposit, and the coal seam the imbedded drift timber brought down by the river from distant forests.

The objections to this theory are all that has been said in favor of the peat bog theory. The pureness of the coal, the fine preservation of even the tenderest parts of plants, the position of such well preserved specimens always on the upper surface of a coal seam, the structureless character of the great mass of the coal, and, above all, stumps and trunks of trees still erect, with their roots still fixed in the clay stratum below—all this seems not only unaccountable but impossible on this theory.

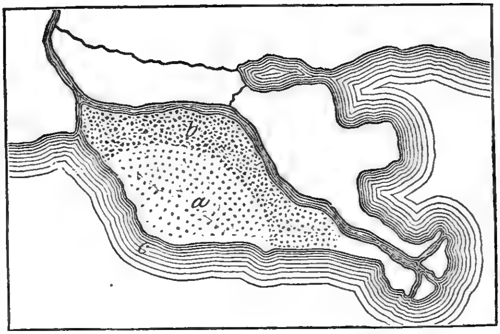
In comparing these two theories it will be seen that the first explains completely the phenomena of an individual coal seam, but signally fails to explain the general phenomena of a coal basin, viz: the alternation of coal seam with marine and fresh water strata; while, on the other hand, the second explains well this alternation, but fails utterly to explain the phenomena of an individual coal seam. There is, then, real and substantial evidence in favor of each, and equally substantial objections. If this had not been the case one or the other would have been relinquished ere this. But we find, on the contrary, that they have both found strenuous advocates from the time geology commenced to exist as a science until now. In every such case of vitality in rival theories it will be found, I think, that there is a real germ of truth in both—that both are true and both are false; both true in some sense, and therefore reconcilable; and both false through narrowness of view, through exclusiveness, through mistaking a partial for a general view. I can best illustrate my meaning by referring you to the familiar but very instructive fable of the shield, which being distinctly seen by two knights of equally good eye sight and of undoubted veracity, was declared by one to be white and by the other to be black. You will recollect that, after several lances were broken and many wounds and bruises endured to decide the knotty point, it was discovered by some one who, strange to say, was more interested in the truth than in the dispute, *that one side was white and the other was black.* The disputants were both right and both wrong, but wrong only by exclusiveness, by mistaking a partial for a general view. So it is with almost all vexed questions. There is truth on both sides, but both err in excluding the other. We are seeking in the right direction when we attempt to show the partialness of both views. We have risen to a higher view, to a philosophic truth, when we show that these two partial and apparently irreconcilable views may be united into one; these two surface views may be stereoscopically combined.

There is an old and much quoted adage, that "truth lies in the middle" between extreme opinions. As generally understood nothing can be more false or hurtful. Through its influence a merely timid or temporizing policy is mistaken for wisdom, the "fence man" is mistaken for the philosopher. There is another old adage, that "*extremes meet;*" *i. e.*, what to the superficial observer *seem* to be extremes, to the deeper thinker are often really closely allied. But the converse of this proposition, though not erected into an adage, is even more profoundly true, viz: that what *seem* to be closely allied are very often *real* extremes. There is often a superficial resemblance between the highest and the lowest, so that by the unthinking multitude the one is often mistaken for the other; pride for nobility of soul, humility for mean-spiritedness, the serenity of self-command for the serenity of insensibility, &c. It is only in this way that the "fence man" resembles the philosopher, for they are as wide apart as the poles. It is in this way only that truth seems to "lie in the middle," although we are further from it there than anywhere else. To refer again to the fable of the shield: It would have been a poor solution of the famous dispute to say that the shield was neither pure white nor pure black, but midway between the two extremes; that it was, in fact, some shade of gray or dusky, or, perhaps, pepper and salt. No; I repeat, truth lies not "in the middle," but the *reconciliation of extremes* in the *harmonious combination of apparent antagonisms*.

Now, it seems to me that the phenomena of a coal seam already enumerated prove most conclusively that the coal was formed *in situ*, as in the peat swamps of the present day. At the same time the frequent alternation of seams with marine and fresh water strata prove also most conclusively that the deposit took place at *the mouths of rivers*. Here are two incontestible facts. We must put them together; we must combine them if we would make a true and sufficient theory. I believe the more this subject is reflected on the more we shall be convinced that coal was deposited *in peat swamps at the mouths of large rivers*, and therefore subject to overflows by the river and occasional inundations by the sea. We are to look for analogies in existing nature, not among the bogs of Ireland, but among the river swamps of the Mississippi.

It is well known that such peat swamps, some of them of enormous extent, exist now on the margins and in the delta of the Mississippi and probably many other large rivers, and that pure peat unmixed with mud is constantly forming in these swamps, although they are annually flooded by the river. This seems at first incredible, when we recollect that the river water is loaded with sediment, and that sediment prevents the growth of peat plants, or at least would entirely destroy the purity of the peat. But this apparent anomaly has been entirely explained by Mr. Lyell. According to this high authority, although the peat swamps of the Mississippi are annually flooded by river water they are entirely untouched by *river mud*. These favored spots are surrounded, particularly on the side next the river, by dense vegetation, which, acting as a sieve, completely strains the water of its mud before it reaches the peat swamp. The water of these swamps is therefore pure, and pure peat has been quietly depositing there for ages.

Fig. 13.



Let us now suppose that there existed during the carboniferous period a large river, perhaps less than the Mississippi, but with enormous swamps and delta, overgrown with rank vegetation far surpassing in luxuriance anything we know at the present day. In the midst of such swamps there would evidently occur spots of great extent, the waters of which, for the reasons already mentioned, would never be contaminated with sediment, as at (*a*) fig. 13. Here for untold ages pure carbonaceous matter would accumulate undisturbed. In the course of time the surrounding portions of the swamps (*b*) where the mud is detained would rise by deposit of sediment, while the peat swamp (*a*) would remain as a sunken country, such as exist now in the swamps of the Mississippi. Finally, at uncertain intervals, a more than usually large freshet, or perhaps some change in the level of the land, would deluge the swamp with mud and bury the peat. Gradually the vegetation would return, and the former condition of things be restored, to pass again through the same changes. We have but one other supposition to make, viz: that the whole river swamp and delta were gradually subsiding during the whole carboniferous period. This is by no means a violent supposition, but one which we have a right in this case to make for two good reasons: 1st. We have the best evidence that many of the large deltas of the present day are thus subsiding. This is proved in the case of the Mississippi delta by cypress stumps *in situ* below the level of the sea. 2d. The coal strata themselves give indubitable evidence of gradual subsidence during the period of their deposit. The character of these strata and their fossils shows that they were deposited in shallow water, but their enormous thickness (nearly three miles in Nova Scotia) renders this clearly impossible, unless we suppose such subsidence; for, if the bottom was stationary, it must have been three miles below the surface of the water when the lowest stratum was deposited. Now, if such subsidence went on constantly, but slowly, so that, under ordinary circumstances, the delta could be maintained by deposit from the river, but at uncertain intervals, more rapidly than the river could build up, so that the sea would again usurp possession and make its deposit of limestone, and again more slowly, so that the area might again be reclaimed by the river, and become a peat swamp, and so on alternately, we should easily, without any violent hypothesis, account for all the phenomena of a coal basin.

It will be observed that by this hypothesis the area of a coal basin has, indeed, been successively above and below the sea-surface, but not by successive upheaval and depression, as it has been supposed necessary on the peat bog theory, but by the contention, with various success, of opposing forces, aqueous and igneous, the river constantly building up, and igneous forces beneath as constantly striving to depress; sometimes one force predominating, sometimes the other. Of such contention we have many instances in existing nature. It is evidently going on in the delta of the Mississippi at the present time.

It may not be possible, in the present condition of science, to picture to ourselves all the circumstances connected with this process. Perhaps I have already gone too far in this attempt; but the general facts upon which the theory rest are incontestible. Coal has almost certainly accumulated *in situ* in extensive peat swamps at the mouths of large rivers, upon ground which was slowly subsiding during the whole period. Under these circumstances it seems not difficult to account for all the phenomena of a coal basin. All we have to do in future is by study of the peat swamp of the Mississippi and the phenomena of delta deposit to discover the details of the process, to fill up the outline of the picture.

There is a fact noticed by Mr. Lyell, which is strongly confirmatory of this theory. In the sandstone of the coal measures it is common to find trunks of trees, but only trunks—no small branches, leaves, or tender parts. Moreover these trunks are observed to be mostly pines, highland trees, while the trunks in the coal seam proper are sigillaria, lepidodendron, calamites—swamp trees. Now, when we recollect that coarse sandstone is the deposit of rapid current, does it not seem evident that the sandstone was deposited by the freshet which overwhelmed the peat swamp, and that the pine trunks are the remains of drift timber brought from the highlands. Here, then, we have ancient drift timber, but how different from a coal seam!

Let us now attempt to estimate approximatively the *time necessary* to bring about these stupendous results. I believe we should never neglect an opportunity of this kind, because the popular mind has not yet grasped the idea of illimitable time required by geology to the same extent as it has the idea of illimitable space required by astronomy; and, as I believe, this is one of the greatest difficulties with which geology has to contend.

According to Boussingault luxuriant vegetation at the present day takes from the atmosphere about a half ton of carbon per acre annually, or 50 tons per acre in a century. Fifty tons of carbon of the specific gravity of coal, about 1.50, spread evenly over the surface of an acre, would make a layer of less than $\frac{1}{3}$ of an inch. Humboldt makes the estimate a little higher, viz: $\frac{1}{2}$ an inch. We are willing to take the higher estimate. It appears, then, that if *all* the carbon taken from the air was preserved in the form of coal, our most luxuriant vegetation would make but a $\frac{1}{2}$ inch of coal in a century. But in the coal measures the aggregate thickness of the coal seams in the same basin is sometimes 150 feet or more. In 150 feet there are 1,800 inches, or 3,600 half inches. At the present rate of vegetation, then, it would take 3,600 centuries, or 360,000 years, to accumulate this amount. But it will be objected that the vegetation of the coal period was probably much more luxuriant than the present, and the tendency of this difference would be to shorten the time. True; but it will be recollected that this estimate was made upon the ground that *all* the carbon was preserved. This is in the highest degree improbable, not to say impossible. Probably much more than half was returned to atmosphere in the form of carbonic acid and carburetted hydrogen. Again, we have taken no account of the enormous periods of time during which there was no carbon deposited on the spot in question, and represented by the intervening strata of limestone, sandstone, and shale. The estimate we have given above, therefore, probably falls very far short of the truth. Let us try another.

According to Messrs. Lyell and Dawson the coal strata of Nova Scotia are about three miles in thickness at the South Joggins. At another point, nearly 100 miles distant, (Albion mines,) they found the thickness nearly the same. There is little danger, therefore, of erring on the side of excess, if we take the average thickness of the strata over the whole basin at one and a half miles. Now, the area of this coal field, according to Mr. Lyell, is about 3,600 square miles. This would give, as the solid contents of these strata, 54,000 cubic miles. But we have already seen that this enormous amount of matter was almost certainly accumulated at the mouth of a great river. Let us see how long it would take one of our great rivers to do the work. I shall select for this purpose the Mississippi and the Ganges, because they are both very large rivers, carrying vast amounts of sediment, and because accurate observations have been made as to the amount of sediment brought down by them. These observations have been made upon the Mississippi by Drs. Forshay and Reddell, of New Orleans, and by Captain Strachey, British engineer, upon the Ganges. According to these observations it would take the Mississippi 2,000,000 years, and the Ganges* 375,000 years to perform the work. And yet the period we are now discussing is probably not one-thirtieth, certainly but a small portion of the entire geological history of the earth.

It will no doubt be objected to this estimate that it is founded upon a particular theory, and this theory may be incorrect, and the estimate thus falls to the ground. In answer to this objection it is only necessary to state that we are acquainted with no other circumstances under which strata accumulate so rapidly as at the mouths of rivers. Any other conceivable theory, therefore, would only increase the time.

Again, it will probably be objected that the agencies of nature may have been and probably were more active in earlier periods of the history of the earth than now. Such a notion, although almost universal among intelligent people and very prevalent even among geologists, is, as it seems to me, utterly without foundation in reason. In reference to this point geologists may be divided into two classes. The first and most numerous class hold that the agencies of nature have gradually decreased in activity from the earliest times until now. The other, to which Mr. Lyell and his followers belong, believes that these agencies have acted much as they do now through all time; that there has been no progressive change of any kind, neither in the earth nor its inhabitants. Now, it seems to me that it can be proved, or at

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* This amazing difference in favor of a smaller river is due to the fact that the Ganges, being a tropical river, the rains all fall during six months, and are therefore very heavy. The washing of the soil and resulting sediment are necessarily in proportion. The mountainous country in which the Ganges takes its rise contributes also to the same result.

least rendered extremely probable, that neither of these theorists is in the right; that, in fact, while the igneous agencies have been decreasing in activity, the aqueous have been constantly increasing in the same proportion. As I believe I differ from all other geologists in my views on this point, I deem it important to go a little more fully into this subject.

It is generally admitted by geologists, and indeed there is good and substantial evidence of the fact, that the earth has been gradually cooling throughout all geological history from an original very high temperature. We have also, as I believe most geologists will admit, good and substantial evidence that the land has constantly increased both in extent and in elevation with the course of time, while the ocean has as constantly decreased in extent in the same proportion. In other words, these two elements, land and water, have been, as it were, gradually differentiated. Admit these two points and all the rest logically follow.

The activity of igneous agencies depends upon the internal temperature of the earth. As this has constantly decreased the igneous agencies have also decreased in energy in the same proportion. The aqueous agencies, on the other hand, are the result of currents of air and water upon the surface of the earth; and the rapidity of these currents depends, not upon the *mean* surface temperature, but upon the difference of temperature in different parts of the surface; *i. e.*, between pole and equator or between land and water. It only remains to prove, then, that this *difference* of temperature has been constantly increasing with the course of time.

Land, as is well known, is both a better absorber and a better radiator of heat than water; *i. e.*, will both heat faster and cool faster under given circumstances than water. A globe of land would be both hotter at the equator and colder at the poles than a globe covered with water and exposed to the same influences. Although the *mean* temperature would be nearly the same in the two cases, the *difference* of temperature would be much greater in the former than in the latter. It follows, therefore, that as the extent of land increased and that of the ocean decreased with the course of time the difference of temperature between pole and equator must have increased in the same proportion. The gradual decrease of the *mean* temperature would evidently contribute to the same result; for it is evident that with a higher mean temperature a larger portion of water would exist in the form of vapor. This excessive vapor would rise into the atmosphere and become condensed into universal clouds, mist or fogs, but seldom, and to a very limited extent, in the earlier periods of the earth's history, into *rain*, because, as yet, there were neither extensive high land nor cool currents sufficient for extensive precipitation. Thus would result a thick, murky atmosphere, enveloping the whole earth. The necessary effect of this would be still further to prevent absorption of heat at the equator and radiation at the poles, and thus to produce still greater uniformity of climate. In the earliest geological periods, therefore, when the surface temperature, from *internal* causes, was very great, and the ocean almost universal, the difference of temperature between pole and equator was reduced to a minimum. In such a condition of things it is evident that the exchange between pole and equator currents of the aqueous and aerial ocean must have been not only very sluggish but perfectly regular northeast and southwest currents in the northern hemisphere, and northwest and southeast currents in the southern. In proportion as the earth cooled the diversity of temperature between pole and equator became greater and the exchange more rapid. In the meantime the gradual increase in the extent and elevation of continents would introduce still greater diversity. The regular oceanic currents, by impinging upon the continents, are reflected in various directions, increasing still further the diversity of climate. Currents of the air, too, are no longer only trade winds, but also monsoons, land and sea breezes, &c. These various currents, mingling and contending, produce the infinitely varying winds of the present epoch. But the most important current we have not yet spoken of. Land and sea may be considered the two poles of a circulating apparatus; water rises in the form of vapor at one pole, passes over through the atmosphere, and is condensed on the other in the form of rain, and so back by the rivers to the ocean. The more rapid the condensation the more rapid the evaporation and the more rapid the circulation. Within certain limits, (*i. e.*, until the land is sufficient to condense all the water evaporated from the ocean,) the amount of evaporation and condensation is in proportion to the extent and elevation of the continents. It is evident, then, that in the earlier periods of the earth's history, when the ocean was almost universal, although the air was saturated with moisture, there was comparatively little rain; and that just in proportion as the continents increased in extent and elevation, evaporation, and condensation would increase in the same proportion. It is impossible to resist the conclusion, then, that from the earliest periods until now there has been a constant increase in activity and variety of currents of ocean and atmosphere; of wind and rain; of cloud and sunshine; of fountains and rivers; in fact of all that constitutes the life, variety, and beauty of our beloved earth.

Thus it appears that at first igneous predominated over aqueous agencies. It was this very predominance which caused uncompensated, progressive change—*development* of the earth as a whole; for perfect balance is incompatible with developement. But gradually aqueous agencies increased in energy; the antagonistic forces approached a balance as the earth approached maturity, until at present the balance may possibly be complete.

In all I have said I have had in view, of course, only the ordinary regular operation of aqueous agencies, or what Mr. Lyell calls "causes now in operation." I say *of course*, because the extraordinary, irregular operation of these agencies, such as are called "*debacles*," &c., are too uncertain and hypothetical, not to say improbable, to form the basis of any reasoning whatever. I repeat, then, that during the coal period the ordinary operation of aqueous or degrading agencies must have been more slow than at present. The accumulation of a certain amount of material in a river delta, other things being equal, would require a longer time than now.

CLIMATE OF THE COAL PERIOD.

It is probable, from what evidence we have on this subject, that the climate of the coal period was characterized by greater warmth, greater humidity, and greater uniformity than now obtains, and that the air was more highly charged with carbonic acid. Of the greater warmth of the climate we have evidence in the astonishing luxuriance and universal tropical character of the vegetation of the period. One of the most marked peculiarities of the flora of coal everywhere is the great relative abundance of ferns and fern allies. In the present flora of Great Britain the ratio of ferns to flowering plants is about 1 to 35, while in the coal flora of the same country nearly one-half of all the known plants are ferns. In the American coal flora the proportion of ferns is said to be still greater. That this abundance of ferns indicates a tropical climate is shown by the fact that in the existing flora, out of about 1,500 known species of ferns, 1,200 are confined to the tropics, and as we pass from the equator towards the poles the proportion of ferns, steadily diminishes. The same may be said with reference to the club-mosses. It is worthy of remark, too, that although conifers are abundant now all over the earth's surface, still those most nearly allied to the conifers of the coal—such, for instance, as the araucaria and salisburia of the present day—are found only in tropical regions. Now, during the coal period, this tropical vegetation extended as far as 75° north latitude. Tree ferns and gigantic club-mosses covered the spot now occupied by the Mellville island. The evidence of remarkable humidity is no less satisfactory, for it is only in warm, *moist* climates that ferns and club-mosses grow in the greatest abundance and luxuriance. On some islands in the tropics and in the south seas the abundance of ferns even approaches that of the coal flora. In fact, as a condition of the growth of these plants, moisture seems even more necessary than heat.

It has been objected to the greater heat of the climate, that coal was evidently formed by accumulation of carbonaceous matter *in situ* as now in peat bogs, and that peat bogs are found only in cool climates. The answer to this objection is not difficult. It is not the heat immediately, but the resulting *capacity for moisture,* or, in common language, dryness of the air of the tropics, which under ordinary circumstances prevents the preservation of carbon. The air is not so constantly at or near the point of saturation. Fogs, and mists, and clouds are not so constant as in cooler climates. But we have supposed greater humidity as well as heat during the coal period. Under these circumstances, there is no reason why peat should not accumulate. We see proof of this in the peat swamps at the mouth of the Mississippi. Here we find peat accumulating in great abundance in a climate which is yet very warm; and we have already seen that it is in such peat swamps, rather than in the bogs of cooler climates, that we are to look for analogies with the peaty accumulations of the coal period. The enormous *extent* of these peat swamps becomes in its turn an additional proof of the great humidity of the climate.

The uniformity of climate—*i. e.* the comparatively equable distribution of heat and moisture on the surface of the earth during the coal period—is evidenced by the remarkable uniformity of the flora. The general character of the coal flora was very much the same in every portion of the earth's surface, and in many cases even the same species are found in the most distant countries. Thus many identical species have been found in Europe, United States, New Holland and Mellville island, countries the existing flora of which differ entirely. Now, although I cannot accede to the doctrine that diversity of climate is the *physical cause* of diversity of fauna and flora, yet, whether we consider the physical or the final cause, the result would evidently be the same, viz: the perfect harmony between the climate and the fauna and flora, the perfect adaptation of the one to the other.

That the atmosphere was highly charged with carbonic acid is rendered probable by the astonishing luxuriance of the vegetation of the period. Some experiments recently made by Mr. Gladstone seem to show that up to a certain limit the growth of ferns is rendered more rapid by the addition of carbonic acid to the atmosphere in which they grow. This probably becomes a certainty, when we reflect upon the enormous amount of carbon contained in the coal deposits, all of which must have been extracted from the atmosphere. It has been estimated that "all the forests of the United States gathered into one heap would fail to furnish materials of a single coal seam equal to that of Pittsburg." Again, that "that there is laid up in the earth, in the form of coal, six times as much carbon as now exists in the atmosphere. If it was all returned to the air, there would be seven times as much carbonic acid in the atmosphere as at present."

Cause of the climate of the coal.—Much speculative ingenuity has been exhausted to little effect in attempts to account for the remarkable climate of this period. We find here the same looseness of reasoning unfortunately so common among geologists when dealing with physical subjects. The subject of most of this speculation has been the cause of the supposed greater heat of the climate. There are two principal methods of accounting for it. The first and most obvious mode is by means of the commonly received hypothesis that the earth has cooled down to its present temperature from an original state of incandescence. But although there is much independent evidence of this original condition—and we think it extremely probable, therefore, that the heat of the coal period was due, at least in part, to this cause—yet, as Hopkins has shown, (Geol. Jour., 1853,) there are strong objections to this as the only cause. We have already said that the surface temperature of the earth is due partly to internal and partly to external causes. At present the surface temperature from internal causes has become almost nothing, *i. e.* only one-twentieth of a degree Fahrenheit. The increase of temperature below the surface is about 1° to sixty feet. Now, if we supposed the surface temperature from this cause to be increased even to 1°, the increase for every sixty feet of depth would be 20°. An increase of 10° surface temperature would make 200° increase of temperature for every sixty feet. The springs, except the most superficial, would all be boiling. Now, it will be recollected that the winter temperature of Mellville, where coal is found abundantly, is —20° Fahrenheit. It would, therefore, take near

100° additional of surface temperature to raise this to tropical heat. This would necessitate a temperature of 2,000° at the depth of sixty feet, a condition of things, it would seem, utterly incompatible with the existence of luxuriant vegetation on the surface.

The second mode of accounting for it is by means of distribution of land and water upon the earth's surface. Land, as compared with water, is both a better absorber and better radiator of heat, *i. e.*, will both heat faster under the influence of a source of heat, as the sun, and cool faster when that source is withdrawn. This is familiarly illustrated by land and sea breezes. Again: the earth at the equator receives more heat from the sun than it radiates, while at the poles, on the contrary, it radiates more than it receives from the sun, the overplus in both cases being balanced by the currents of ocean and atmosphere. If these currents could be prevented, the equator, for a time, would get progressively warmer, and the poles progressively colder. We may evidently, then, look upon the earth as a body heating at the equator and cooling at the poles. Now, when we recollect the great absorbing and radiating power of land, as compared with water, it is easy to see that the mean temperature of the earth's surface may be materially affected by the distribution of these elements with reference to the two points in question. For instance, if the water be all collected in a belt about the equator, and the poles be occupied entirely by land, we would have the conditions most unfavorable for heating at the equator and most favorable for cooling at the poles. The result would be a considerable lowering of the mean temperature. If, on the contrary, the waters be gathered into polar oceans, leaving an equatorial belt of land, the conditions would be most favorable for heating at the equator and most unfavorable for cooling at the poles, and the mean temperature would consequently rise. It is estimated that these two extreme conditions would bring down the mean temperature to 32°, or raise it to tropical heat. It is not to be supposed that such extreme conditions ever existed; but any approximation to such conditions—for instance, a decided predominance of land towards the equator or poles—would produce the same effects to a corresponding degree. Now, it is possible that the greater heat of the coal period may be due to some such distribution of land and water.

The fatal objection to this explanation is that we find no coal in tropical regions. As every coal field presupposes a large river, and therefore a considerable extent of land, the distribution of coal may be looked upon as in a general way indicative of the distribution of land during the period. It would seem from this that the larger bodies of land existed in temperate and arctic rather than in tropical regions.

But if it is impossible by distribution of land and water to account for the greater *mean* temperature, it is at least easy in this way to account for the *greater humidity* and *uniformity of climate* which we have found equally to characterize this period. I have already alluded to the fact that the palæozoic seas were probably very wide and the land correspondingly small in extent and low, and that such a condition of things, on account of the very limited condensation and precipitation of vapor, would produce a very *humid climate*. Now, water being both a bad absorber and bad radiator of heat, both heating very slowly and cooling very slowly, it is evident that a great predominance of that element would produce, also, a *very uniform climate.* The difference of temperature between pole and equator, and between winter and summer, would be less than at present.

Some geologists think, with Mr. Lyell, that this uniformity and humidity of climate is sufficient to account for the coal vegetation without the necessity of a higher mean temperature than now exists. If the present mean temperature was distributed more equably both over the earth surface and over the year, the effect would be to produce cooler equator, it is true, but also much warmer high latitudes, and particularly the winters of high latitudes would be much less severe. The evidence is, however, it seems to me, in favor of some elevation of the *mean* temperature also. It is difficult to conceive how any uniformity of distribution of the present mean temperature, such as would be produced by the predominance of water, could raise the winter temperature of Mellville island to the point necessary for the luxuriant growth of tree ferns. Some increase of temperature from internal cause seems to be necessary. I suppose, therefore, that if the temperature of the earth from internal causes was slightly elevated, say 10°, so that the mean temperature from 60° should become 70°, and then this mean temperature distributed over the earth surface as uniformly as possible, by means of a wide extent of ocean, we should have all the conditions necessary to produce the phenomena of coal vegetation. It will be recollected, too, that we have much independent evidence of the cooling of the earth from an original very high temperature.

With reference to the highly carbonated condition of the atmosphere, we may suppose this to be the result of the greater activity of carbonic acid producing causes, or else we may refer it to the original constitution of the air—the natural process by which carbonic acid is given to the air, decomposition, combustion, respiration of animals, and volcanoes, carbonated springs, &c. It will be admitted by all that the first three may be neglected, since they return to the air only what had been previously taken from it. The carbonic acid supplied to the air by volcanoes and carbonated springs, according to Bischoff, is so inconsiderable that, unless we suppose these sources much more active than now, it would take millions of years to affect materially the constitution of the air. But even this refuge is taken away, when we recollect that volcanoes and springs derive their carbonic acid from carbonates, and chiefly from carbonate of lime, or common limestone. But limestones, according to the testimony of all who have carefully studied them, and particularly according to the recent microscopic observations of Sorby, are entirely of animal origin, *i. e.* entirely made up of broken fragments of shells, corals, crinoids, sometimes recognizable under the microscope, sometimes reduced to impalpable powder. This carbonate of lime is evidently derived from sea-water. Whence, then, does sea-water derive its carbonate of lime? The lime is derived, beyond doubt, from igneous rocks, the carbonic acid probably from the atmosphere, through the animal and vegetable kingdoms, since lime exists in igneous rocks not as a carbonate but as a silicate. It would seem to follow, then, that springs and volcanoes, also, only return to the atmosphere what had been previously taken from it. The only difference between these sources and the three first is, that while decomposition, combustion, and respiration return to the air what had been taken from it *but a little while before*, springs and volcanoes return to the air what had been taken from it during some previous geological epoch. Thus the atmosphere becomes the great original source of all the carbonic acid in the world.

But whatever be the cause of the excess of carbonic acid in the atmosphere during the coal period, we cannot fail to see an evident and beneficent design in its removal. Carbonic acid, as is well known, is as poisonous to animals as it is nourishing to plants. Previous to the coal period there lived none but aquatic animals of low order. These, on account of low vitality, sluggish circulation, and little necessity for rapid and constant oxygenation of the blood, have great endurance of carbonic acid. But now the earth was prepared to receive air-breathing animals, the atmosphere must be purified for the purpose. This was accomplished by the astonishing vegetation of the coal period. But observe, and never cease to admire and wonder, that the self-same providential act which purified the atmosphere and rendered the earth a fit habitation for reptiles and birds, had reference also to the coming of man countless ages after, and laid up materials for his use. In the carbon thus silently extracted from the atmosphere was buried a mechanical energy which, after a sleep of millions of years, was to rise again as the great physical regenerator of the human race.

ORIGIN OF COAL.

It is now universally admitted among geologists that coal is entirely of vegetable origin. There was a time, however, and that not many years ago, when the vegetable or mineral origin of coal was a question warmly contested by the best geologists; but its vegetable character is now so firmly established and so universally admitted that the history of the controversy has lost its interest. I will not, therefore, tire you with its details, but proceed to state the evidence upon which the universal belief is founded.

First, then, the enormous profusion of fossil plants, in the form of impressions of leaves, trunks and branches of trees, fruits, &c., found in immediate connexion with a coal seam, affords strong presumption in its favor. In the second place, this presumption is strengthened, and becomes, in fact, almost certainty in the case of trunks of trees retaining their external conformation, and under the microscope their internal structure even to the minutest sculpturing upon their cell walls, and yet turned to perfect coal. It might possibly be objected that it may be a substitution of one substance for another, similar to what takes place in petrification, where we find, also, the external conformation and internal structure perfectly preserved, but the organic matter all gone, that the ancient trunk having been buried in bituminous matter and thoroughly impregnated therewith, as particle by particle the woody matter was removed by decomposition the bituminous matter took its place, and thus perfectly imitated its structure. But this objection is forever set aside, when, in the third place, we subject even the most structureless coal to microscopic scrutiny. The distinguished American microscopist, Professor Bailey, of West Point, has been able to detect the unmistakable evidences of vegetable structure even in the hardest anthracite. In fact it may be affirmed that there is no coal which, under careful examination, will not reveal a vegetable structure.

Again: All the stages of gradation between perfect wood and perfect coal may be traced with the greatest certainty. We find the first stage of this process in the blackened semi-bituminized logs of our peat bogs and deltas of the present epoch. The next stage we find in the lignites or brown coal of the tertiary period; the next the highly bituminous coal of the oolite; then the coals of the true carboniferous; and lastly, the anthracites of the same and lower strata. Thus we may trace the whole embryology of coal from its immature to its most perfect condition—may trace and identify all the intermediate links of the chain of conditions of which wood and coal form the extreme limits. But not only in external form and appearance, but also in chemical composition we can trace these several stages. Wood consists of carbon, hydrogen, and oxygen; coal consists of the same elements but in different proportions. In coal the proportion of carbon is greater and of oxygen and hydrogen less than in wood. Now, if we compare the chemical composition of wood, peat, lignite, bituminous coal and anthracite, we find a progressive decrease in the proportion of oxygen and hydrogen, until, in anthracite, we find the carbon almost pure, and absolutely pure in graphite, if we acknowledge this as of similar origin. This chemical evidence is, it seems to me, absolutely demonstrative.

Lastly, direct experiment proves that peat, which we know to be of vegetable origin, may, by strong pressure, be made to assume the hardness, the density, the general appearance, and all the useful properties of coal.

Assuming, then, the vegetable origin of coal as a basis of argument, we will proceed to speak of, and to account for, *the principal varieties of coal.*

All coal consists of two parts, the one combustible the other incombustible. It is easy to separate these from one another. If a piece of coal is thrown into the fire the combustible portion passes away in the form of gases, the incombustible remains behind in the form of ash. Now, the relative proportion of these two vary infinitely in different coals. We have every stage of gradation between pure shale and pure coal, between pure incombustible and almost as pure combustible. In the purest coal the amount of ash is only 1 to 2 per cent.; others, more impure, contain 5, 10, 20, 50 per cent. of ash. At this point coal loses the property of ready combustion, and with it loses also the name of *coal* in popular language. But the geologist recognizes no remarkable change at this particular point—no scientific reason why the name should change from coal to shale, as there is no corresponding change of nature. From this point, under the name of shaly coal, black slate, &c., the amount of ash may continue to increase and the amount of combustible matter to decrease, until, in pure shale or slate, the whole becomes incombustible.

Now, wood consists also of combustible matter and ash, but the amount of ash in wood is much less than in coal—the wood of elm contains about 2 per cent.; willow, $\frac{1}{2}$ half per cent.; beech, $\frac{1}{3}$ per cent.; oak and pine about $\frac{1}{4}$ per cent. The leaves and bark of trees, however, contain much more than this. The fully matured leaves of the beech, willow, and elm contain, severally, 6.6, 8, and 11 per cent. of ash. It is probable, then, that 2 to 3 per cent. is a fair average of the per centage of ash in dry vegetable matter. But even if the coal is perfectly pure, that is, formed of vegetable matter without foreign admixture, we should find a higher proportion of ash than in the wood from which it was formed, for, as we have already seen, wood loses hydrogen and oxygen in the process of change into coal. The weight therefore diminishes, but the absolute amount of ash remains the same, and consequently the relative amount increases. We may safely say, then, that if coal contains not more than 5 per cent. of ash it may be considered quite pure; but if it contains more than 10 per cent. it is probably impure, *i. e.*, mixed with foreign matter. This foreign matter being evidently the *mud* or *clay* upon which the carbonaceous matter was originally laid down or by which it was afterwards covered. Hence we find the purest coal in the largest seams and in the middle portions equally removed from the floor and roof. As we pass towards the roof of a seam the coal passes by imperceptible degrees into black slate, which is, in fact, mud, more or less mixed with carbonaceous matter.

So much for the varieties of coal depending upon purity or impurity, upon the relative proportion of earthy, incombustible, inorganic matter, and of combustible organic matter.

But, aside from the earthy matter, the combustible or organic matter of coal consists of two proximate elements mechanically mixed, viz: carbon and bitumen; charcoal is nearly pure carbon; common tar or pitch is very similar both in chemical composition and in general appearance to bitumen. If, then, we conceive a piece of charcoal, carefully burnt so that the vegetable structure is perfectly retained, to be thoroughly impregnated with pitch or tar, we should have a substance extremely similar to common coal. These two ingredients of coal may also be easily separated from one another. This is constantly done in the process of coking and in the manufacture of illuminating gas. The more volatile bitumen is driven off in the form of gas or collects in the pipes as coal tar and the carbon remains as coke. Now, the relative proportion of these two ingredients also vary infinitely in different coals. We may have a coal of pure carbon, or a coal of pure bitumen, or a coal containing these two in every proportion. It is the relative proportion of these which give rise to the principal varieties of coal. A coal of pure carbon is called anthracite; with a small amount of bitumen, say 10 to 20 per cent., it is called dry coals or semi-bituminous coal; when there is 20 to 30 per cent. of bitumen it is called bituminous or coking coal; when the per centage is above this and the coal burns with a strong blaze and melts, it is called fat coals. Besides these there are certain varieties depending upon hardness, fracture, &c., such, for instance, as cannel, which is a highly bituminous coal, but very hard, compact, fine-grained, and remarkably free from vegetable structure ; splint coal, &c.

There are at least three possible methods of accounting for these varieties. 1st. The cause may have existed before the coal was laid down, in the nature of the wood of which the coals were formed. 2d. The cause may be sought for in the changes through which the vegetable matter passed in the process of becoming coal. 3d. We may find it in changes to which the coal was subjected after it became coal.

First. It is possible that the kind of wood may in some degree determine the variety of coal, as, for instance, the accumulation of pines and other resinous wood may have given rise to the fat coals, while the non-resinous woods to the drier coals. This, I say, is possible, particularly as we know that coniferous trees grew in considerable abundance during the coal period ; but it seems very improbable as a general explanation.

Second. We have already remarked that wood consists, chemically, of carbon, hydrogen, oxygen, and a small quantity of nitrogen, which may be neglected ; and that pit coal consists of the same chemical elements, only in different proportions, the carbon being in excess. It is obvious, then, that in the fermentation process by which wood is changed into coal a portion of the gases, hydrogen and oxygen, escapes. The amount which thus escapes determines the variety of coal.

The composition of wood is variously stated by chemists ; in fact it is not a definite compound, but consists of the mixture of several proximate principles. It therefore varies much, according to the relative abundance of these principles, such as starch, sugar, cellulose, lignire ; in other words, according to the kind or even the age of the wood. For the harder kinds of wood, such as the oak, Liebeg gives the formula, $C_{36}\,H_{22}\,O_{22}$. For softer kinds of wood, and particularly for succulent vegetable substances, the proportion of carbon is not so great. Whether, however, the formula which I have adopted be correct for the plants of the coal, or not, would not affect the general correctness of the reasoning upon which my conclusions are based. The composition of bitumen varies also very much, and for the same reason, viz : that it is composed of several proximate principles variously mixed. It is generally given as $C_{20}\,H_{16}$, and a variable but small amount of oxygen, from 2 to 4. The composition of cannel coal is given by Regnault as $C_{24}\,H_{13}\,O_1$.

Wood........ $= C_{36}\,H_{22}\,O_{22}$
Bitumen..... $= C_{20}\,H_{16}\,O_2$
Cannel coal $= C_{24}\,H_{13}\,O_1$

It will be seen that the proportion of carbon is greatest in coal and least in bitumen, but that the most striking difference between these substances and wood is the almost entire want of oxygen. Now, according to Liebeg, wood in the process of decay in the open air forms carbonic acid ($C\,O_2$) and water ($H\,O$,) and the carbonic acid is formed by the union of the carbon with the oxygen of the *wood*, while the water is formed by the union of the hydrogen of the wood with the oxygen of the *air*. As in the formation of carbonic acid, oxygen is consumed faster than the carbon; if the decay goes on the residue will be at least pure carbon.

Wood .... $= C_{36}\ H_{22}\ O_{22}$
Deduct $C\ O_2 + H$ (the H unites with O of air) $= C_{35}\ H_{21}\ O_{20}$ = partly decayed.
Deduct 5 $(C\ O_2)$ $(= C_5\ O_{10}) + 11\ H$ .... $= C_{30}\ H_{10}\ O_{10}$ = further decayed.

But if decomposition take place out of contact, or with limited supply of air, the process is more complex. The carbon, hydrogen, and oxygen combine with one another in various proportions, and the products of decomposition are: carbonic acid ($C\ O_2$,) carburetted hydrogen ($C\ H_2$ or $C_2\ H_2$,) and water ($H\ O$,) and thus result the deadly choke-damp ($C\ O_2$) and the dreaded fire-damp ($C\ H_2$) of the coal mines.

Let us now see how, according to this theory, the different varieties of coal may be formed.

$$\begin{array}{lcl} & \text{Wood} = & C_{36}\ H_{22}\ O_2 \\ \left.\begin{array}{l}\text{Deduct } 11\ C\ O_2 = C_{11}\ O_{22} \\ \text{Deduct } 22\ H \text{ oxydized by the air}\end{array}\right\} & \ldots\ldots = & \underline{C_{11}\ H_{22}\ O_{22}} \\ & & C_{25} \end{array}$$

and twenty-five atoms of carbon alone remain; and this is the compostion of pure anthracite. Again: If decomposition takes place out of contact of air, bitumen or bituminous coal is formed. Thus—

$$\begin{array}{ll} \text{Wood} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & = C_{36}\ H_{22}\ O_{22} \\ \left.\begin{array}{l}\text{Deduct } 9\ C\ O_2 = C_9\quad O_{18} \\ \text{Deduct } 3\ H\ O = \quad H_3\ O_3 \\ \text{Deduct } 3\ C\ H_2 = C_3\ H_6\end{array}\right\} & = \underline{C_{12}\ H_9\ O_{21}} \\ \text{The remainder is cannel coal} \ldots\ldots\ldots & = C_{24}\ H_{13}\ O_1 \end{array}$$

Again:

Wood .... $= C_{36}\ H_{22}\ O_{22}$

and if from this we deduct

$$\left.\begin{array}{l}10 \text{ atoms carbonic acid} = C_{10}\quad O_{20} \\ 3 \text{ atoms olefiant gas} = C_6\ H_6\end{array}\right\} = \underline{C_{16}\ H_6\ O_{20}}$$

the remainder is bitumen .... $= C_{20}\ H_{16}\ O_2$

In the same manner, by supposing the union of these three elements to take place in various proportions, under circumstances of more or less imperfect access of air, we may, without difficulty, account for all the different varieties of coal.

There can be no doubt, it seems to me, that bituminous coal is actually formed by this play of affinities. But with reference to the extremes of this series, viz: anthracite and bitumen, naptha, &c., it seems much more probable that these have been the result of an *after change*, the last of the three possible causes with which we started.

In the third place, then, we have many reasons for believing that bituminous coal is really the normal coal, and that which is always formed by the play of affinities, of which we have spoken above, and that anthracite and bitumen are the result of the action of igneous agency upon such bituminous coal.

We have already said that bituminous coal may be considered as a mechanical mixture of carbon and bitumen, and these two may easily be separated by heat. Anthracite is the residue after separation, and bitumen and naptha is the matter separated by distillation and condensed elsewhere. As in the gas manufactories we find bituminous coal decomposed—a part remaining behind as coke, (pure carbon,) a part passing off as gas and a part collecting in pipes as *coal tar*—so in the laboratory of Nature coal beds subjected to heat give rise to the same three substances; anthracite is left behind, coal gas is discharged into the atmosphere and bitumen collects in subterranean pipes and gives rise to naptha and bituminous springs, pitch lakes, &c. Thus, the enormous lake of boiling pitch in Trinidad is, probably, in connexion with coal strata below. If so, such coal will be left in the condition of *anthracite.* All the strata of the earth are subject to change under the influence of heat: limestones become marbles, clays become slate. This change is called by geologists metamorphism. Now, the proposition is that anthracite is metamorphic coal. The proofs of this proposition are as follows:

In the first place, anthracite is never found except in regions very much disturbed by igneous agency, the strata highly inclined, contorted and broken; and even in the same coal field the coal is anthracite or bituminous, according as the region is more or less disturbed. Thus, in eastern Pennsylvania, where the coal strata are very much contorted and sometimes perpendicular, (fig. 9,) the coal is all anthracite; while in western Pennsylvania, where the strata are nearly horizontal, the coal is bituminous. The *actual* transition of anthracite into bituminous coal cannot be studied with advantage in Pennsylvania, because the coal strata have been carried away to such an extent that only outlying patches are left; but in Wales the same seam may be traced from the bituminous to the anthracite condition; so that there can be no doubt that, in this case at least, anthracite is metamorphic coal.

Second. Anthracite is never found except in metamorphic rocks, and conversely all coal contained in metamorphic strata is anthracite. This universal connexion of two things proves, as it seems to me, beyond doubt, their community of origin; that they have a common cause. Thus, in the lowest stratified or primary rocks, where the rocks are altogether metamorphic, and even in the silurian, where a less complete metamorphism is almost universal, what little coal is found is always anthracite. In the coal measures we have coal both bituminous and anthracitic, but the anthracite always in altered and the bituminous in unaltered rocks. As we pass upward we find anthracite more rare, because metamorphism is more rare and local; and when metamorphism entirely disappears in the tertiary rocks we find that anthracite disappears also.

Third. Trap dykes, as it is well known, are formed by the outbreaking and outpouring of melted rock (lava) forced up through the superincumbent stratified rocks, which are altered and rendered metamorphic by the contact. Now, when a dyke passes through coal strata the coal is always thoroughly coked by the contact; that is, it is changed into a substance identical in chemical composition with anthracite. These two substances are doubtless similar in their origin as well as in chemical composition, the great difference in their density being due only to the pressure under which the change took place. Anthracite is produced slowly under enormous pressure, while coke is produced under ordinary atmospheric pressure, and the rapid disengagement of gas renders it light and porous.

THE PLANTS OF THE COAL—THEIR STRUCTURE AND AFFINITIES.

Geology is the latest developed among the sciences. This is not an accidental phenomenon in the history of human intellectual progress, but one absolutely necessary, and the cause of which we can clearly trace. The great divisions of science in the order of their complexity are mathematics, mechanical sciences, chemical sciences, organical sciences, and geology. The first is limited to ideas of number and quantity; the second comprises, in addition to the preceding, ideas of force; the third, in addition, ideas of chemical affinity; the fourth, in addition to the preceding, ideas of *life*, and the last, in addition to all the preceding, ideas of historic development. Now, this order of increasing complexity has necessitated a corresponding order of development in time. It is impossible that mechanics and physics should have assumed even the form of a science until mathematics was already mature. And so of the rest. Together they form a column, of which mathematics is the pediment and geology the capital; or, rather, I should say, a magnificent temple, of which mathematics forms the solid foundation and geology the *heaven* pointing spire; the most wonderful and perfect work which human genius has erected in honor of Deity.

It is evident, therefore, that geology was compelled to await the development of other sciences. She could not come forward until her time was fulfilled, for her problems are the most complex and difficult which are to be found in the whole range of science. It is evident, also, that the geologist must be thoroughly accomplished in all departments of science. He must be thoroughly grounded in mechanical and physical sciences, or how shall he reason successfully on the upheaval of continents, the formation of mountain chains, the dynamics of earthquakes and volcanoes, the actions of currents, &c. He must be familiar with chemistry, for disintegration and consolidation of rocks, the deposits of springs, the formation of coal, are chemical questions. Still more necessary to him is an acquaintance with organic science, for the organic remains are the Divine hieroglyphs in which the history of the earth is recorded. It is this very complexity, this very elevation in the scale, this almost universal culture required of her votaries, which constitutes the greatest obstacle in the way of real progress in this science. I know it is thought by many that geology is an easy and simple science, that any one, by industrious collection of fossils and persevering exercise of memory, may be a good geologist; but this is a sad and very pernicious error. In so vast a science collectors of materials must be numerous, but the philosophical generalizer is very rare. In so vast an edifice the fetchers of stone and brick and mortar are innumerable, but heaps of brick and stone and mortar do not constitute a temple; the one may be accumulated by the human hand, the other can be constructed only by the human mind, and in this case only by genius of the highest order. In fact, a master builder in this science has not yet lived. No man has yet been able to sketch the outlines of this noble work with a hand so firm and decided that all shall labor in harmony and mutual confidence, and the work shall thenceforward proceed with steadiness and certainty.

In some sense, therefore, all departments of science may be looked upon as the handmaids of geology. And it is curious and instructive to observe how, in reward for their services, she stamps each one with the seal of philosophy; how each science becomes, in her service, more comprehensive, more philosophic, more exact. The problems in physics and chemistry which geology proposes are so difficult, the conditions under which well known forces act are so numerous and complicated, and the scale on which they operate are so vast, that every formula must be revised, every law must be made more exact. Thus, under the guidance of geology, these two old and mature sciences seem entering on a new and higher career.

But perhaps the most remarkable instance of the favorable change and philosophic character which the advent of geology has impressed upon other departments of science is to be found in the case of natural history.

The zoology and botany of the last age were little more than the knowledge of the names and external forms of species, and their arrangement according to an arbitrary system of classification. But it is evident that such zoology and botany can be of little service to geology. The external form of an extinct species is seldom seen. Generally all that we have of an animal is a few bones or teeth, sometimes a single scale; of a plant, a fragment of wood or a leaf, and the problem which geology proposes is, from such meagre materials to reconstruct the whole organism. To the unskilled this seems impossible. But the harmony which exists between all parts of an organism is so perfect that each may be said to necessitate every other. A complete knowledge of the laws of organization would thus enable us, from any one part, to reconstruct the whole. One strain of song instantly suggests all that is necessary to make the harmony complete. Thus a profounder knowledge of animals and plants becomes necessary—a knowledge not only of external forms, but also of internal structure and the harmonious relation of parts. Classification is no longer an ingenious artifice to facilitate the acquisition of knowledge, but becomes the highest expression of knowledge, the epitome of nature. Thus, from a mere mass of barren details, natural history has risen to the highest philosophic rank. Even astronomy has been compelled to take a lesson of philosophy from her younger sister. She must relax the severity of her dogmas. She must modify somewhat the absoluteness of her assertions concerning the stability of all things, fenced, though they be, round about with mathematical formulæ, now since the idea of infinite time has been introduced by geology. "The causes which tend to destroy the stability of the solar system," says astronomy, "are infinitely small, and therefore may be rejected from the equation." True, but infinitely small quantities accumulating *through infinite ages* become *finite*, in fact, become very important; for it is these very same infinitely small residual quantities, rejected by astronomy as of no value, which, by their accumulation, constitute the progressive development of the earth and solar system. Without such small uncompensated forces history, whether geological, national, or individual, would be impossible. An insect philosopher, the span of whose life is a single day, attentively observing the daily cycle of the healthy human body, might rationally assert the *stability of the human system.* The body, at the end of twenty-four hours, has come back to the same spot whence it started. At least the variation, if any, must be infinitely small, and therefore, for all purposes of insect life, may be rejected as of no value. And yet it is the accumulation of this same infinitely small variation which constitutes the growth and progressive development of the body. This is not an exaggerated illustration, for 2,000 years, the whole age of astronomy, is but one day, yea, but a small fraction of a day, in the geological history of the earth.

The flora of the coal period is more complete than that of any previous or succeeding geological epoch. The whole number of fossil species of plants known is probably not far from 2,000. Of these, according to estimates made more than ten years ago, about 816 are from the "coal measures." The constant additions which have been made since that time, particularly by Dr. Newberry and others, from an examination of the coal fields of our own country, would probably bring the number up to at least 900. Probably, therefore, nearly if not quite one-half of all known fossil plants belong to this period. I have already said that a coal seam is made up of the remains of such plants, yet it is not in the coal seams themselves that we find the best preserved specimens of coal plants. On the contrary, the vegetable matter is here so thoroughly disorganized that it is only by means of the microscope that we are able to detect its original structure. It is rather in the associated shale strata that the most beautiful impressions occur, particularly in the overlying *black slate.* Between the thin sheets of this slate the stems and leaves are as perfectly preserved, every vein and nerve, as between the leaves of the botanist's herbarium. This fact, viz: that the well-preserved plants are always found in abundance in this position, and never in the coal seam proper has, as it seems to me, an important bearing upon the theory of coal deposit. But of this we shall speak again in another place. You have here before you a magnificent slab of black slate, profusely covered with beautiful impressions of leaves and stems of ferns and calamites. In this case, as perhaps in most others, the impressions, though well-defined, are not conspicuous at a distance, because the color of the ground and of the figures are so nearly alike, but in some cases, when the shale background is light-colored, the relief of the coal-black impressions is very beautiful. The newly exposed roof of a coal mine has been compared by Dr. Buckland to the most magnificent fresco painted ceilings of Italian buildings.

But although the number of species of coal plants is so great, yet *coal* is supposed to be composed principally of the remains of four families only, viz: *Ferns*, *Sigillariæ*, *Lepidodendrons*, and *Calamites*. The abundance of individuals belonging to these families is so great, and their size so enormous, that they must have given character to the vegetation of this period, and may therefore be taken as representatives of its flora. As such, therefore, I shall consider them, and it will be our object in this lecture to give you some idea of their appearance and affinities.

There are certain periods in the history of our race upon which we are apt to gaze with peculiar interest and admiration—when the human mind, awakening from its sleep of barbarism, rejoices in the ostentatious display of its strength and its beauty, so in the history of our earth, the period of the coal stands out beyond all others as the "*heroic age*," when nature seemed to delight herself in the fantastic exercise of power, and to exhaust her strength in the production of vegetable giants and monsters. It will be my object to show that this age, although to the popular mind it may appear a mythological age, an age of wonders and prodigies, an age to which ordinary principles of reasoning are inapplicable; that this age is but one chapter, a page, in a connected history, one step in the accomplishment of the unvarying plans of Deity.

A glance at these drawings of coal plants will give you some general idea of the strange forms which constituted the flora of this period. But it is not only a vague general idea of external form which I wish to give you; we have already had too much of this in popular lectures on geology. If we would grasp the real thought expressed in the vegetation of this period; if we would understand the true significance of the coal flora in the Divine economy; if we would catch the key-note of this Divine harmony, we must take more than a superficial glance—we must look deeply, thoughtfully, reverently. But, in order to make myself understood, I find it necessary to step a little out of the way, to give you a sketch of the great divisions of the vegetable kingdom and the characteristics of each, so that, by comparison, we may be able to determine the position of the coal plants. Whatever is noble and elevating in science must be equally interesting to every intelligent mind; but in order to appreciate it, it is absolutely necessary to master in some degree uninteresting technicalities. The jewel is inclosed always in an unattractive casket of lead; we must find the key before we can gain the prize.

The vegetable kingdom, then, is divided into two great classes: the *Phænogams*, or flowering plants, and the *Cryptogams*, or flowerless. The *Cryptogams* may be again divided into cellular and vascular *Cryptogams*. The cellular *Cryptogams*, such as the mosses, fungi lichens, sea weeds, &c., consist entirely of cellular tissue, while the vascular *Cryptogams*, such as ferns, club-mosses, equisetaceæ, (horse-tails,) combine the vascular tissue with the cellular. The *Phænogams* may also be divided into two sub-classes, viz: the *Gymnosperms*, or naked seeded plants, and the *Angiosperms*, or covered seeded plants. The *Gymnosperms* bear their seeds naked or exposed, either near the base of an open capillary leaf, as in the pine family, (*Conifers*,) fig. 12, or else on its edges, as in the cycas family. Figs. 12 and 13 represent cross sections of the capillary leaves of naked seeded plants. The *Angiosperms*, on the contrary, bear their seeds enfolded within the capillary leaf or seed vessel, (figs. 14 and 15,) as in all the ordinary flowering plants. The *Angiosperms* are again subdivided into *Monocotyledons*, (one cotyledon or seed leaf in the embryo,) fig. 16, and *Dicotyledons*, (two seed leaves in the embryo,) fig. 17.

Fig. 12.

Fig. 13.

Fig. 14.

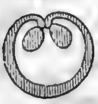


Fig. 15.

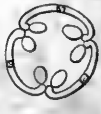


Fig. 16.

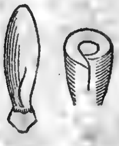
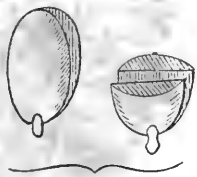


Fig. 17.



Phænogams,	Dicotyledons, Monocotyledons,	Angiosperms.
	Conifers & Cycadæ,	Gymnosperms.
Cryptogams,	Vascular Cryptogams. Cellular Cryptogams.	

Now, the most important means of determining the families of coal plants are the *internal structure of the stem* and the *venation of the leaves.* Generally, indeed, these are the only means at our command. Let us inquire, then, how the great divisions of the vegetable kingdom are characterized in these respects.

Among *Phænogams* there are two very distinct types or plans of internal structure of the stem, viz: the *Exogenous*, or outside-growing, and the *Endogenous*, or inside-growing; the one represented by the hard-wood trees and shrubs, the other by the palms, canes, grasses, &c. On cross section of an exogen (fig. 18) we find three distinct zones of tissue. In the centre a zone of cellular tissue, the pith; exterior to this a zone of wood, and around this again a zone of cellular tissue, the bark. The zone of wood is, moreover, subdivided into concentric rings, which represent the annual layers of growth, and separated into wedges by radiating lines of cellular tissue (silver grain) connecting the cellular tissue of the pith with the cellular tissue of the bark. In the *Endogens*, on the contrary, we have the woody tissue in the form of thread-like bundles, irregularly interspersed amongst the cellular. The dry stalk of an Indian corn is a familiar illustration of this structure. If such a stalk is broken across and the two parts carefully separated, the thread-like bundles of woody and vascular tissue are observed to draw

Fig. 18.

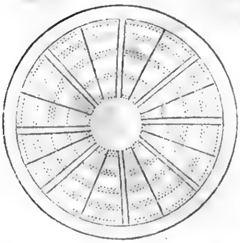
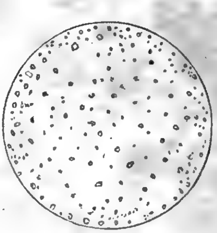


Fig. 19.

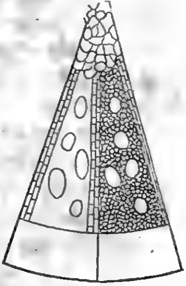


out from the softer cellular tissue. Here we observe no distinct pith; on distinct bark separable from the wood; the wood not collected into a distinct zone; not arranged into concentric layers, nor divided by medullary rays. The exogenous plan of structure includes the *Dicotyledons* and the pine and cycas families; while endogen may be considered synonymous with monocotyledon.

In the vascular *Cryptogams* the woody and vascular tissue is still differently arranged. The stem of a club-moss, for instance, consists of a mass of cellular tissue inclosed in a rind of the same tissue more condensed, with a single central thread of vascular tissue. Sometimes there seems to be in the centre of this something like a very imperfect pith. The cellular *Cryptogams*, as their name indicates, consist entirely of cellular tissue.

It will be observed that, in the general structure and mode of growth, the family of pines (*Gymnosperms*) is allied to the highest order of plants, viz: the *Dicotyledons*, while in its reproduction it is below the *Monocotyledons*. This latter position is beyond doubt the true one; and a more attentive examination of the wood of pine in comparison with that of *Dicotyledons* will confirm us in this view. As this is a very important point, and as much false theorizing on the subject of the plants of the coal has been the result of a misconception of the true position of conifers, I will dwell a little more minutely than I should have otherwise considered it necessary to do.

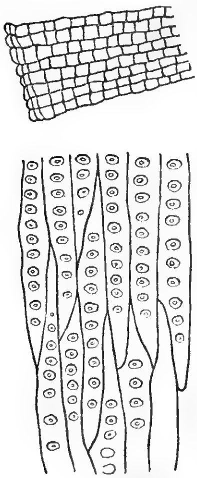
Fig. 20.



The wood of *Dicotyledons* consists of two distinct tissues, viz: the woody tissue proper and the vascular tissue. The woody tissue proper is composed of elongated cells, too small to be distinguished by the naked eye, while the vascular tissue is composed of very much larger cells or tubes. The visible pores in such wood as oak, chestnut, vine, &c., belong to this tissue. Fig. 20 represents cross section of two wooden wedges, with their medullary rays. The comparative size of the wood cells and the vessels is well shown. The difference is often much greater than in the figure. In pine wood, on the contrary, there is no distinction of woody and vascular tissue; but the so-called wood consists entirely of an open, thin-walled tissue, intermediate in every respect between the vascular and the woody layer and thinner walled than the true woody, but smaller than the true vascular. This is shown in the cross section, (fig. 21.) On a longitudinal section, (fig. 22,) the cells of pine wood are marked by large disc-like elliptical plates, which are entirely characteristic of this family. The smallest fragment is sufficient to distinguish it with the utmost certainty.

Now, if we trace the development of the tissues, either by passing from the lowest to the highest plants, or from the earliest embryonic to the mature condition of one of the higher plants, we shall find that all the different kinds of tissue are modifications of the cellular; that there is a more and more complete differentiation of form and special-

Figs. 21 and 22.

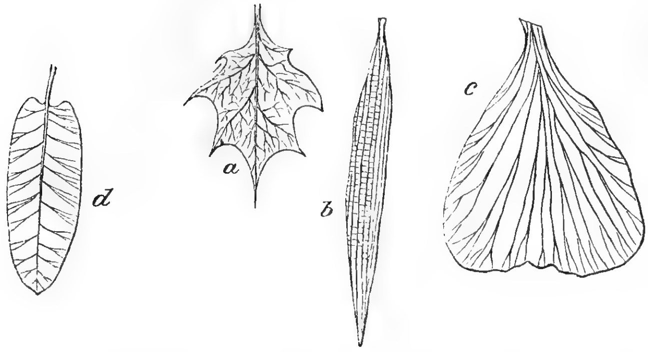


ization of function as development progresses. The longitudinal system is first formed by modification of the cellular, and then this is again differentiated into the two forms of woody and vascular tissue. Now, in the pine family, this last differentiation has not taken place. So far as its tissues are concerned, therefore, this family should rank below all other flowering plants.

Let us next examine the different classes of plants with respect to the venation of their leaves.

With respect to their venation the leaves of plants are divided into three distinct kinds, viz: the reticulated, or netted veined, the parallel veined, and the dicholomously veined. In the first the veins branch and again run together, forming an inextricable net-work. (Fig. 23, *a.*) In the second the veins run parallel from one end of the leaf to the other, connected only by slender transverse bars, so that the leaf may be torn into parallel ribbons. (Fig. 23, *b.*) In the third the veins branch, but do not run together again. (Fig. 23, *c* and *d.*) The first is characteristic of the *Dicotyledons;* the second of the *Monocotyledons;* and the third of the *Ferns*—perhaps of the vascular *Cryptogams* generally. The leaves of cellular *Cryptogams* are veinless. In this enumeration it will be observed I have not mentioned the *Conifers.* To which class, then, do the leaves of the pine family belong? Undoubtedly to the third. This fact cannot be easily demonstrated upon leaves of ordinary pines, for their cylindrical leaves show no veins, or, if visible, they seem to be parallel. But there are a few broad-leaved *Conifers,* and these always show the dichotomous branching of the veins in the most unmistakable manner. In the *Salisburia,* for instance, we have as beautiful an instance of this mode of branching as can be found among the *Ferns.* The leaves of this *Conifer* are about two or three inches broad, the shape and venation very similar to that represented in Fig. 23, *c,* but much more beautiful. This close alliance in the venation of the leaves between the pines and the ferns is another evidence of the low position of the former among flowering plants. Thus it appears that this remarkable family of plants is allied to the highest *Phænogams*

Fig. 23.



in the general structure of its wood, and to the *Cryptogams* in the venation of its leaves. If there was no other evidence we might be in doubt as to its true position; but the simplicity of its reproduction and of its tissues settles the question, as it seems to me, forever. There are other points of alliance between pines and club-mosses, which it would lead me too far to notice. In fact this family seems to be, in a remarkable degree, both a connecting and an embryonic type, and therefore, as we shall presently see, eminently calculated to throw light upon the plants of the coal.

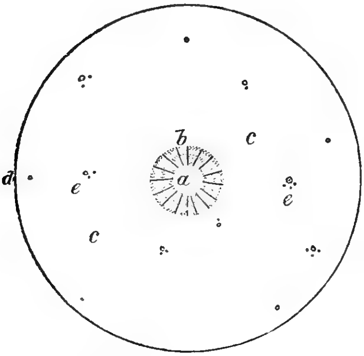
Let us now attempt to apply these principles in the interpretation of the plants of the *Coal*, and particularly of the four families already taken as representatives of the flora of this period, viz: the *Ferns*, *Sigillariæ*, *Lepidodendron*, and *Calamites*. We shall confine our attention principally to the second and third. With reference to the *Ferns* there is little dispute; their unmistakable resemblance to the ferns of the present flora leave no doubt as to their affinities. I will only remark, in passing, that many of the coal genera of this family seem to have affinities also with the *Cycadæ* and *Coniferæ.* With reference to the other three families the difficulty is much greater; they are generally supposed, however, to be most nearly allied to the *Lycopodiaceæ* (club-mosses) and the *Equisetaceæ,* (horse-tails;) the *Sigillariæ* and *Lepidodendrons* being considered most nearly allied to the club-mosses, and the *Calamites* to the horse-tails. If so, then we are at once struck with the enormous size of the coal plants in comparison with their humble representatives at the present day. *Sigillariæ* and *Lepidodendrons* attained the amazing height of seventy to one hundred feet, and a diameter of five to six feet, while the club-mosses of the present day seldom rise to an altitude of more than a few inches. *Calamites* attain a diameter of fourteen or fifteen inches, and a height of thirty to forty feet, while the horse-tails are among our humblest plants. This enormous difference in size is sufficient of itself to lead us to suspect that these are not true club-mosses and horse-tails. Let us examine them more closely.

Here you have rude sketches of these families. This is *Sigillaria.* This genus is so little known as to its external appearance that I cannot represent or speak of it with any confidence. In almost every case it is formed as a straight cylindrical trunk, without branches or leaves. So that, although this plant is so common, yet its mode of branching and the form of its leaves is still a matter of dispute among botanists. In a few cases *Sigillaria* trunks have been found to bifurcate and produce long cylindrical branches. In a single, perhaps doubtful, case (*Sig. lepidodendrifolia*) leaves have been found similar to *Lepidodendron.* One of two views seems probable: either that many so-called *Lepidodendrons,* so commonly found in connexion with *Sigillaria,* are the branches of the latter, in which case the branching and foliage of this genus are similar to the *Lepidodendron,* or else that *Sigillaria,* like tree ferns, were generally branchless, and that the large fronds, (generally supposed to belong to *Ferns,*) which are so commonly found strewed in profusion about their bases, were their leaves. What I have represented by these sketches are therefore ideal restorations on the former hypothesis, rather than actual specimens. You will observe, then, the sparse dichotomous branching, the cylindrical limbs with blunt extremities, so characteristic of the club-moss, but which is found, also, in some species of pines. Like the club-moss, too, the leaves are crowded, pointed, strung along the stem for some distance, but longer, slenderer, and more nearly resembling the leaves of the pine. On this trunk you will observe the seal-like impressions (*sigilla*) characteristic of this family, and from which its name is derived. Also longitudinal depressions running from one end of the trunk to the other, and along which the sigilla are arranged in vertical rows. Thus each trunk of a *Sigillaria* resembled a noble fluted doric column beautifully but variously sculptured the pattern changing with the species. These sigillae are evidently leaf scars, and therefore indicate the leaf arrangement peculiar to this family.

The *Lepidodendron*, of which you have here a drawing, was still more like the club-moss, the crowded leaves being shorter, rhomboidal, and more scale-like, the same long, slender, cylindrical, sparse dichotomous branches. But even here we find an almost equal resemblance to *Conifers*, for it will be recollected that in a large number of *Conifers* as the *Juniperus*, the *Araucaria*, &c., the same rhomboidal, plaited scale-like leaves prevail. The impression of a shoot of an *Araucaria* could scarcely be distinguished from that of some species of club-moss, except by superior size of the former. In its fructification there is the same difficulty, for it is doubtful whether it most nearly resembled the cone of pines, or the cone-like fructification of club-mosses, although the recent investigations of Hooker leave little doubt that the latter is the truer view. All that we know, then, of the external appearance of these families lead us to the conclusion that they were intermediate between pines and club-mosses, and that the *Sigillaria* approached most nearly the pines, and the *Lepidodendrons* most nearly the club-mosses.

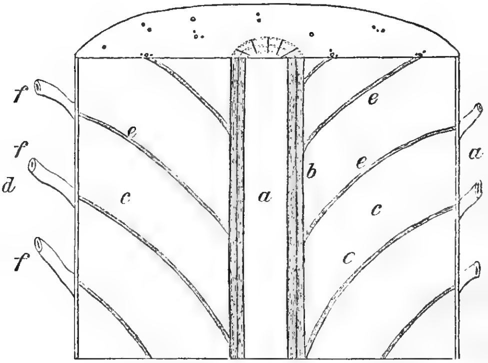
Let us next see what light is thrown upon this subject by examination of the internal structure.

Fig. 24.



Cross section of *Sigillaria*: *a* the pith; *b* the woody cylinder; *c* the cellular tissue; *d* the rind; *e* the bundles of vascular tissue running from central sheath to the leaves.

Fig. 25.



Cross and longitudinal section of *Sigillaria*; letters represent same as in fig. 24; *fff* the leaves.

If we make a section of the stem of a *Sigillaria*, (figs 24 and 25,) we find externally a *bark*, or, more probably, a *rind*(*a*) of condensed cellular tissue, sometimes a half or an inch thick; within this an enormous amount of loose cellular tissue,(*c*,) often 2 feet or more thick. Through the centre of this runs a slender sheath(*b*) of vascular or woody tissue, which in a *Sigillaria* 5 feet in diameter is not more than 3 inches in diameter; a mere thread of vascular in the midst of a mass of cellular tissue. This again incloses a small pith (*a*) which occupies the very centre of the trunk. These vascular cylinders, with their inclosed pith, being the most indestructible portion of the trunk, are often found alone, and described under the name of *Endogenites*. Figs. 24 and 25 represent cross and longitudinal ideal sections of this plant, (*a*) the cellular tissue of the pith, (*b*) the vascular or woody sheath, (*c*) the mass of cellular tissue between the vascular sheath and (*d*) the rind, (*e*) slender vascular bundles connecting the leaves with the central sheath. Upon closer examination of this woody or vascular cylinder (*b*) it is found to consist of concentric layers, somewhat analogous to the layers of growth of exogenous trees, and divided into wedges by medullary rays, like the tree exogens. Upon still closer examination, however, of a good cross section under a microscope (fig. 26) no distinction of vascular and woody tissue, such as is found in the wood of *Dicotylodons*, is observed, but the whole is made up of one kind of tissue, open and thin-walled, in comparison with woody tissue proper, but closely resembling the wood of pines. But a longitudinal section shows no disc-like markings such as characterize the wood of *Conifers*, but reveals the fact that it consists entirely of spiral vessels, (figs. 27 and 27;) and that, therefore, the sheath of the *Sigillaria* consists of vascular rather than of woody tissue. In consequence of the great predominance of cellular tissue, these stems, as well as those of the *Lepidodendron* and *Calamites*, are generally found very much flattened by pressure.

Figs. 26 and 27.

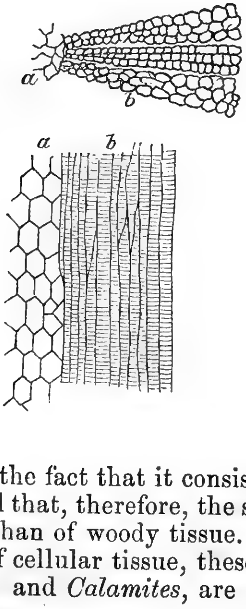


Fig. 28.

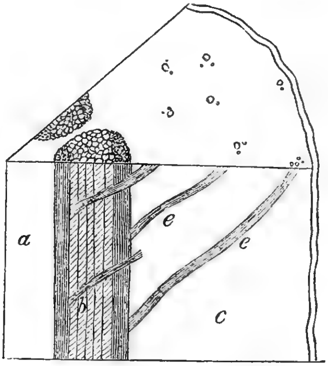


Fig. 28. A cross section and longitudinal section of a *Sigillaria*. The letters *a*, *b*, *c*, *d*, *e* represent same as in previous figs. 1, 2, 3 are the 3 layers of the vascular cylinder *b*, *m* is a medullary ray.

A cross and longitudinal section of the *Lepidodendron* shows a similar but still less highly organized structure, (figs. 29 and 30.)

Fig. 29.

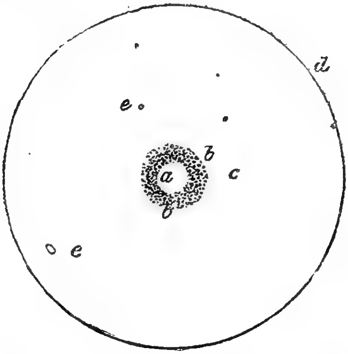
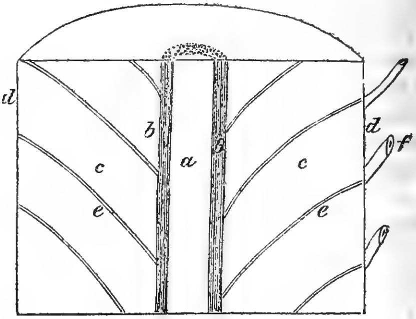


Fig. 30.



The vascular sheath is still smaller, extremely thin, forming on cross section an exceedingly narrow zone. It is moreover not separated into concentric rings nor divided by medullary rays. The cellular tissue both within and without the sheath is very open and loose. The rind (*d*) consists of similar cellular tissue, but more condensed, and there seems to be no line of demarcation, but a gradual transition; in other words, there is apparently no true bark. Here, also, we find long slender bundles of vascular tissue (spiral vessels) connecting the leaves with the central sheath. Microscopic examination of the vascular sheath shows no sign of woody tissue.

Calamites we know much less about, but it would seem that in them there is a still greater predominance of cellular tissue, if, indeed, they possessed any vascular tissue at all. They are often found pressed perfectly flat, indicating that they were either hollow, or more probably consisted of a simple rind of condensed cellular tissue, inclosing looser tissue of the same kind. Of this plant, however, we know too little to draw any conclusion as to its affinities.

Now, if we examine by sections a common *Lycopodium*, or club-moss, we find an internal structure closely resembling what we have found in *Sigillaria* and *Lepidodendron*. Externally a thin but tough rind, or epidermis of condensed cellular tissue, inclosing a mass of very loose cellular tissue, through the centre of which runs a slender thread of vascular tissue, sending off in every direction still slenderer threads of the same to the crowded leaves. Upon longitudinal section the vascular tissue is found to be chiefly spiral ducts. The principal difference between this structure and that of the *Lepidodendron* is that the latter has a more perfect pith, and in this respect seems to be allied to the higher order of plants. But I am convinced, from personal examination of the *Lycopodium*, that its vascular thread was the outline of both pith and medullary rays. I call more particular attention to this observation, because, as far as I know, it is new, and as it seems to me calculated to throw much light on the affinities of coal plants.

This very remarkable structure, viz: the existence of a slender central thread of vascular tissue in the midst of a large mass of very loose cellular, does not exist, I believe, among existing plants in the mature condition, except in the family of club-mosses. In the embryonic state, however, of the *Dicotyledons* we find something similar. If we make a cross section of a *Dicotyledon* soon after germination, *i. e.*, while the first two or three pairs of leaves are expanding, we will find a structure very similar to that of the *Lepidodendron.* We find in the centre a small pith surrounded by a thin zone of vascular tissue, (mostly spiral vessels,) around this a large mass of cellular tissue, destined to become partly bark and partly wood, but which is yet neither one nor the other, and the whole inclosed in a thin epidermis of condensed cellular tissue.

Thus it appears, both from external and internal examination, that these families combined the characters of pines and club-mosses. Or if we are disposed to attach more importance to their exogenous affinities, and thus to place them among the pines, then we must compare them with the earliest embryonic condition of this class. The true view, I am convinced, is, that they are both connecting and embryonic types, or connecting types with embryonic characters. In fact, all embryonic types seem to be more or less connecting, and conversely connecting types, at least in *Palæontology*, are also embryonic. Now, what I have said of the *Sigillaria* and *Lepidodendron* is equally true, I believe, of other coal plants. I have taken these two because they are better known; but all that is known concerning other genera seem to point in the same direction. They all seem to be more or less connecting types. The *Sphenophyllum*, *Nöggerathia*, and probably many of the so-called *Ferns* of this period are of this character.

Let us inquire now what important conclusions may be drawn from what we have seen of the affinities of these plants:

1. The distinction of plants into *Cryptogams* and *Phænogams* is considered by botanists a fundamental one. Many recent investigations, however, have combined to throw some doubt upon the entire distinctness of these classes. The study of the Coal Plants, particularly of the two families *Sigillaria* and *Lepidodendron*, it seems to me entirely destroys this as a fundamental division, or, at least, as one at all comparable to the great divisions of the animal kingdom. The pines belong unequivocally to the *Phænogams* and the club-mosses to the *Cryptogams*. If the *Sigillaria* and *Lepidodendron* are connecting links between these two families then the classes to which they belong can no longer be considered as fundamentally distinct types or plans of structure. The study of animals, both existing and extinct, have confirmed the wonderful generalization of Cuvier. The four types—*Vertebrata, Articulata, Mollusca, and Radiata*—were as distinct during the palæozoic period as now. If such distinct plans of structure exist in the vegetable kingdom at all they have not yet been indicated as such by botanists. The distinction into exogen and endogen would seem more likely to be fundamental, as this is apparently not a mere distinction of rank or complexity of structure, but of *plan* of structure. If so, then we shall probably be able to trace these two types downwards until, overleaping the distinction of *Phænogams* and *Cryptogams* as one of complexity of structure only, they reach the lower confines of the vegetable kingdom.

2. We have seen that the plants of the coal are most, if not all of

them, connecting types with embryonic characters. This is not an isolated fact, but one which meets us at every step in the course of our study of the geologic history of the earth. It is but one illustration of a *general law*, a law of the deepest philosophic import, and yet one which is still very imperfectly recognized among geologists. The law may be thus stated: The first introduced animals or plants of any class have been combining types, *i. e.*, have united within themselves the characters of several families, now distinct and even widely separated. Thus the first vertebrates introduced were fishes, but not typical fishes, as we might be led *a priori* to expect, but *Placoids* and *Ganoids*, families which, particularly in their earlier representatives, united with ordinary fish characters others which connected them with the class of reptiles, and even of mammals; and still others which connect them with the embryonic condition of the typical fishes. It is this combination of embryonic characters with others which connect them with the higher classes, this union of high and low characters, which has given rise to all the dispute concerning the position of these families in the scale of Fishes as well as to much of the difference of opinion concerning the law of succession of animals in Geology. Again, the first introduced reptiles, viz: the reptiles found in the old red sandstone and coal, are the most remarkable instances of connecting types of which we have any knowledge. In the first place they seem to have been amphibious, (in the proper sense of the word,) and thus to have connected land animals and water animals, air breathing with water breathing, and all of them united characters, which are now represented by widely separated families. To give a single instance: the carboniferous reptile, recently described by Professor Wyman and exhibited at the last meeting of the Scientific Association at Albany, so remarkably combined characters which are now parcelled out between the three families of *Batrachians*, *Saurians*, and *Ophidians*, that this distinguished comparative anatomist seemed almost at a loss as to which of these families to assign it. He decided, however, that it most nearly resembled a *Salamandroid Batrachian* with characters closely connecting it with the other families already mentioned.

The *Labyrinthodon* of the new red sandstone has been classed by some anatomists with *Batrachians*, and by others with crocodiles. There seems yet a doubt whether it should be called a tailless crocodile or a crawling frog with crocodilian teeth. The huge *Saurians* of the secondary period combined reptilian with fish, and even some mammalian characters. Even in the tertiary period and in the introduction of the highest animals this law is not forgotten. The recent investigations of Professor Owen have shown that the first introduced *Pachyderms* were not typical *Pachyderms*, but that they combined the characters of *Pachyderms* and *Ruminants* to such a degree that it is almost impossible to assign them with certainty to one or the other order. In fact, the study of these extinct forms has led this great anatomist to class the *Pachyderms* and *Ruminants* together as subdivisions of one and the same order.

Thus in every case in the earliest faunæ and floræ one class stood for many. The earliest families combined the characters of several families or classes, and stood as their representative until these families or classes were separately introduced. The *Placoids* and *Ganoids*, for instance, stood during almost the whole palæozoic period the sole representatives of the vertebrate type, combining in themselves the characters of all classes, and thus prophesying their coming, until Nature was fully prepared for their introduction. The *Sigillaria* and *Lepidodendron* stood as the representatives of both *Cryptogam* and *Phœnogam*, until these two *ideas* were separately and more distinctly expressed by the subsequent introduction of the typical forms of these two classes. It is as if Nature first sketched out her work in general terms and then elaborated each subordinate idea in separate families; all these families, taken together as an organic whole, still containing the original idea in a more completely developed form, as if the problem of organic nature was first expressed in a few simple but comprehensive symbols and then differentiated. Organic nature has often been compared to a *broken chain*, the disjointed links of which are the widely separated and distinctly marked families of the present fauna and flora, and the connecting links of which are to be found deep buried in the strata of the earth. But the complexity, the beauty, and, more than all, the life, growth, and development of Nature, is not to be represented by any such miserable mechanical contrivance as a chain. It is rather a *tree*—a tree of life—a tree whose trunk is deeply rooted in the lowest palæozoic strata, whose first giant arms are given off in the carboniferous, which branch again in the secondary and again in the tertiary periods, while its extreme branchlets, and also its flower and fruit, are the fauna and flora of the present epoch. The object of geology is to trace each branch to its fellow branch, and each limb to its fellow limb, and thus gradually to restore the whole noble form and determine the laws of its growth.

This differentiation, this passing from simplicity to complexity, from unity through diversity to a higher unity, is the fundamental law of development. Let me illustrate my meaning by a few simple examples: The ultimate anatomical elements of every organized body, whether animal or vegetable, are cells. The whole body is made up of cells, and all the bodily functions are performed by cells. In fact, the body may be looked upon as an organized community of individual cells. Now, if we trace these cells from their earliest condition in the embryo to their mature condition in the fully developed animal or plant, or from the lowest animal or plant regularly to the top of the scale, we will observe a most beautiful instance of the differentiation of which I speak. The cells are at first all alike, simple and globular, and each performs all the functions appertaining to cells, though comparatively imperfectly. But as development advances the cells begin to take on different forms and to perform different functions. Some become nervous cells, some muscular cells, some biliary cells, &c., until, in the mature condition and in the highest animals, the diversity of form and specialization of function reaches the highest point, each form of cell being confined to the performance of a single function.

If, instead of the ultimate anatomical elements, the cells, we take the proximate anatomical elements, the organs, or even the regions of the body, still the same differentiation of form and specialization of fuction is observable as we pass from the embryonic to the mature condition, or from the lowest to the highest animals. I might give many other examples taken from the organic kingdom. I will give but one other example, and that taken from a still higher kingdom. Human society is also an organized body, the ultimate anatomical elements of which are individuals. Now, in the earliest conditions of human society we find these elements, so far as their social functions are concerned, identical. Each man performs all the social functions apertaining to man. He is his own tailor, shoemaker, agriculturist, scientific man, &c. But in proportion as society advances in the same proportion does specialization of social functions advance, until, if we could conceive of a society perfectly organized on a purely material basis, *i. e.* according to the French material philosophy, then the social function of each individual would be reduced to the narrowest possible limits. This is only impossible or undesirable on account of man's moral and spiritual nature. Still it is no less evident that, in so far as human society is a *material organization,* specialization of function, differentiation is the law of development.

Now, it will be recollected that in the geological history of animals and plants we have everywhere found the same differentiation of form and specialization of function. As in the history of the animal body, one cell form in the embryo was the representative of many widely separated cell forms in the mature animal; so also in the geological history of that greater and more complex organism, the animal and vegetable kingdom, one form in the early periods stood as the representative of many widely separated forms in its present mature condition. Am I not justified, then, in saying that the great law which has governed the introduction of successive animal and vegetable species is that of gradual development of the animal and vegetable kingdom as an *organic whole?*

It seems to me that all the dispute and misunderstanding on this subject have been the result of too narrow a view, have arisen from fixing the mind upon genera and species instead of upon the larger divisions of classes and orders, upon the individual elements instead of the organic whole. Development does not necessarily involve the idea of progression in all the individual elements. In the differentiation of the cells of the living body, of the individuals of an advancing community, or of the forms of an advancing fauna, the whole organism progresses, but as a necessary result of differentiation, while the highest individuals are successively higher and higher, the lowest, considered in themselves, and not as parts of an organized whole, *may become lower.* Certainly the difference between the high and the low becomes constantly greater. It should not surprise us, then, that some of the lowest forms of animal life have been among the latest introduced. It is precisely what, according to a true appreciation of the law of development, we should be naturally led to expect.

Mr. Hugh Miller, the eminent Scotch geologist, in his admirable work, "*Footprints of the Creator,*" by taking too limited a view of this subject, has been led, if not into error, at least into a statement of views which has misled many. In his zeal against the Lamarckian theorists, and more particularly against the author of the "Vestiges of Creation," he has attempted to show that, in certain families, at least, the law has been that of degradation, instead of progression. He has labored to prove that the earliest fishes have been the highest, instead of the lowest fishes, and that the earliest reptiles have been higher in the scale than the present reptiles. This idea has been seized upon by some in this country, and it has been attempted, by connecting it with the fall and degradation of man, to show that the universal law of history, both geological and human, is degradation. The disciples of this melancholy philosophy believe that divine power successively introduced higher and higher classes, but each class, left to its own laws, continued to degrade itself. The Deity repeatedly attempted progression, by the miraculous introduction of successively higher classes, but some malign influence as constantly interposed and, to some extent, frustrated these attempts.

Now, it is evident that these theorizers have never thoroughly grasped the fundamental idea of development. They mistake *specialization* for *degradation*. Upon this theory all our boasted modern civilization, so far as it is the result of division of labor, specialization of social functions, and mutual dependence of parts, is degradation.

Upon what ground are the *Ganoids* and *Placoids* considered the highest fishes? Only on the ground that they combine with their fish characters others which ally them with the higher classes, particularly with reptiles. In other words, they fall into the very error of the Lamarckians themselves, viz: that of supposing that the animal kingdom is to be represented by a *linear series*, and that, therefore, the highest fishes approach the lowest reptiles, and the highest reptiles the next higher class, &c. But the very reverse of this is the fact. The animal kingdom should be represented by an infinitely branching tree, rather than by an ascending right line; for we find, in every case, classes approach each other in the lowest members of each, and diverge as they ascend. Thus, it is the lowest, and not the highest plants, which approach the animal kingdom. As we ascend, they become more and more widely separated, until, in the highest representatives of each, the separation reaches its highest point. So also each branch of these kingdoms diverges from its fellow branches. It is, therefore, in its lowest, not its highest, members that we should naturally expect, according to the law of differentiation, the class of fishes to approach the class of reptiles. In some sense, indeed, *Placoids* and *Ganoids* may be considered higher than typical fishes. Their brain and nervous system is more highly organized, their reproduction is more complex, their young are better cared for. But it will be recollected that they are both connecting and embryonic types. Now, it is their connecting characters which seem to elevate them, for their true fish characters are all *embryonic*. As *vertebrates* they may possibly be considered higher than other fishes, but as fishes they must be considered low. Anatomists may place them high but morphologists will always place them low. If the several classes of the animal kingdom, diverging in various directions, be, as it were, projected upon a vertical plane, the *Placoids* and *Ganoids* may possibly occupy a higher position than the typical fishes; but, in such a rectilinear projection, all the variety and beauty of nature is lost. It is evident that, for purposes of classification, the morphologist is right; for if the principle of the anatomists is consistently carried out, no classification is possible, for animals the most diverse, an echinoderm and a fish, may be brought together. The Divine classifier, in the introduction of species, has followed the principle of the morphologist.

Geology, then, teaches, and, as it seems to me, unmistakably teaches, that the law of succession of animals and plants is that of progressive development in time of these two kingdoms. But, although there has been a development, it is not the development of the Lamarckian, of the author of the Vestiges of Creation, and the pantheist. The development which geology teaches is not a development which is the result of physical laws and physical forces. If there is anything which geology teaches with clearness, it is that the animal and vegetable kingdoms *did not commence as monads*, or vital points, but as organisms so perfect that even the maddest Lamarckian must admit that they could not have been formed by agency of physical forces; that species *did not pass into one another by transmutation*, but that each species was introduced in full perfection, remained unchanged during the term of their existence, and died in full perfection; that physical conditions cannot change one species into another, but that a species will give up its life rather than its specific character. In passing from the equator to the poles we pass from one geographical fauna to another, from one set of species to another, but observe no transmutation, but only substitutions; so also in passing from the oldest geological to the present fauna we pass from one set of species to another; not, however, by transmutation, but always by substitution. This has been repeated so many thousand times in the geological history of the earth that there is no room for doubt on the subject. As far as the evidence of geology extends, *each species was introduced by the direct miraculous interference of a personal intelligence.* There has, indeed, been a constantly increasing series, but the connexion between the terms of the series has not been physical or genetic, but intellectual; not founded in the laws of reproduction, but in the eternal counsels of the Almighty. There has, indeed, been a development, but not a development the force of which exists within the thing developing; but rather the development of a great work of art, under the hand of the Divine Artist—a work conceived in eternity, and elaborated throughout all time. What an overwhelming idea this thought gives us of the unchangeableness, the all-comprehensive intelligence and foreknowledge of the Deity! The infinite diversity of nature, the whole idea of this infinite work of art, was contained in the first strokes of the Great Artist's pencil, and the ceaseless activity of Deity has been exercised only in the eternal unfolding of the original conception.

LECTURE ON THE VASTNESS OF THE VISIBLE CREATION.

BY PROFESSOR STEPHEN ALEXANDER OF THE COLLEGE, OF NEW JERSEY.

My object on this occasion is, in itself, a very simple one. I desire to give some illustrations of the vastness of the visible creation, as made known by modern astronomy. I say emphatically modern astronomy, for some knowledge of this science is probably nearly as old as the world itself. Almost from the first issuing of the great decree that the sun and moon should serve for signs, and for seasons, and for days, and for years, men have been careful to observe the heavens; for the Great Creator had so written that decree upon the heavens themselves that men have not been slow to read the lesson thus visibly inculcated. I would observe, moreover, that the objects of astronomical research, with very trifling exceptions, are, of all others, with which we have to do, the most unalterable. It is almost exactly true that the very constellations which we now see were gazed upon by the antedeluvian patriarchs; were in full view of Noah when the great flood of waters was upon the earth; met the upturned eye of Abraham when he was led out by Divine command to behold in them the symbol of the promise; guided the ancient Greeks in navigation, and still serve the modern astronomer as so many guide-points in the heavens.

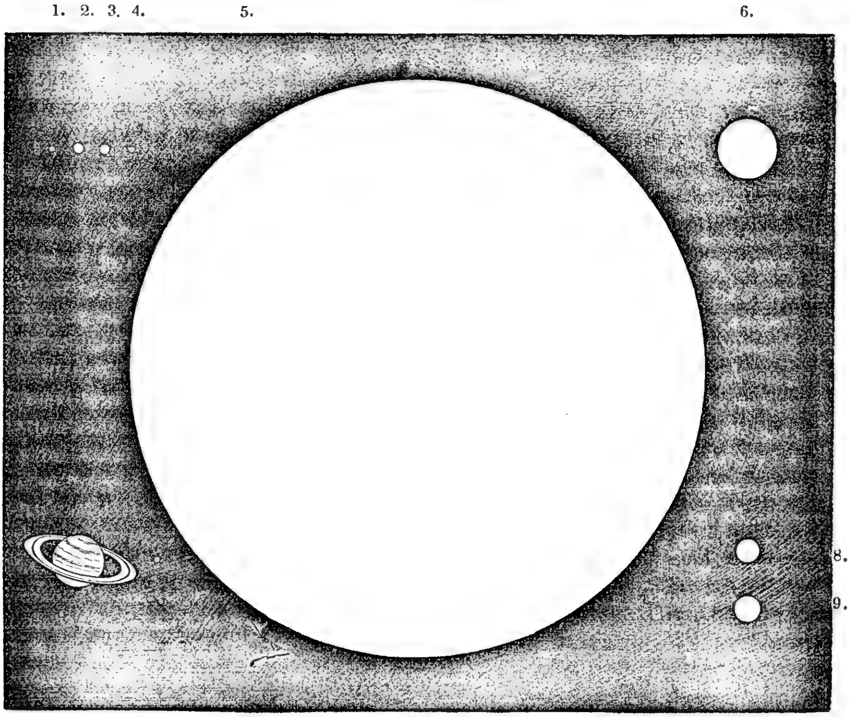
My purpose, as already indicated, is to illustrate, not to demonstrate. To accomplish the latter in a single lecture would not be practicable; and certainly of astronomy, above all other sciences, it is true that it may throw itself on its character for veracity when it requests that its conclusions should be received as reliable. A science which can trace a comet in its course, where no eye has had even a telescopic view of it for three-quarters of a century, and bring it back by computation correctly almost to a day, or which can predict an eclipse a century hence as readily as one that will occur this year, and to whose accuracy experience throughout bears such abundant testimony—such a science may fearlessly throw itself on its character for veracity. Before I proceed, however, to elucidate the subject, let me call attention for a moment to an old-fashioned problem, whose bearings upon the subject will, I trust, be presently seen. I allude to the problem of the price of a horse, in which a farthing was allowed for the first nail in his shoes, two for the second, four for the third, and so on. There were thirty-two nails in all, and yet, from the small beginning of a farthing, owing to this doubling thirty-one times, the value of the horse was only to be computed in millions of pounds. Now, with reference to the subject of astronomy, we shall have occasion to see that, though commencing with a comparatively moderate unit, we shall advance upon a similar plan, but much more rapidly. Keeping, then, in view the illustration already given, you will at once see how gigantic, after a very few steps, must be the last result compared with the first. Our first object to-night will be to gain some idea of the size of the earth itself, on which we stand. The half diameter of the earth is the measuring unit with which to compare the distance of the earth from the sun, and thus obtain a new unit with which afterwards to compare the distances of the other planets. To give a just idea of the size of the earth we will avail ourselves of the largest tangible measure attainable, that is, the highest mountain on the earth's surface. The highest mountains are the Himalayas, their altitude being five and a half miles. Now, we do not exaggerate when we say that, if we could uncover the base of one of those mountains, it would cover four times the original area of the District of Columbia, or the surface of one of the ordinary counties of our States, rising above that surface to the height of five and a half miles, about equal to the height of Chimborazo added to that of the highest of the Alps. This shall be our standard of comparison with regard to the magnitude of the earth. Such a mountain is rather more than $\frac{1}{1440}$ of the earth's diameter or about $\frac{1}{720}$ of its radius. In making the comparison, after the ordinary mode, two difficulties present themselves. It is said that, if you represent the earth by a globe, the highest mountain on its surface may be represented by a small grain of sand. You thus proceed from the greater to the less, whereas, in nature, we must proceed from the less to the greater. Besides, a grain of sand is too small to give an adequate idea of the matter to be illustrated. To avoid this we shall make use of a scale sufficiently large to present the mountain distinctly, and shall proceed in the natural order from the less to the greater. This diagram before me is thirty-nine feet six inches in length, and is intended to represent two radii of the earth opening to the extent of one degree. At the further end of it is a blue band, representing the atmosphere, and immediately beneath which is a small row of mountains. Their heights, on this scale, is a trifle less than two-thirds of an inch, and their actual height, as compared with the real half diameter of the earth, is as two-thirds of an inch compared with thirty-nine and a half feet, and doubling the half diameter we shall have the ratio of two-thirds of an inch to seventy-nine feet. Below the row of mountains you have a dark blue band, representing the ocean. Below that again a darker portion still, representing that portion of the earth's crust through which you must go to find a red heat, and beyond that you have the red color continued until it passes into whiteness; it indicates the depth at which we would probably arrive at a white heat.

[It would be impossible, in a wood-cut, to do justice to the illustration here explained by the lecturer. The explanation itself will doubtless be sufficient.]

The diameter of the earth is, then, a very large unit in comparison with the height of the highest mountain. The circumference, of course, is more than three times the diameter. If you should attempt to walk around the earth at the rate of twenty miles a day, three years and five months would be spent in completing the circuit; and if you should fly around it at the rate at which the steam car travels, say thirty miles an hour, you would accomplish its circuit in thirty-four and a half days; but, if its circumference be great in comparison with ordinary standards, its surface in comparison with that of a sphere of ordinary size must be still more enormous. The illustrations, I would remark, that I give you here, are most of them originally devised, and the results in all cases verified by actual computation. We could not pass over the surface of the earth and take a good look at the surface at a more rapid rate than that of twenty square miles a day, and yet this would occupy us a period of 27,000 years. To view that portion of the earth which is inhabited, if we should estimate it at but one-fourth of the whole, would, at the same rate of progress, require 6,750 years; or to view the habitable portion of the surface of the earth would require, in the case of the same individual, provided he could live so long, more than the time from the creation of man down to the present day to walk. If the surface of the earth be so large, its capacity, of course, compared with an ordinary standard, will be found to be to it in a still greater ratio. The largest tangible measure, as I have said, is the largest mountain on the earth's surface. Suppose such a mountain to be regularly shaped, and to have a diameter of twenty miles at the base, it would then contain 576 cubic or solid miles of material. Make use of that huge body as the unit of measurement of the bulk of the earth, and the bulk of the earth would contain it 450,000,000 of times, and even more. How can we appreciate so large a number? We find it even difficult to form an idea how large a number a million is; we may obtain some idea of the vastness of numbers, such as those in question, by ascertaining the time required to count them. If, then, you should count at the rate of two per second, continuing the work for eight hours a day, twenty-one years and five months would be spent in counting the number which expresses the bulk of the earth in comparison with that of the mountain. Perhaps I do not exaggerate the matter when I say, that the most accurate idea of a bulk so vast may be obtained by regarding the image which we frame to ourselves when we attempt to form an idea of infinite space. As we cannot grasp infinity this image must have a dim and misty outline; but it may be that it approaches more nearly than anything else to presenting an adequate idea of the actual size of the earth.

Having obtained some idea of the size of the earth let us proceed a step further, not in the way of doubling, but much faster. In so doing we next notice the distance of the earth from the moon, which is represented here on a much smaller scale than that employed in our first figure. The distance from the centre of the earth to the centre of the moon is about sixty radii, or thirty diameters of the earth. The magnificent appendage of Saturn compares very well in size with this, its diameter being about twenty times that of the earth. We pass from this to the diameter of the sun, which is about one hundred and twelve times that of the earth, and, of course, the surface is more than ten thousand times the surface of the earth. The scale we have at first adopted we should find to be inadequate to compare the earth with the sun. No ordinary apartment could contain the necessary illustration. The scale has therefore been reduced a thousand times, instead of being that of a hundred miles to a foot. This diagram is constituted on a scale of 100,000 miles to a foot. On it the earth has shrunk down to $\frac{94}{100}$ of an inch in diameter. This, then, [pointing to the figure,] is the relative size of the sun, 112 diameters of the earth being equal to the diameter of the sun. The liveliest imagination, however exercised, can form no adequate idea of the size of this magnificent luminary of the day. Its surface occupies an area greater than that of twice ten thousand oceans, each larger than the Pacific. And this surface is tossed into waves of intense brilliancy, beneath which the Himalayas would be buried and "melt with fervent heat;" and whether we regard him as issuing from the chambers of the east, he commences like a giant to run his course; or whether in unveiled meridian splendor, he almost seems to pause a moment to gaze upon a world rejoicing in his presence, or enwrapped in robes of surpassing magnificence he sinks to rest at night; under any and all these points of view, he is at once the fitting representative and chosen emblem of all that is good and beautiful.

From the size of the sun we proceed, in the next place, to that of the diameter of the earth's orbit. But I would observe, in passing, that the relative size of most of the planets is represented in this diagram. Thus, we have that of Mercury, Venus, Mars, Jupiter, Saturn, &c. The moon is represented by a ball, the size of a pea, at the place to which I now point, almost touching the sun. That represents the comparative size of the moon. The distance from the centre to the surface of the sun is one and two-thirds the distance of the moon from the earth, which itself is thirty diameters of the earth.



Upper line—1. Mercury. 2. Venus. 3. Earth. 4. Mars. 5. Moon. 6. Jupiter.
Lower line—7. Saturn and the three largest of his satellites. 8. Uranus, with the two large satellites. 9. Neptune, with his satellites.

The distance of the earth from the sun is about 12,000 diameters of the earth, or, if we proceed in the other way, multiplying the last unit, we shall find it to be 107 diameters of the sun, vast as is that body in extent. To travel this distance at the rate of thirty miles an hour, going on continually, would occupy three hundred and sixty two years and seven months; and merely to count it at at the rate already mentioned, that of two per second for eight hours of every day, would fully occupy four and a half years; and yet more than three times this distance the earth travels every year. To turn around but once in a year requires but a very slow angular motion. Imagine the hand of a dial-plate to turn around only once in a year, how large the dial-plate must be in order that we might see the motion at all; yet in completing its circuit the earth travels at the rate of nineteen miles per second; or, while I deliberately say to you, it moves, we are borne nineteen miles. This result cannot be in error by more than its two hundred and thirty-second part. When nearest to the sun, which is about the last of December, we travel about three-tenths of a mile per second faster than this, and about the first of July three-tenths of a mile slower. Even this excess of velocity is fearful. Who could think of being conveyed, mechanically, over the surface of the earth at the rate of three-tenths of a mile per second.

We are now compelled again to reduce our scale, and, instead of one, one hundred thousand miles to the foot, make use of one, two hundred millions of miles to a foot; and thus the sun, though magnificent in comparison with the earth, shrinks down and becomes no larger than the head of a pin. The orbit of the earth is represented by a white curve, to which the rod now points. Here we have the disturbed regions of the smaller planets, and there we have portions of that of Uranus and the most remote of the known planets, Neptune. This long and complete curve is the orbit of Halley's comet. The distance of the earth from the sun being now taken as our unit, the distance of Neptune will be thirty times that, or thirty times ninety-five million miles. Of course, to travel it at thirty miles per day continuously would occupy about ten thousand eight hundred and seventy-five years. Five distances of the earth from the sun from the place of Neptune would carry you to the end of the orbit of Halley's comet. The distance from this, again, to the nearest star is, we had almost said, a void of immense extent compared, with that which we have already had to do. It is scarcely worth while to regard miles at all in speaking of the distance of a star; the number becomes so large that we cannot grasp it. We may, however, obtain a speaking illustration of the enormous distance of the nearest of the fixed stars by ascertaining what must represent it in comparison with the small globe which I hold in my hand, which has a diameter of three inches. We must despair any more of illustrating distances so vast by any picture, however large. We are not about to deal in magnificent oriental fiction, but with ascertained facts. Let this globe represent the earth; then one hundred and seventeen thousand five hundred miles will represent the distance of the nearest fixed star.

It is useless, almost, to state how long it would take to count this distance—one hundred and seventeen thousand years would thus be occupied; and, if you thought of travelling it at all, you would find that it could not be accomplished in seventy-four millions of years. Having thus ascended where the nearest of the fixed stars are, let us, in the next place, ascertain what they are—whether planets or suns, or what? We all know with how much facility we see a bright light, though it may be very small. A candle or taper can be seen in foggy weather long before the building containing it; and even in the case of reflected light, the merest spicula of glass, how brightly it shines, and how readily it can be distinguished from the dark substances surrounding it. The light of a star must be very intense, for even when highly magnified by a telescope, so that its light is enfeebled, it yet shines brightly, though appearing nearly as a mere point; and if the light of it is reflected light why do we not see the body that illuminates the star? What is that body? It cannot be the sun, because, even at the very moderate distance of the planets, it becomes very feeble; if, then, we could suppose the light coming from the stars to be reflected light, we would be at a loss to discover the luminous body that shines upon them. But it has been ascertained, by careful experiment, that the light of the very brightest fixed star, Sirius or the Dog star, which, if the night were clear, my audience might see as they passed out of the lecture room—we say it has been ascertained that the actual light emitted by this star, (with quite a probable allowance for distance,) is full sixty-three times that of our sun; such is not always the case, as some stars do not give quite as much light as the sun. But it is true, notwithstanding, that if many of the stars are not suns they are more. It is unnecessary to contend about the name, for you must either call them suns or invent a name which shall mean a larger thing. When we make the statement that all the fixed stars are suns, are we aware of the sublimity involved in that statement? I undertook to show my audience, as well as I could, a short time ago, what constituted a single sun; but it is also true that the tiny ray which gladdens our eye, as shooting from some twinkling star, it trembles in the casement; it is true that this is a miniature sunbeam, and the faint and feeble glow of starlight, which sometimes, like a semi-transparent veil, covers the fair face of nature is woven of the scattered glory of thousands of suns. In the very fact that it is thus but faint and feeble we have the most speaking illustration of their awful distance; when we arrive at such a distance as this, it becomes quite evident that such a unit as the earth's distance from the sun is altogether too small. The distance of the earth from the sun must be taken some 500,000 times or more, in order to make a comparison, and we must therefore resort to something that will give us an adequate measuring unit. This may be found in the velocity of progression of the light which comes from the stars themselves. According to two different and independent results this velocity is about 192,000 miles per second; the distance of the earth from the sun will thus be represented by 8¼ minutes. It takes a very trifle more than that for light to pass from the sun to the earth. The light comes from α Centauri, the nearest of the fixed stars, in 3½ years; from 61 in the

Swan in 9½ years; from Arcturus in 26 years; from the Polar star in 48 years; and from Capella in 70¾ years; or Capella, the beautiful star in the Goat, is seen by the light which left it nearly three-quarters of a century ago, and has been travelling at the rate of one hundred and ninety-two thousand miles per second during the whole of that interval.

Let us next notice the combinations of the stars. It is a very curious circumstance, to say the least, that wherever we direct the telescope to the heavens we shall find the stars combined in pairs; and so frequently does this combination occur that we cannot regard it as the result of accidental position. It is true that when two stars are almost one behind the other they might not appear to be very far apart, though really at very different distances from us; but by careful measurement, in some cases, it has been ascertained that they are really, as well as apparently, near. In fact they are connected together, and revolve around each other, as is the case with the earth and sun. We have here represented two or three such double stars. There is one in Gemini; also one in Scorpio, one of the two stars being blue and the other yellow. The blue star does not show well, unless in a very good light; but the representation is therefore the more true to nature, the sky being itself so blue that it is more difficult to see such a star. Red and yellow stars are also of frequent occurrence; and in the case of the beautiful star in Andromeda, the two individual stars are, the one rose color, and the other green; the colors of the double stars are complementary, or such as, when combined together, form a white light, the star appearing white and single to the bare eye. We can perceive something extremely elegant in the arrangement if planets should circulate around these red or green suns; then a red or a green light would be seen as long as it alone were visible; but a white light, when both suns were above the horizon, poetic fancy never sketched anything more sublimely elegant than this combination of tinted suns, these parti-colored gems which sparkle in the diadem which surrounds the dark brow of night.

We come now to a more extensive combination of stars. We cannot look at the sky with any sort of attention even once without perceiving an amazing collection of the stars in the direction of one single great band or girdle. This constitutes what is called the milky way. Throughout one half of its circuit it is divided into at least two parts. Most of the stars in heaven are situated in one part, and in the other portions of the sky the stars are comparatively sparse. The attempt was made by Sir William Herschel to ascertain the relative distance of the fixed stars before the actual distance of any of them was determined. Some idea may be formed of this by ascertaining how many more can be seen in one direction rather than another, as we might judge of the extent of a crowded audience in one direction rather than in another, by ascertaining how many could be seen in the one and in the other direction. A better method of sounding the heavens, as it was called, consisted in using successively telescopes of greater and greater space-penetrating power. The space-penetrating power may be ascertained by comparing the brightness of the beam of light emitted by a telescope with that seen by the bare eye. The science of optics will readily enable us to ascertain that. Then, if we bear in mind that light at twice the distance is four times as feeble, &c., it will be seen that a telescope which would increase the intensity of light to four times that of the light seen by the bare eye might enable us to see twice as far, &c.

By making use of a telescope of a greater and greater space-penetrating power Sir William Herschel, in investigating portions of the milky way, continued to see new stars up to the twenty-eighth order of distance. The borders of the milky way are supposed to be at the nine hundredth order of distance. If this be so the time of the arrival of light from the borders of the milky way must not be measured by a single year, but by centuries; in fact, so far as we may rely on the conclusions of Dr. Mädler, the distance of the centre of this our group from us, as thus estimated, is 537 years. He concludes, moreover, that the stars in the milky way and our sun with them revolve at the rate of once in about eighteen million years. Whether we regard this as accurately ascertained or not, very certain it is that the sun and all planets are moving in the regions of space.

The researches of Herschel, Argelander, Struve, and others, have all contributed to point out very accurately a single spot in the heavens, towards which we are incessantly travelling by a motion very slow when we consider the magnitude of the orbit, the distance travelled being about four-fifths of the diameter of the earth's orbit every year. When we scrutinize the outskirts of the milky way and attempt to see beyond it, we find what seems to be an entirely detached combination of stars. If what we see in them be stars only about the size of those in the milky way we might readily conclude that they were at no greater distance; but it may be that what are apparently single stars are themselves combinations. These groups are called clusters. This is the representation of a coarse cluster. We find others much more closely arranged, as in the figure, where they are represented by a white, powdery substance. The stars near the centre are not to be counted by hundreds. When clusters become so remote that you cannot make out the individual stars you may still discern clusters of a granular shape and appearance in their structure; or that they are made up of a "star dust," an expression sublime from its very simplicity. In this *quasi* crystalline mass the molecules are double stars, the ultimate particles are suns, and the atoms, if any, are planets. If the cluster be a globular one it may also be true that all the stars, the outer ones only excepted, are revolving around the centre in the self-same time. Beyond these still are the nebulæ, some of which the most powerful telescopes have failed to resolve; that is, have failed to show that they are made up of stars. In other cases they are found to be made up of stars, and resolvable. We cannot positively assert that there is no cloudy-looking substance existing in the heavens which is not made up in this way; some appearances, surrounding stars, cannot as yet be resolved. Other whole nebulæ cannot yet be resolved by telescopes of large space-penetrating power. Some idea of the distance of a nebula not resolvable may be obtained by ascertaining the space-penetrating power which will cause that nebula to present the appearance put on by another before power sufficient was applied to resolve it; and thus, comparing the powers employed in the two cases, we arrive at a distance so great as that a comparison by means of the velocity of light itself becomes almost inadequate. Even light, (which could we thus curb its motion would girdle the earth in a twinkling,) which rebounds to us from the moon in a second and a quarter, and which, springing from its home in the sun, visits the most distant of the known planets and returns in less than a day, even this swiftly flying messenger, borne upon the very wings of the morning, can only reach us from those remote bounds after the lapse of centuries. Admitting all this to be true, then, although an accurate result is here no longer possible, there is a reasonable probability that the sublime idea presented by Huygens is itself a fact; that some of these bodies are so remote that the light by which we see them must have left them before the creation of man. There is something almost awful in the thought of our having arrived at a reasonable probability that we see these objects as they were before the race of man had being; to behold, as it were, the record of eternity past, unrolled to be read in time. We are compelled to view them from such a distance looking towards them; but in imagination we may place ourselves at the other extremity of the line thus defined, then the light from the earth and solar system would have been as long in reaching that position as the light from the other way has been in reaching us; and if we had the optical power and could look down upon the earth, then the mastodon, which is now a mere fossil in our cabinets, would be seen as the living, moving, breathing mastodon. The fact, in more general terms, is this: There are portions of the universe through which the visible record of very much that is great and awful that has been transacted here is still travelling through the regions of space, and might be discerned by a being provided with sufficient optical power. I think it necessary to notice but one thing more. The fixed stars are not merely like the sun in the intensity of their light, but, it would also seem, in revolving around their axes. We ascertain that the sun revolves around its axis by noticing the spots on its surface. When there are many spots towards us the light of the sun must be enfeebled, sometimes even sensibly so. There are variable stars that periodically become dim and then again resume their former brightness. The natural solution of this fact is that these stars are like the sun, not merely in their light, but also in the way in which that light is produced. Perhaps upon their surface there are spots which, when turned towards us, cause their light to become dim, and when away from us there is an increase of brightness. There are stars also which may be called temporary stars; for after appearing in the heavens a brief period they become seemingly very small or they disappear altogether, a fact which can hardly well be accounted for, except by the supposition that there has been a real physical change in the body itself. In undergoing these changes, changes in color have also been manifest, so great that we may suppose that there has been a combustion or partial destruction of the body in question. The star seen by Anshelm in 1670 was of the third magnitude, passed through great fluctuations of light for two years, and then became either excessively small or quite invisible. There are, moreover, lost stars, whose places are now vacant, though some of them have been recently observed. When we look at these strange fluctuations we may suppose that something like combustion has taken place, or that, for the time being, its power of giving light has been suspended. In reviewing these facts it appears difficult not to conclude that here was a world whose destiny was, for the time being, completed, and the fitful glare of whose gorgeous funeral pile shooting across almost the vast distance which separates us came with undiminished velocity to tell us the tale that once it was. However this may be, we certainly know that He who, "by His strength, setteth fast the mountains, being girded with power," hath also "of old laid the foundation of the earth, and the heavens are the work of his hands. They shall perish but He shall endure; yea, all of them shall wax old, like a garment, and as a vesture shall He change them, and they shall be changed; but He is the same and his years shall have no end;" for "He inhabiteth eternity and the praises thereof."

METEOROLOGY.

COMMUNICATION FROM A. FENDLER.

Colonia Tovar, Venezuela, South America,
August 5, 1856.

Dear Sir: I sailed from Philadelphia on the 5th of May, and arrived at Laguayra three weeks after. Colonia Tovar I reached on the 7th of June, and commenced my meteorological observations on the 10th. The barometer and the dry and wet bulb thermometers, which by your kindness I received from Mr. Green, I have brought home safe and in good order.

Accompanying this I send you two registers of meteorological observations of the month of June and July, 1856; and here I have to make the following remarks:

1. As I am very much interested in the results of the observations, I need not say that I pay the most particular care and attention to the condition of the instruments, as well as to the nicety in taking observations and in noting them down.

2. The column under the head of "Barometer height reduced to freezing point," I could not fill up for want of the necessary tables.

3. By comparing my old thermometer, which is one of the more common kinds, marked "T. Barry, London," with the Smithsonian dry bulb thermometer, I found that the former is from one and a half to five degrees too high; so that I was obliged to use the dry bulb of the psychrometer also as thermometer in the open air. The wet bulb was therefore exposed to the open air also. According to the first principles of evaporation it is, however, evident that the more rapid the motion of air is which touches the wet bulb the more energetic will be the evaporation of the water contained in the wet linen, and the lower will the mercury sink. This I found to be confirmed by every breeze, and even the lightest breath of wind that happened to strike the wet bulb at the time I took observations. I therefore regard all observations with the psychrometer, that are not taken in a calm atmosphere, or in an atmosphere the velocity of which at the time of observation is known, as of little value.

As I had no other standard thermometer besides the dry and wet bulb, I can give the psychrometrical observations only, with the remark that they are worth just as much as all other such observations made in the open air without regard to the currents of the atmosphere. In future I shall try to shelter the wet bulb against the influence of wind at the time of observation.

4. As I have no rain gage I can only put down the time of beginning and ending of rain.

5. With regard to clouds I may say, that the higher clouds are mostly hidden from view by the masses of lower clouds, so that the course of the former can very seldom be ascertained in the rainy season, and, when seen, there are several strata, one above the other. Instead of the higher clouds, I have carefully noticed and put down

the course of the *lower* clouds, under the head of "winds." The motion of these lower clouds may justly be said to indicate the real course of the wind; for in such a mountainous country as this the atmosphere at the bottom of the kettle-shaped valley of the colony, is set in motion by a great number of local causes, and this motion is changed and modified by the many ravines and watercourses, and by every slope of the irregularly shaped mountains. The colony is surrounded by mountain ridges, crowned by several peaks. These barriers open only in one direction, towards the east, where they form an outlet for the river Tuy, which has its sources in the neighboring fields and adjacent forests. In such a region as this it is next to impossible to note, even in *one* narrow district, all the different little breaths and jerks of wind, which frequently change every moment.

As to the motion of the lower clouds, they frequently showed a velocity which I estimated at about 7 miles per hour; and as there is no number corresponding to this velocity in the tables, I introduced the number "2½," which means 7 miles per hour.

Fog is a considerable item in this region in the rainy season, and I have accordingly noted it down under the head of "kinds of clouds."

Thunder and lightning are very rare here, and when they occur they make so little show that, with regard to force, they may be compared to those of the United States as the zephyr to a strong gale. In the register I have noted them down in the margin.

Tornadoes I have never seen in the colony, not even a gale of wind, within the two and a half years that I have been living here. Hail storms are unknown in this part of the country.

Of the 48 observations recorded in July, at 7 a. m. and 2 p. m., on the course of the lower clouds, 10 are E., 15 E.SE., and 15 SE., which shows the prevailing winds to be between E. and SE. Their mean velocity is a fraction over four miles per hour.

Of rain, fog, mist, and clouds, we had more than a sufficiency, the mean cloudiness being 6.4.

The weather has been so unfavorable since my return from the States that I have not yet measured any of the neighboring heights and passes by barometer.

The thermometer in the open air shows a mean temperature of 58.3 for the month of July, a rather low temperature for the height of 6,500 feet in latitude 10° 26′. The minimum of the month was 54°, the maximum 69°.

I also inclose the half-hourly and hourly barometrical observations for seven days, made in order to ascertain the hour of maximum and minimum of the daily periodical variations. And here I found that these variations within the tropics, at least at the colony, are not so regular as we sometimes find stated in books. As, for instance, the following: "Such is the regularity with which these motions are effected within the equatorial zones that they might there serve to give the true time of the day."—(Nicollet, Essay on Meteor. Observ., page 7.) For we find maximums at 9½ a. m., 10, 11, 12 m., and minimums at 4 p. m., 4½, 5, 5½, 6, 6½, 7, and all this within the short period of seven days. This irregularity is the more remarkable, as the colony is a place where none of the extremes of heat and cold, or of gales, hurricanes, and thunder storms are felt, that could disturb the equilibrium of the atmosphere.

Besides the two registers and the hourly observations, I have copied for you and inclosed the thermometrical observations for 12 months in 1854 and 1855. These have been taken with my old thermometer, which proves to be from 1½ to 5 degrees too high, as compared with the Smithsonian thermometer. Although this would make the mean temperature of the year about 3 degrees too high, we are still enabled to make some comparisons between the different months, which show that from August the mean monthly temperature is gradually sinking till January, which is the coldest month. After January it rises again till May, and then sinks till July. This seems to indicate that the rising and falling of the mean temperature keeps equal pace with the declination of the sun. If we now compare the means of the different hours of the day of each month, we find that the highest temperature of the day is not at 2 or 3 p. m., as in the United States, but at 12 o'clock at noon, and that the temperature at 3 p. m. is but a fraction greater than that at 9 a. m. In *five* months of the year it is nearly or quite the same with that at 9 a. m., viz: from November till March, inclusive; during the other part of the year, from May till September, inclusive, the mean temperature is higher at 3 p. m. than at 9 a. m., with the exception of October and April, where the temperature at 3 is even lower than that at 9; and these are the two months which follow immediately after the equinoxes. Another curious fact is the sudden rise of mean temperature from July to August. In Santa Fé de Bogota, in 4° 35′ north latitude, July is said to be even the coldest month of the year.

Some other facts could, no doubt, be drawn from this register by comparison, if its observations were founded upon a standard thermometer.

On the last page of this register of Colonia Tovar you will find some observations, taken with the same thermometer, of "Barry," during my stay at Chagres, on the Isthmus of Panama.

During my absence from the colony last winter some persons here, who can be relied upon, have seen white frost one morning. This is of extremely rare occurrence, but anyhow very remarkable for the latitude of 10° 26′, even at the height of 6,500 feet.

The characteristics of this region are its clouded sky, its equable temperature, and its great amount of moisture. It is the "happy region of the *ferns*," where these interesting plants find their most suitable climate and grow in the greatest profusion. Here it is where the stately tree-fern sometimes is seen to reach a height of 40 feet.

The produce most profitable to raise in the colony are potatoes, rye, and oats. The apple tree grows side by side with the banana. The strawberry is found in the greatest abundance, spontaneously growing about the fields. Indian corn does not come to maturity here, while I have seen it raised and matured in Santa Fé, New Mexico, which is at least 700 feet higher than the colony, and besides this is near 36° north latitude. But in New Mexico they have a cloudless sky nearly the whole year round and an extremely dry atmosphere, while the colonists of Tovar are not much molested from the beginning of May to the beginning of January by the rays of the sun.

The valley in which Colonia Tovar is situated was, so late as December, 1841, a perfect wilderness, covered with primitive forest. Not even the existence of this valley was known fifteen years ago, neither to the government nor to its owner. although it is only thirty-five miles west of Caracas, the capital of Venezuela, and in a straight line cannot be more than twelve miles from the sea. And when an attempt was made to explore this region not even a guide could be found for the small exploring party of fifteen men, headed by Colonel Codazzi, a skillful officer and compiler of the new map of Venezuela. When this party at last succeeded in crossing this region and reaching the sea-shore, they thought they had achieved a most extraordinary thing, (to cross a distance of twelve miles in six days;) and after they had returned to their homes none of them had a desire to do the feat over again. This was a party of natives. And when, at a later period, after the establishment of the colony, another skillful engineer found, with a party of colonists, his way to the opposite port of the sea-shore, the party did not venture to go back the same route, but rather chose the way by sea to Laguayra, from there to Caracas and back to the colony, a very circuitous route certainly. Such is the nature of this mountain region, with its precipices, waterfalls, deep ravines, and its dense, almost impenetrable primeval forests.

In collecting botanical specimens, I have penetrated, without a companion, the wilderness around in different directions, also that on the other side of the principal mountain range towards the sea, and can testify to the difficulties and hardships which are met with in exploring such a country. On excursions of this kind the most needful thing besides a compass is a short sabre, called "machetta," which I have to use continually in cutting through the lianos, the erect and climbing canes, the under shrub, which is all matted and intermingled in a thousand different ways into a dense mass of vegetation.

In these woods, where the rays of the sun never touch the ground, there it is where moisture and a cool temperature reign forever. The trunk of every tree and its branches are covered with Ferns, Lycopodiaceæ, Mosses, Hepaticæ, Lichens, Orchids, Bromeliads, Araceæ and besides Piperacæ with many exogenous plants too numerous to mention.

The soil in these forests is one entire mass of slender rootlets most completely intermingled and interwoven, more than a foot in thickness, the interstices filled with a brown but imperfectly decomposed vegetable mould, which is kept in its place by the network of the rootlets. This stratum is covered with mosses and remnants of leaves, so that on the mountain ridges not only the ground, but also the trunks and branches of the trees, act like a thick layer of sponges in retaining the water that either pours down in form of rain or settles more slowly in the form of mist and clouds. This water is allowed to trickle and sink down but very gradually, and is, therefore, a never-failing source from which are constantly fed the many little rivulets that hurry down the steep declivities into their common receptacle, the narrow chasm of the river Tuy, which, in one continued row of cascades, rushes thundering down SE. and S. until after a run of twenty miles, turning suddenly to the east, it finds a more level country.

In the depth of such a mass of vegetation, when man is by himself, a feeling of loneliness takes the ascendency over every other emotion; no animal is seen, and but seldom the voice of a bird heard. While on the sea-side of the mountains I was only made twice aware of the vicinity of a bird in two days. In the neighborhood of farms and habitations of men a greater variety of birds are seen and heard, and sometimes the grunting or howling of monkeys and the deafening cry of parrots.

The dry season commences here generally soon after New Year's day and lasts till the end of April. The remainder of the year is taken up by the rainy season. This is *generally* so, for there are many exceptions, and our notions about the great regularity and sharply defined seasons of the tropics, which we have received from books, are sometimes materially upset and corrected by experience. When I first came to the colony, in March, 1854, we had a dry season in its usual way. The rainy season then commenced on the 23d of April, but it did not end with the latter part of December, as is usually the case; it lasted till the end of January, and commenced again with the first of March, and then kept uniformly on till the end of December, 1855. The dry season was, therefore, only of one month's duration instead of four. The last dry season has been, on the contrary, unusually long, and lasted till the latter part of May.

I have often thought that the climate of North America may stand in some kind of relation to the climate of this country. It was on the 24th of December, 1853, when I left New York, to sail for Laguayra. We were hardly out of sight of land when a furious NW. gale, a real hurricane, (which is still in fresh remembrance with some of the captains I have lately seen,) during a period of three days threatened our destruction. After my arrival in Venezuela I was told that about Christmas, 1853, one of the most fearful gales from the north was felt at Laguayra.* Another question is, whether the late remarkably dry and cold winter of the United States and the unusually long *dry season* of Venezuela, as also the remarkable appearance of white frost in the colony, are not connected in some way or other.

As to the trade winds, I found on my trip from Philadelphia to Laguayra that *within the tropics* we had no E.NE. wind, which is thought to be the regular trade winds of those regions. After crossing latitude 23½°, in longitude 68½°, we were becalmed for one day, and soon after got a fresh breeze from the south, which we kept all the way to longitude 63°. By tacking we got to latitude 22°, longitude 63½°. From thence we had the wind all the time from S.SE, which we kept to latitude 11½° the day before we reached Laguayra. Capt. Wilkins, who has been in this southern trade for eighteen years, assured me that within the last eight years he never could depend much upon the trade winds. He finds that between latitude 23° and 18° the south wind frequently keeps on blowing very brisk for eight days in succession.

On the way from the colony to Caracas, along the high ridge of the principal mountain chain, which stretches E. and W., parallel

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* See page 188.

with the coast, at an elevation of from 7,000 to 8,000 feet, we travel about six miles over a region bare of forest, where we nearly at all times find a very strong breeze from the south, rushing up the declivity and over the ridge, hurries off to the north towards the ocean. The ocean can be plainly seen from this elevation. That this great current of air does not sink down along the northern slope, but, on the contrary, is somewhat projected upwards by the shape of the mountain, can be seen by the course of the condensed vapors which, in the form of fog and mist, are driven along. May not this current of air sink gradually lower and lower until it reaches about latitude 18°, where it strikes the sea? I have found this south wind at sea always much colder than any of the other winds in these latitudes.

I wish I was in possession of some good work on the winds and the currents of the ocean.

Vegetation at the colony is uninterrupted throughout the whole year, except in a small class of plants which cannot thrive without a great deal of moisture. Even in the dry season, when the lower regions are parched up with heat, if there is any moisture at all in the atmosphere capable of being condensed, the mountainous districts, especially those covered with forests, are sure to get some of it. Trees here are evergreens; they keep their branches and twigs clothed with leaves until death. Day after day, and month after month, the surrounding forest presents the same unchanged view in its deep green garment. Single leaves fall here and there one by one; and new leaves appear as slowly and gradually as the old ones die away—unnoticed and unobserved. The pleasing and hope-inspiring spectacle of returning spring, in the sudden appearance of the new and tender foliage, as seen in the temperate regions, is here unknown.

Colonia Tovar, *January* 8, 1857.

Dear Sir: Under date of August 5 I sent you a letter and some registers of meteorological observations up to the 31st of July, which, I hope, you will have received long before this.

Inclosed in a separate envelope I send you now four meteorological registers for the months of August, September, October and November. I would have sent one for December also, but I have no more blanks.

Besides these registers, I have inclosed diagrams* on four separate sheets, one table of half-hourly barometrical observations, and one about the course of the clouds.

The barometrical observations in the registers have their full value only up to October 30, at 2 p. m; for when I looked at the height of the mercury one hour afterwards I found it more than one inch below its usual level. This was so extraordinary that I expected something wrong with the instrument. As soon as I touched it the whole column of mercury sank rapidly down. In unscrewing the brass cup which contains the little leather bag I found the former half filled with mercury. On the surface of the bag, a little below

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* The diagrams and curves could not be given in this report.

where it is tied and where it was in contact with the surrounding brass tube, I found a spot of one-eighth of an inch diameter, as if corroded by some kind of acid In the centre of this spot was a hole one-sixteenth inch diameter. The corroded rim around the hole was very smooth and viscid, similar to partly dissolved india rubber. After sewing up the whole and giving it a coat of glue, to prevent the mercury from leaking out, I filled the glass tube again as cautiously as possible, to prevent the formation of air bubbles. In this I succeeded pretty well, and, with the exception of one minute portion of air, which escaped into the vacuum, the latter seemed to be complete. The mercury then showed but a small difference ($\frac{2}{100}$ to $\frac{3}{100}$ parts of an inch lower) compared with its former state. Hoping to succeed still better the second time, I tried my hand once more at it, but did not succeed so well this time, as some moisture had settled in the glass tube. The mercury is now at least one-tenth of an inch lower than it ought to be.

The barometrical observations made with this instrument since the 1st November, 1856, can, of course, not be considered as normal, and can be used only with a view to institute comparisons among themselves.

I feel this defect the more acutely as I hoped to measure a number of mountains and other localities, and to complete a twelve months' register, to find out the mean height of the barometrical column for the different months of the year. Up to the 1st November I found the mean height greatest in July. Hitherto I have measured only the pass over the mountains on the road from the colony to Victoria. On this spot the barometer was 23.334 at 7*h.* 30*m.* a. m., September 9, with the thermometer at 61°.

In the diagrams on sheet No. 1, I have laid down, in a graphical manner, the hourly and half-hourly rise and fall of the barometer from 6 a. m. till 9 p. m. for 12 days. We can see here, at once, the greater amplitude of the daily periodical variations in October compared with that of June; also that the hours of maximum of the different days in October are not far apart from each other and near to 10½ a. m., and the hours of minimum not far from 4 p. m.; while, on the contrary, in June, the hours of maximum, as well as those of minimum, are much more scattered, and therefore not so regular.

On sheet No. 2 are the half-hourly observations laid down for 24 hours, from 4 a. m., October 7, till 4 a. m. next day. Here we observe that, in the morning, the maximum, as well as the minimum, is somewhat higher than the maximum and the minimum in the evening. This seems to be a general rule with all the daily periodical variations.

On sheet No. 3 the daily mean barometer heights from June 10 to October 30 are put down and connected by straight lines to denote the course of the barometer from day to day throughout the several months. A kind of periodical rising and sinking is observable here, alternately taking place in periods of 4 or 5 days, at least for June, July, August and September.

On sheet No. 4 is to be found a comparison of the mean monthly barometer heights of Colonia Tovar with those of St. Louis, Mo., made by Dr. G. Englemann in 1851, which shows the remarkably small monthly variation in the colony against the extreme range of atmospheric pressure at St. Louis.

In all these illustrations the barometer height has not been reduced to the freezing point for want of the necessary tables; but, as the difference of temperature connected with these observations does not range much over 8 degrees F., the results may be considered not far from their true value.

Table No. 5 shows that the most prevailing currents of air at an elevation of about 7,000 or 8,000 feet above the level of the sea, in the months of June, July, August, September and October, are here from E., E.SE., SE., S.SE., and S., but especially from SE.

Table No. 6 contains half-hourly barometrical observations for 17 days, taken down at three different periods of the year. From this and from sheet No 1 we see that the amplitude of the daily periodical variations is not a constant quantity in one and the same place, but changes with the different periods of the year; as also does the hour of maximums and minimums. To find out, by continued observation, the mean amount of amplitude and the precise time of the maximums and minimums for each month of the year seemed to me desiderata of much interest to meteorology.

With a view to investigate this matter I have made observations accordingly. The first set I made from 18th to 24th June; the second, from 1st to 7th October; the third, from 10th to 12th November, and the fourth, from 22d to 28th December. These observations give the mean amplitude for the latter part of June 0.058; for the first part of October, 0.079; for November, 0.060, and for the end of December, 0.043.

By a peculiar view of the cause of periodical variations, and by the aid of an artificial globe, I had calculated as early as last September that the amplitude at Colonia Tovar ought to be greatest about the 16th May and 26th September, and least on the 21st January. The above-mentioned numbers of amplitude for October, November, and December coincide with my calculations so far, and it remains to be seen how they will do for the remaining portion of the year.

With regard to temperature I will only say that the mean of the three months of June, July, and August, (that is, of the *meteorological* summer,) is 58.9; the mean of September, October, and November (the meteorological autumn) is 58.9, or exactly the same. The mean temperature of December is 56.6. During 204 days (from June 10 to December 31) the sky was only once free of clouds at 2 p. m., 18 times free at 7 a. m., and 41 times at 9 p. m. Of these 204 days 143 were rainy days.

On the 5th of January I made a botanical excursion to one of the highest mountains of this region, about twelve miles to the east of the colony. The mountain, according to my estimation, may be about 7,800 feet above the level of the sea, and is a kind of central point or knot, from which several rivers, flowing in different directions, take their origin. This mountain is covered by a dense forest, with the exception of a level spot of about half a mile in length and a quarter of a mile in width, which forms a kind of shallow basin, only sparingly covered by a thin coat of short grass and other small plants. These plants I found the next morning at six o'clock white and stiffened with heavy hoar frost, which augmented and lasted till the rays of the sun fell upon it. The stiffened leaves of the herbs broke under the least pressure, like thin layers of ice. The thermometer was 37° at *6h. 30m.* From all the information I could gather, hoar frost seems to be common in this spot throughout the months of January and February. The wind blew during the night from northeast, and was very piercing.

Notwithstanding this low temperature, the forests of the neighboring heights surrounding this basin are clothed in perpetual green, and the stately wax palm, with its straight and polished trunk of 70 or 80 feet, (by actual measurement,) rears, uninjured, its slender form and its leaf adorned head high above all other trees.

In this excursion I had also an opportunity to form some idea of the vast extent of destruction which was carried into the mountain forest last February by a lucifer match and a thoughtless boy. Over whole tracts of this primeval forest the trees lie dead one over the other, as if uprooted by a whirlwind, scarcely showing any marks of fire on their trunks. I was struck more than ever with the easy manner in which fire can destroy these dense and humid forests, which, by their shade, preserve a cool and moist atmosphere, and thereby cause the vapors of the adjacent strata of air to condense into clouds, that rest upon them, with little intermission, during nine months in the year. In these high regions the temperature is so low and equable that the vegetable matter which is gathered on the ground between the trees is decomposed very incompletely and very slowly. It forms a stratum of loose half-decomposed matter, in some places two to three feet thick, which, in the rainy season, like an immense layer of sponge filled with water, feeds and supplies the rivulets and rivers *gradually.* In the midst of the dry season this layer becomes sometimes dry enough to burn, when kindled, with but little flame, and more like tinder, spreading in all directions.

In this way the fire extends until met by a river or a road, or some other obstacle. The sub-soil which underlies the spongy stratum on these mountains is also very shallow and resting on hard rocks. The roots of the trees therefore, do not go down very deep, but extend more in a horizontal direction. When the spongy layer, with the smaller roots, are burnt, the trees lose their hold entirely and fall, one over the other, in all directions. They die less from being burnt than from being uprooted. Many different kinds of tall reeds soon take the place of the trees. In a few years these reeds exclude everything else. The fertile mould that may perhaps have escaped destruction by fire is by and by carried down the declivities by the frequent rains. The region, no longer shaded by high trees, becomes dry. Subsequent conflagrations of adjacent savannahs, which are intentionally set on fire to procure a new growth of young grass, take hold of the reeds of the ruined forest, until, by the repeated attacks of these fires, the roots of the reeds can stand it no longer, and the smaller grasses, interspersed with a few other plants, take their places.

On the road from the colony to Caracas we pass through a region in which this process is going on; the reeds giving gradually way to the smaller grasses. Here the great number of half burnt yet standing trunks of the wax palm tell plainly enough that there existed not long ago a dense and humid forest, in which they luxuriated in all their beauty, for these palms are never found, in their natural state, growing in any other but humid forests. Here they stand isolated in the midst of reeds. Most of them have died already, but many linger yet in a dying condition, until their last green leaf has turned brown, and then they stand like tall and slender pillars, the mournful remnants of a once stately forest.

This is the same extensive region of which I spoke in my first letter, where a strong southern breeze, sometimes amounting to a gale, sweeps constantly over the mountain ridge towards the sea. I have traversed this region since at four different times, in the months of August and September, and found every time the same southern wind blowing there, only somewhat more violent.

Before closing this letter I wish to add to the statement made in my first letter* about the gale of December 24, 1853, that my informant here, in saying that the gale was felt at Laguayra, forgot to mention that it was felt only in the unprecedented agitation of the *ocean*, but *not* in the *atmosphere*. This agitation of the sea is observed every time a violent gale from the north has been blowing in the higher latitudes, not the least breeze from the north being felt at the same time at Laguayra, although it is an open roadstead, not in the least sheltered against the north winds. This agitation of the sea, when the air was perfectly calm, I have seen myself several times at Laguayra; but at the time above mentioned the sea was so unusually high that long, enormous, foam-crested waves rolled up to the very parapet of the custom-house, a phenomenon scarcely ever seen before.

During my stay in Victoria, a town twenty miles south of the colony, situate in a valley about 1,700 feet above the level of the sea, I made the following observations as to the temperature of that place:

December	21	22	23	24	25	26	27	28	29
6 a. m	70½	69	69	69	68	68	68	69	66
1 p. m	86	86	75	75	81½	83	84	84	84
9 p. m	74	72	72½	72	71	72	72	74	......

The dry season has already set in, and my time is so much taken up by botanical labors, on which my sustenance depends, that I am unable to give at present a more full and extended account of the climate and other atmospherical phenomena of this region.

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* See page 183.

No. 1.—*Register of Meteorological Observations.*

Date.	Barometer.*						Thermometer in open air.				Psychrometer.			
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.		
1856.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	*Mean*		7 A. M.	2 P. M.	9 P. M.
Dec'r 1	23.794	23 804	23.800	56°	62°	58°	55°	60°	54°	56.3	The same as thermometer in open air.	53	58	53
2	.790	.792	.798	56	61	58	56	58	54	56.0		54	57	52
3	.780	.803	.808	53	64	58	52	65	54	57.0		48	61	53
4	.810	.800	.810	57	62	58	56	64	56	58.7		55	61	55
5	.824	.814	.820	51	61	60	57	60	57	58.0		56	59	56
6	.802	.810	.814	54	61	59	51	60	57	56.0		46	58	55
7	.800	.808	.804	54	64	54	52	62	52	55.3		47	56	48
8	.804	.805	.800	56	62	59	54	61	60	58.3		53	60	58
9	.814	.806	.818	59	63	60	60	65	57	60.7		58	61	56
10	.812	.810	.788	58	61	58	57	63	56	58.7		56	62	55
11	.786	.776	.798	58	61	58	57	60	57	58.0		56	59	56
12	.786	.782	.770	58	61	54	57	64	52	57.7		55	61	46
13	.808	.814	.808	52	63	54	53	64	57	58.0		49	59	55
14	.782	.790	.796	54	61	56	54	60	54	56 0		52	59	51
15	.784	.802	.812	54	61	58	52	62	56	56.7		51	61	54
16	.800	.804	.810	53	60	56	52	59	53	54.7		51	58	52
17	.790	.796	.796	53	61	56	54	60	51	55.0		48	58	49
18	.772	.777	.786	54	60	55	53	60½	53	55.5		49	58	46
19	.762	.776	.780	54	61	57	54	62	52	56.0		48	56	50
20	.762	.766	.792	55	62	56	52	60	53	55.0		51	57	53
21	.764	.782	.800	48	63	56	49	62	51	54.0		41	58	48
22	.790	.788	.792	56	64	57	55	67	52	58.0		54	61	50
23	.772	.774	.760	53	62	52	51	65	53	56.3		50	60	52
24	.788	.790	.752	52	63	54	51	61	51	54.3		50	58	48
25	.752	.780	.800	53	65	57	52	63	55	56.7		41	57	53
26	.818	.812	.816	58	63	61	56	61	56	57.7		54½	60	55
27	.808	.802	.796	58	63	60	56	60	57	57.7		55	59	55
28	.774	.784	.772	56	60	56	55	60	52	55.7		52	55	51
29	.762	.778	.784	51	61	55	50	60	50	53.3		45	58	48
30	.794	.793	.816	54	61	59	52	61	54	55.7		51	57	53
31	.808	.808	.820	55	64	57	54	65	55	58.0		52	60	54½
Total....	24492	24626	24716	....	....	....	1669	1914	1681	17550	....	1581.5	1822	1620.5
Mean	23.790	23.794	23.797	....	....	....	53.8	61.8	54.2	56.6	....	51.0	58.8	52.3
		23.794						56.6					54.0	

* .200 too low; barometer defective.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Am'nt.	Course.	Veloc'y	Kinds.	Am'nt.	Course.	Veloc'y	Kinds.	Am'nt.	Course.	Veloc'y	Kinds.	Direc'n	Force.	Direc'n.	Force.	Direc'n.	Force.
1856. Dec. 1	2.30 p. m.	3.10 p. m.	1	E	2½		10	E	3		0									
2	1 p. m. 4 p. m.	2.15 p. m. 4.20 p. m.	5	N	2		10	SE	2½		0									
3			1				8				0									
4	11.50 a. m.	4.5 p. m	7	SE	1		7	E	2½		5	E	2							
5	12.25 p. m.	6.10 p. m.	8	NE. & SE	1		10				5	E	2½							
6	12.50 p. m.	2.30 p. m.	0				7	E	2½		10	E	2							
7			0				2	SE	2½		0									
8	1 p. m.	2.15 p. m.	1	SE	2		8	SE	3		0									
9	4.30 p. m.	6.20 p. m.	7	E	2		9	E.SE	2½		2	E	2							
10	12.10 p. m.	2.15 p. m.	10				7	SE	2½		10	E								
11	8.30 a. m.		10	E	2		10	E	3		7	SE	2½							
12	11.30 a. m.	12.30 p. m.	9	E	2½		10	E	2		5									
13			10	E	2		9	E	2		0									
14	8.45 a. m.	6.20 p. m.	0				10	E	2½		0									
15	2.10 a. m.	4.30 p. m.	3	E.SE	2½		10	E	2		3									
16	1 p. m.	4.10 p. m.	9	NE			10	E			0									
17	1.30 p. m.	3 p. m.	0				10	E.SE	2		0				N	4				
18	12 m. 5 p. m.	2.15 p. m. 6.40 p. m.	2	E.NE	2		10	E.NE	2	Mist	0									
19			2	N	4		5	E	2½		0									
20	5.30 p. m.	5.50 p. m.	9	N	3		7	N & E.SE	2		9	N	4							
21			0				9	SE	2½		0									
22	1.15 p. m.	5 p. m.	10	NE	2	Mist	9	E.SE	3		0									
23	2.30 p. m.	3 p. m.	0				9	SW	3		0								W	2
24			0				8	SE	2½		0								W	2
25			0				5	SE	2		0								W	2½
26	8.30 a. m. 10.30 a. m. 2 p. m.	9.15 a. m. 11 a. m. 8 p. m.	10	E.SE	2		10	NE			0									
27	1.30 p. m.	3.15 p. m.	9	N	3		10	E	3		2								W	2
28			2	NW	4		7	N	3		1								W	2
29			1				10	E	3		1				W	1				
30	10 a. m. 2.10 p. m.	11.15 a. m. 3 p. m.	8	NE	3		10	NE	2½		7									
31			2				6	E.SE	2½		4	NW	4							
Total			136				262				71									
Mean			4.4				8.5				2.3									

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.*						Thermometer in open air.				Psychrometer.				Low temperatures.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
1857.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	*Mean.*		7 A. M.	2 P. M.	9 P. M.	
Jan. 1	23.814	23.814	23.824	55°	63°	59°	54°	64°	55°	57.7	The same as thermometer in open air.	52	60	54	
2	.808	.800	.800	56	63	56	55	65	53	57.7		53½	62	50	
3	.795	.794	.804	55	62	57	55	64	53	58.0		50	60	54	
4	.800	.804	.805	55	65	57	55	67	53	58.3		53	60	51	
5	.804	.796	.796	53	63	52	53	66	49	56.0		47	60	43	
6	.776	.782	.808	47	61	55	46	63	50	53.0		40	56	48	
7	.812	.812	.830	56	62	54	57	63	51	57.0		49	58	49	
8	.804	.818	.836	53	60	55	52	61	53	55.3		50	57	52	At 6.20 a. m.=51°; at 6.30 a. m. 49°; at 6.35 a.m 50°.
9	.808	.828	.838	51	59	55	49	58	52	53.0		46	56	51	At 6.30 a. m. 49°.
10	.808	.811	.808	55	58	55	52	54	52	52.7		52	54	51	
11	.802	.810	.828	53	60	56	52	60	53	55.0		49	58	52	At 6.30 a. m. 50°.
12	.826	.836	.843	51	63	54	51	62	52	55.0		49	58	48	At 6.30 a. m. 47½°.
13	.830	.825	.820	53	60	55	53	61	51	55.0		50½	59	48	At 6.30 a. m. 51°.
14	.814	.828	.830	49	61	53	49	62	51	54.0		42	50	49	At 6.15 a. m. 46°; at 6.25 a.m. 45°; at 6.30 a m. 46°
15	.828	.836	.852	50	61	54	48	62	52	54.0		43	57	49	
16	.842	.846	.844	52	62	55	51	58	51	53.3		49	56	51	
17	.826	.826	.820	52	62	57	52	62	52	55.3		47	57	51	
18	.808	.822	.832	49	60	53	50	63	51	54.7		46	59	48	
19	.820	.828	.830	52	60	54	51	61	51	54.3		48	55	49	
20	.828	.828	.842	53	59	53	52	57	53	54.0		51	56	47	
21	.826	.840	.842	50	59	54	50	59	50	53.0		46	56	47	
22	.822	.826	.818	50	62	54	50	65	52	55.7		47	58	50	
23	.820	.826	.820	52	60	53	52	60	53	55.0		49	56	44	
24	.818	.830	.844	50	60	52	49	62	49	53.3		45	57	47	
25	.828	.828	.832	52	58	52	52	58	50	53.3		50	55	44	
26	.824	.824	.820	52	56	52	51	55	50	52.0		51	53	48	
27	.846	.802	.804	51	55	52	50	56	50	52.0		50	54	49	
28	.788	.792	.800	52	52	56	50½	57	52	53.0		50½	55	52	
29	.796	.802	.804	54	57	52	54	58	50	54.0		53	56	49	
30	.806	.820	.836	51	59	53	51	60	51	54.0		49	58	49	
31	.832	.834	.838	52	60	53	54	60	52	55.3		53	57	50	
Total..	25259	25368	25528	....	....	....	1600	1883	1599	16939	....	1511.5	1763	1524	
Mean...	23.815	23.818	23.823	....	....	....	51.6	60.7	51.6	54.6	....	48.7	56.9	49.2	
		23.819						54.6					51.6		

* .200 too low; barometer defective.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Jan. 1	1 p. m.	1.30 p. m.	1				7	E.			0				W.	2				
2			5	NE	2½	Mist; 8, 8.5 a.m	9	SE	3		0								W.	2
3			0				6	NE.	2½		3								N.	2
4			0				8	NE.	3		1								W.	2
5			2				9	S.	2½		0								W.	2
6			0								0								W.	2
7			1				5	N.NW	1		0								W.	2
8	5.15 p. m.	5.45 p. m.	0	NW.	2		9	S.		Mist.	9	NW.	2½							
9			0				9	N.NW. & S.	2 2	Mist.	2	N.	2½		W.	1			W.	2
10	5 p.m.	5.30 p. m.	8	N.	4		9	E.NE. N.	2 3	Upper. Lower.	5	NE.	3							
11			0				9	N.	2		0				W.	2				
12			1				9	E.	2		0				W.	2			W.	2
13	12.45 p. m. 2.30 p. m.	1.10 p. m. 5.15 p. m.	0				9	E.SE.	1		0				W.	2			W.	2
14			0				3	E.	2		1				W.	2½			W.	3
15			0				9	N. SE.	2 2½		0				SW.	2½				
16			2	NE.			10	N.		Mist.	5	NW.		Mist.						
17	2.40 p. m.	3.10 p. m.	4	N.			9	N.			0								W.	2
18			0				9	S.			0								W.	2
19			0				8	N.			0				N.				W.	2
20	11 a. m. 12.50 p. m.	12.15 p. m. 5.30 p. m.	10	NE.			10	E.			0								W.	2
21	4.10 p. m.	4.30 p. m.	2				8	N.	2		0								W.	2
22			0				7	NE.	2		0				W.				W.	2
23			1				8	N.	3		0				W.				W.	2
24			1				9	S.	2		0				W.				W.	2
25			7	E.			9	NE.	2		0								W.	2
26	11.30 a. m.	2.20 p. m.	9	N.		Mist.	10	N.	3		0								W.	2
27	7 a. m.	5.30 p. m.	10	N.			10	N.	2		0								W.	2

28			10	N.		Mist.	10	NE.	2	Mist.	9			Mist.						
29			7	NE.			10	SE	2		0								W.	2
30			2	E.			9	S.			7	W.								
31	2.20 p.m.	2.25 p m.	1				10	SE			0								W.	2
Total...			84				256				42									
Mean...			2.7				8.3				1.4									

No. 1.--*Register of Meteorological Observations*—Continued.

Date.	Barometer.*						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
1857.	7 A. M.	2 P. M.	9 P. M	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	*Mean.*		7 A. M.	2 P. M.	9 P. M.	
Feb. 1	23.844	23.824	23.822	55°	60°	56°	56°	63°	53°	57.3°	The same as thermometer in open air.	54°	61°	51°	At 6 a. m., 50°.
2	.814	.819	.826	54	60	55	56	59	52	55.7		53	57½	50	
3	.816	.828	.826	51	60	53	54	60	49	54.3		42	56	43½	At 6.20 a. m., 51°.
4	.818	.808	.814	51	61	52	54	62	46	54.0		51	62	42	At 6 a. m., 47°.
5	.802	.780	.780	53	59	55	55	60	52	55.7		48	58	50	
6	.768	.764	.762	55	61	55	55	64	52	57.0		53	60	50	
7	.750	.760	.770	53	61	58	52	60	57	56.3		50	57	54	At 6.30 a. m., 49°.
8	....	.782	.808	....	62	57	53	62	55	56.7		51	57	53	
9	.780	.782	.792	56	59	56	56	57	55	56.0		54	55	51	
10	.784	.788	.796	55	61	57	55	63	51	56.3		50	58	51	
11	.784	.790	.808	55	59	54	53	58	51	54.0		53	56	49	
12	.798	.820	.834	53	61	57	56	61	54	57.0		49	57	52	Short and faint muttering of thunder, the first of this year.
13	.832	.800	.814	55	62	58	56	62	56	58.0		54	59	54	Faint thunder.
14	.798	.792	.808	55	61	59	55	59	55	56.3		53	57½	54	Thunder at 1½ p. m.
15	.808	.790	.810	57	60	56	56	58	55	56.3		55½	57	53½	
16	.808	.798	.800	55	62	55	56	60	55	57.0		53	59	50	
17	.810	.796	.816	56	63	55	59	63	52	58.0		53	58½	49	
18	.800	.788	.792	55	62	59	55	59	57	57.0		54	59	55	
19	.804	.787	.810	58	62	60	59	61	57	59.0		56	59	56	
20	.803	.792	.814	59	64	60	58	64	58	60.0		56	61	57	
21	.804	.776	.808	59	63	59	58	62	57	59.0		56½	62	56	
22	.792	.774	.796	58	63	59	57	63	56	58.7		55	60	55	
23	.792	.768	.792	57	62	60	57	64	58	59.7		55	62	56	
24	.800	.784	.818	59	63	58	58	61	55	58.0		57	61	54	
25	.812	.815	.820	56	63	58	57	63	54	58.0		54	60	53	
26	.820	.810	.814	55	63	55	56½	67	53	58.8		53	62	51	
27	.810	.800	.802	54	60	53	54	59	51	54.7		52	56	45	
28	.796	.796	.788	51	58	53	53	58	51	54.0		50	57	49	
Total...	21.647	22.211	22.540	....	....	....	1559	1712	1507	1592.8	....	1475	1641.5	1444	
Mean...	23.801	23.793	23.805	....	....	....	55.7	61.1	53.8	56.9	....	52.7	58.7	51.6	
	23.800						56.9					54.3			

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* .200 too low; barometer defective.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Feb. 1	1 p. m.	2.30 p. m.	1	E.			10	E.			7								W	
2	1.30 p. m.	3.45 p. m.	2	N.	1		10	E.	2		0								W	2½
3			0				9	N.	2½		0				N.NE.	3			W	2½
4			1	SE			9	SE			0								NW	2
5	12.45 p. m.	2 p. m.	1	E.	1		9	N.	2		1								W	2
	4.30 p. m.	4.45 p. m.						E.	2											
6			0				9	NE.			0								W	1½
7			0				9	S.	2		7	S.	3							
8			1				9	S.			1								W	
9	12 m.	2.30 p. m.	1	N.			10	N.			10									
10	9.30 a. m.	10.45 a. m.	9	N.			9	S.			1								W	
11	11.30 a. m.	1 p. m.	10	N.		Fog.	10	S.			2								W	
	3.30 a. m.	5.45 p. m.																		
12			7				9	S.	2		0								W	1
13	11.30 a. m.	12.45 p. m.	9	S.	2		8	SE	1		2								W	2½
	3.15 p. m.	4.30 p. m.																		
	5.30 p. m.	5.45 p. m.																		
14	11.45 a. m.	3.30 p. m.	7	N.	1		10				3								Calm.	
15	11 a. m.	6 p. m.	10	SE	2	Mist.	10				10								Calm.	
16	1.30 p. m.	3 p. m.	7				10	SE	2		0								W	2
17	5.30 p. m.	6.15 p. m	4	N.	1		9	E.	1		2								SW	3
18	12.30 p. m.	1.45 p. m.	8				10	E.	2½	Fog.	6									
19	12.55 p. m.	1.15 p. m.	6	SE	2		8	S.SE	3		6									
20	4 a. m.	5.30 a. m.	9	S.	2½		9	SE	2½	Fog.	10			Fog.						
	8.15 a. m.	11 a. m.																		
	3.15 p. m.	9.30 p. m.																		
21	1.15 p. m.	4.10 p. m.	6			Fog.	10	E.	2	Fog.	9									
22	9.5 a. m.	1.30 p. m.	10				10	E.SE	1		3								W	2
	2.30 p. m.	4.55 p. m.																		
23	9.45 a. m.	10.10 a. m.	10	E.	1		10	E SE	2½	Fog.	7			Fog.						
	11.15 a. m.	12.30 a. m.																		
	1.5 p. m.	5 p. m.																		

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Feb. 24	7.55 a. m. 11.15 a. m.	8.15 a. m. 6.30 p. m.	4				10				1									
25	2.55 p. m. 5.15 p. m.	3.10 p. m. 5.45 p. m.	2				8	E.	1		0								W	1
26			0				9	N. S. E.	2 2 2½	Upper Middle Lower	1						N.	3	W	4
27			9	N.	2½		9	N.	2½		0								W	2
28	12.15 p. m.	12.30 p. m.	1				10	SE.	2	Fog.	0								W	2
Total			135				262				89									
Mean			4.8				9.4				3.2									

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.*						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
1857.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	*Mean.*		7 A. M.	2 P. M.	9 P. M.	
March 1	23.800	23.784	23.795	55°	61°	59°	55°	63°	57°	58.0°	The same as thermometer in open air.	53°	57°	55°	
2	.806	.794	.820	56	63	61	55	63	59	59.0		54	57	57	
3	.814	.804	.810	58	63	56	57	64	53	58.0		54	60	49	
4	.810	.818	.808	56	64	55	56	64	56	58.7		52	57	53	
5	.794	.794	.796	53	62	53	54	62	50	55.3		48	57	47	
6	.792	.794	.790	52	62	53	54	67	50	57.0		51	59	47	
7	.794	.800	.806	53	63	55	54	69	57	60.0		49	58	49	
8	.814	.818	.826	54	61	54	52	63	51	55.3		51	57	49	
9	.820	.824	.808	55	61	55	54	62	50	55.3		52	58	48	
10	.806	.800	.802	52	62	55	54	63½	53	56.8		51	59	51	
11	.814	.822	.844	55	61	58	55	60	55	56.7		53	58	55	
12	.830	.830	.834	56	60	57	51	61	56	56.0		50	58	53	
13	.804	.810	.810	54	61	56	56	59	52	55 7		48	58	50	
14	.820	.816	.820	55	59	55	52	61	53	55.3		42	54	50	
15	.822	.810	.816	53	62	56	54	62	53	56.3		50	58	50	
16	.808	.812	.810	55	62	59	57½	64	57	59.5		54½	59	55	
17	.812	.815	.829	57	65	60	57	69	57	61.0		55	62	55	
18	.839	.832	.842	58	64	59	58	63	54	58.3		55½	59	53	
19	.822	.818	.814	57	64	57	58	66	55	59.7		53	61	52	
20	.807	.810	.802	56	62	57	56	61½	55	57.5		54½	59	51	
21	.808	.805	.800	55	61	57	54½	61½	55	57.0		52	59	53	
22	.800	.796	.796	57	61	56	57½	63	54	58.2		54	58	52	
23	.788	.784	.792	55	61	58	56	61½	56	57.8		54	59	54	
24	.790	.785	.798	58	62	58	56	61	56½	57.8		55	58½	55	
25	.778	.768	.762	58	61	59	60	62	57½	59.8		58	59	56	
26	.764	.760	.768	58	61	60	55	62	57	58.0		54	58	56	
27	.778	.788	.800	59	63	60	56	66	59	60.3		56	60	57	
28	.804	.812	.828	58	63	61	57	66	60	61.0		55	60	58	
29	.852	.818	.840	60	60	59	59	60	57	58.7		59	57	56	
30	.844	.820	.826	58	64	60	59	68	58	61.7		57	59½	56	
31	.812	.794	.806	59	62	60	57	61	59	59.0		56	59	57	Lightning and thunder of short duration.
Total...	25.046	24.935	25.098	....	....	....	1726.5	1958	1712	1798.7	....	1650.5	1812	1639	
Mean...	23.808	23.804	23.810	....	....	....	55.7	63.2	55.2	58.0	....	53.2	58.4	52.9	
		23.807						58.0					54.8		

* .200 too low; barometer defective.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. March 1	9.30 a.m.	10 a. m.	10	S.E	2		7	SW	2		7	S.SE	2½							
2			10	S.SE	2		6	S	3		7	S	3							
3	2.30 p. m.	2.35 p. m.	3	E			10	S	2		2								W	
4			3	NW			5	S	2		1								W	
5			0				5	S	2½		0								W	
6			0				8	S	2		0								W	
7			1	E			4	E	2½		0								W	
8			9	SE			10	E.SE	2		2								W	
9			3	E			10	E			1								W	
10			1				9	E.SE			5								W	
11	1 p. m.	2 p. m.	5	E			10	E			10	E								
12			10	E			10	E			9								Stationary	
13	2.15 p. m.	3 p. m.	2				10	NE		Fog	2								W	
14			10	E			5	S			0								W	
15			3				9	NW SE	2½ 2½	Higher Lower	0								W	
16			7	W	2		8	W	2		0								W	
17			6				8	S.SE	2½		5								W	
18			5	NW SE	2 2½	Upper Lower	7	Stationary SE	 2	Higher Lower	2	W	1							
19			1	W		High	7	W.NW SE	3 3	Higher Lower	3								SW	3
20	11.30 a. m.	12.15 p. m.	4	W E	1 2	High Lower	10	E	3	Fog	1								W	3
21	1.15 p. m.	1.20 p. m.	0				10	Stationary			0								W	2
22			0				9	SE	2½		0								W	2½
23			1	NW	2	Higher	10	E.SE	2		4								SW	3
24			10				10	SE	2½		7	Stationary								
25			8				10	E.SE	2		10									
26			10			Fog	10	S	2½		5									
27	4.45 p. m.	5 p. m.	10			Fog	9	S	2½		4								W	2½
28			10	SE			10	E.SE	2		9									

29	5 a. m....	8.30 a. m.	10	E.SE....	2	....	10	SE ...... NW......	2½ 1	Fog...... Higher ..	10	....	......	....	....	......	....	......	S......	
30	....	....	8	W.NW. .. SE	2 2½	Higher. Lower.	7	S........	2	....	10	S.SE	2	....	....	......	....	......	Calm ..	......
31	2.40 p. m.. 5.25 p. m..	3.15 p. m.. 6.10 p. m..	9	W....... S .... E	2 3 2	Higher. Middle. Lower.	9	NW...... S.........	2 3	Higher .. Lower ..	[illegible]	....	......	....	....	......	....	......	....	......
Mean ..	....	....	169	....	......	....	262	....	......	....	124	....	......	....	....	......	....	......	....	......
Total ...	....	....	5.5	....	......	....	8.5	....	......	....	4.0	....	......	....	....	......	....	......	......	......

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.*						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.		7 A. M.	2 P. M.	9 P. M.	
1857.				°	°	°	°	°	°	°		°	°	°	
April 1	23.792	23.788	23.798	60	63	58	58	60	57	58.3	The same as thermometer in open air.	56½	59½	54	Lightning without thunder 2.25 p. m.—2.55 p. m.
2	.798	.820	.819	57	64	55	58	66	53	59.0		55½	60	47	
3	.609	.828	.824	56	66	58	57	67	56	60.0		52	60	51	
4	.800	.812	.810	55	64	59	55	65	56	58.7		51	59	54	Therm. 50° at 6 a. m.
5	.788	.792	.796	56	63	59	56	65	56	59.0		54	59	54	
6	.791	.788	.800	58	65	60	60	67	57	61.3		57	60	55	
7	.788	.792	.790	59	63	59	59	62	55	58 7		56	59	53	
8	.784	.784	.790	56	65	60	58	69	58	61.3		55	59	55	
9	.792	.784	.794	59	65	62	58	70	59	62.3		56	61	56	
10	.784	.788	.810	60	65	62	57	67	59	61.0		56	60	58	
11	.800	.803	.814	58	62	61	55	62	59	58.7		55	59	58	
12	.812	.814	.840	59	58	57	57	57	58	57.3		57	56½	56	
13	.842	.836	.854	57	61	60	5[illegible]	65	58	59.3		55	62	57	
14	.842	.820	.834	57	64	59	55	72	57	61.3		54	62	55	
15	.829	.810	.818	57	63	59	56	64	57	59.0		55	58	55	
16	.800	.803	.811	57	62	60	57	60	57	58.0		52	57	56	
17	.806	.800	.812	59	64	60	57	66	59	60.7		55½	60	57	
18	.800	.800	.806	57	62	59	57	63½	56	58.8		55	60½	53	
19	.794	.802	.800	59	63	59	58½	62	55	58.5		55½	57	53	
20	.796	.792	.794	56	63	58	60	64½	54	59.5		55	60½	51	
21	.794	.782	.798	56	64	59	59	67	56	60.7		53	59	54½	
22	.802	.809	.834	59	63	61	58½	63	59	60.0		56	58½	56	
23	.826	.832	.856	58	63	61	57	65	59	60.3		56	60	58	Thunder, muttering, at 6 p. m.
24	.798	.836	.850	57	63	59	56	66	56	59.3		55	59	53	
25	.823	.814	.808	58	63	59	60	63	56½	59.8		57½	59	55	
26	.809	.806	.812	59	65	59	59	70	55	61.3		56	57	52	
27	.822	.832	.834	57	65	59	59	67	58	61.3		55	59	54	
28	.822	.820	.814	59	65	58	62	68	57	62.3		57	58	54	
29	.834	.826	.822	58	66	59	59	68	56	61.0		55	56	54	
30	.828	.820	.820	59	63	59	58	64	57	59.7		56	59	56	Thunder.
Total.....	24.205	24.233	24.462	....	....	....	1731	1955	1705½	1796.4	....	1654.5	1773.5	1634.5	
Mean.....	23.807	23.808	23.815	....	....	....	57.7	65.2	56.8	59.9	....	55.1	59.1	54.5	
		23.810						59.9					56.2		

* .200 too low ; barometer defective.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. April 1			10	S.	1		10	E SE	3		4	SW.	1	High						
2			4	SW.	1	Cirr.	8	N.	1	High	1								S SW. Cold & dry.	3
								E.	2	Middle										
3			5	W.	1	Cirr.	7	N.NE.	2	High	3	W.	1	Cirr.	S.SW*					
								SE.	3	Low.										
4			8				8				7								S.SW.	2½
5			5	SW.	2		7	S.	3		5	S.	2						W.	2
6			6	N.NW.	2	Higher.	7	S.	3		0								SW.	3
				S.	3	Lower.														
7			6	W.SW.	3	Higher.	8	S.	2½		1								SW.	2
				S.	3	Lower.														
8			6	W.	2	High	5	W	1	Middle	3	S.	2							
				S.	3	Low		S.	3	Low										
9			10	S.	2		6	SW	3		2								SW	1
10	5.45 p.m.	6 p.m.	9	S.	2		6	S.	2		10									
11	The greater part of last night.		10	E.SE.	3	Fog.	9	SE	3		9	S.	1	Fog						
12	7 a.m. Also, last night.	9.30 a.m.	10	S.	1	Fog.	10	E.	1		5									
13	6 a.m.	9.5 a.m.	10				9	N.	1	High	3				N.	3				
								SE.	1	Middle										
								SE.	2½	Low										
14			10	E.	3		6	SE.	2	High	0								SW.	1
								SE.	3	Low										
15			9	S.SE.	2½		7	S.	2		1								S.	2
16			2	S.	2½		10	S.	3		6	S.	2½							
17	4.35 p.m.	4.45 p.m.	9	S.	2		7	N.	2	High	7	S.	2							
								S.	2	Low										
18			9	SE		Middle.	9	N.	1		3								S.	2½
				SE		Low		E.	2											

* Therm. 53° at 6 a. m.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. April 19	......	......	7	W......	2½	......	7	E.	1	......	0	......	......	......	......	......	......	......	S......	2
				W......	2½			W	3											
20	......	......	4	NW....	3	......	8	NW......	2	......	1	......	......	......	......	......	......	......	......	......
21	......	......	1	......	......	......	7	W......	2	High	1	......	......	......	......	......	......	......	W......	2
								S......	2	Middle										
								E.	2½	Low										
22	......	......	8	S......	2	......	10	S......	2	......	8	......	......	......	......	......	......	......	W......	2
23	6.20 p.m...	6.45 p.m...	9	SE....	3	......	7	W......	2	High ...	10	......	......	......	......	......	......	......	......	......
								S......	3	Low .										
24	......	......	10	S.SE....	2	......	7	N.	1	......	0	......	......	......	......	......	......	......	W....	2
								S.SE....	3											
25	......	......	3	W......	2	......	9	N.	1	......	2	......	......	......	......	......	......	......	W......	2
								S......	2½											
26	......	......	6	N.	2½	......	3	S......	2	......	0	......	......	......	......	......	......	......	W. ...	2
				SW......	2															
27	......	......	2	W......	1	......	6	SE	2	......	3	S......	2	......	......	......	......	......	W......	2
								S......	2½											
28	......	......	3	SW.	2	......	6	NE.	1	......	0	......	......	......	......	......	......	......	W......	2
								S......	2											
29	......	......	3	S......	2½	......	3	S......	2	......	0	......	......	......	......	......	......	......	W......	2
30	6.15 p.m...	11 p.m....	9	S......	2	Higher.	8	Station ..	....	High	10	......	......	......	......	......	......	......	......	......
				S......	3	Lower.	......	S......	3	Low										
Total....	......	......	203	......	......	......	220	......	......	......	105	......	......	......	......	......	......	......	......	......
Mean....	......	......	6.7	......	......	......	7.3	......	......	......	3.5	......	......	......	......	......	......	......	......	......

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.*						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.		7 A. M.	2 P. M.	9 P. M.	
1857.				°	°	°	°	°	°	°		°	°	°	
May 1	....	....	....	....	....	....	56	60	56	57.3	Same as thermometer in open air.	54	59	53	
2	....	....	....	....	....	....	58	60	57	58.3		56	58	56	
3	....	....	....	....	....	....	55	58	57	56.7		55	57	53	
4	....	....	....	....	....	....	57	64	58	59.7		54	60	57	Thunder, faint.
5	....	....	....	....	....	....	57	61	55	57.7		56	59	54	
6	....	....	....	....	....	....	59	62	56	59.0		55	61	56	
7	....	....	....	....	....	....	56	61	55	57.3		55½	59	55	
8	....	....	....	....	....	....	56	59	58	57.7		56	58	57	
9	23.988	23.986	23.988	59	63	60	57	64	59	60.0		56½	60	58	
10	.980	.958	.974	59	63	60	58	64½	59	60.5		57	59½	57½	
11	.976	.956	.984	59	63	59	59	63	57	59.7		58	59	55	
12	.983	.976	24.003	60	60	58	61	60½	58	59.8		59	60	57	
13	.980	.968	24.006	59	60	59	58	59½	58	58.3		58	59	58	
14	24.004	.972	23.994	58	61	58	57	62	57	58.7		57	61	56½	
15	23.986	.964	.994	58	59	58	56½	59	57	57.5		56	57	56	
16	.988	.963	.960	58	63	60	56	62	58	58.7		56	58	58	
17	.996	.980	24.012	58	62	59	57	63	58	59.3		56	60	56½	
18	24.004	.974	24.000	58	60	57	57½	59	56	57.5		56	58	55	
19	23.978	.968	24.010	58	62	60	58	62	59	59.7		57	59	58	
20	.990	.970	24.000	59	61	59	58½	61	58	59.0		58	59	56	
21	.993	.984	23.986	58	61	60	58	62	58	59.3		57	59	57	
22	.996	.984	24.000	59	62	59	57	61½	58	58.8		57	60	56	
23	.996	.972	24.002	59	62	59	59	64	57	60.0		58	60	55	
24	.988	.973	24.002	57	62	61	57	64	60	60.3		56	61	59	
25	.988	.968	23.984	59	62	60	58½	61	59	59.5		57	59½	58	
26	.980	.986	24.011	57	62	62	55½	61	59	58.5		55	59	59	
27	24.002	.986	24.010	59	63	57	59	61	53	57.7		55	60	52	
28	23.976	.970	23.976	59	64	59	59	65	58	60.7		55	59	57	
29	.960	.941	.972	57	63	60	58	65	59	60.7		56	61	58	
30	.960	.964	.974	58	62	57	60	62	55	59.0		57	59	54½	Thunder, muttering.
31	.988	.982	24.000	57	62	57	57	62	55	58.0		56	59	54	
Total.....	91.680	1645	91.842				1785	1913	1777	1824.9	....	1746	1837	1741.5	
Mean.....	23.986	23.972	23.993				57.6	61.7	57.3	58.9	....	56.3	59.3	56.2	
		23.984						58.9					57.3		

* Barometer at normal height.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction	Force.	Direction	Force.
1857. May 1	11.15 a. m.	11.40 a. m.	6	W. SW SW	2 2	Cirr	10	S.	2½	......	5	......	......	......	......	......	......	......	......	......
2	11.30 a. m. 2.15 p. m. 5.5 p. m.	1.10 p. m. 3 p. m. 5.25 p. m.	10	S. E	2½ 2½	......	9	S.	2	......	10	......	......	......	......	......	......	......	......	......
3	6.20 a. m. 9.30 a. m.	8.30 a. m. 3.15 p. m.	10	...... E	 2	Fog. Low	10	...... E.	 2	...... Low	5	......	......	......	......	......	......	......	W.	2
4	4.50 p. m.	7.40 p. m.	7	SW S.	1 1	......	9	S.	2	......	10	S.	2	......	......	......	......	......	......	......
5	2.10 p. m.	3.15 p. m.	10	SE E	2½ 2	......	10	S. SE	2½ 2½	...... Low	8	S.	1	......	......	......	......	......	......	......
6	1.25 p. m.	4.10 p. m.	6	S.	2½	......	10	S SE	2 2	...... Low.	9	S.	2½	......	......	......	......	......	......	......
7	3.30 a. m. 7.40 p. m.	7.15 a. m. 9.20 p. m.	10	...... E	 2	Fog Low	10	E.	2½	......	10	......	......	......	......	......	......	......	......	......
8	6.40 a. m.	10.30 a. m.	10	......	......	Fog	10	S. and E.	2½ 3	......	10	S.SE	3	......	NE	......	......	......	NE	2½
9	......	......	10	S. and E.	2½ 2½	Fog	7	S.	2½	......	9	SE	2½	......	......	......	NE	2½	......	......
10	......	......	9	S S.SE	2½ 3	Fog	7	S. S.SE. SE	3 2½ 2	...... Low	5	S.	2	......	......	......	......	......	......	......
11	......	......	10	S. E.	2½ 1	Fog	9	S.SE E.	2½ 2	...... Low	1	......	......	......	......	......	......	......	SW.	......
12	9.45 a. m.	3.20 p. m.	5	S. S.	2 3	Cirr	10	......	......	Fog.	10	......	......	......	NE. Cold.	......	NE.	......	......	......
13	7.25 a. m. 9.30 a. m.	8 a. m. 8.5 p. m.	10	......	......	Fog	10	S. E	2 2	......	10	......	......	Mist	NE	......	......	......	......	......
14	5.30 a. m. And greater part of night.	5.40 p. m.	10	......	......	Fog	10	......	......	Fog	10	......	......	......	N.&NE	......	NE	......	W.	2
15	6.30 a. m. 3.45 p. m. 4.30 p. m.	11.15 a. m. 4.10 p. m. 6 p. m.	10	......	......	Fog	10	S. S.SE	2 2½	Fog	10	......	......	Fog	......	......	......	......	......	......
16	9 p. m.	9.15 p. m.	10	......	......	Fog	9	E. S.	2½ 2½	......	10	......	......	......	NE	......	......	......	......	......

17	3.5 p. m. 5.25 p. m.	3.10 p. m. 5.40 p. m.	10	S.SE E.SE	2½ 3	......	9	E.SE	3	......	8	......	......	......	......	......	......	......	......	......
18	9.45 a. m. 11.30 a. m. 1.20 p. m.	10.30 a. m. 12.10 p. m. 4.15 p. m.	9	E	1	......	10	SE	2	......	7	......	......	......	......	......	......	......	S	......
19	......	......	5	S	2½	......	9	SE	2	......	8	......	......	......	......	......	......	......	......	......
20	1.40 a. m.	6.10 a. m.	9	SE	2	......	8	S E.SE	2 2½	......	6	......	......	......	......	......	......	......	......	......
21	......	......	9	E.SE	2	......	10	S	2	......	10	......	......	Fog	......	......	......	......	......	......
22	6.40 a. m. 1.25 p. m. 3.5 p. m.	8.20 a. m. 1.50 p. m. 3.25 p. m.	10	......	......	......	10	S.SE	2½	......	10	......	......	......	......	......	......	......	......	......
23	4.40 p. m.	5.30 p. m.	9	W S	1 2	Cirr	9	SE	2	......	6	......	......	......	......	......	......	......	......	......
24	6.10 p. m. 7.45 p. m. 9 p. m.	6.35 p. m. 8.30 p. m. 9.30 p. m.	10	S.SE	2½	......	10	S.SE E	2½ 2	......	9	......	......	......	......	......	......	......	......	......
25	11.40 a. m. 2.10 p. m. 8.30 p. m.	1.50 p. m. 3 35 p. m. 9 p. m.	8	SE	2½	......	10	SE	2½	......	9	S.SE	2	......	......	......	......	......	......	......
26	5.30 a. m. 9.10 a. m.	6.20 a. m. 12.40 p. m.	10	S.SE	2	......	10	S.SE	1	......	10	......	......	Fog	......	......	......	......	......	......
27	12.55 p m. 5.30 p. m.	3.40 p. m. 8.10 p. m.	6	SE	1	......	10	......	......	......	5	......	......	......	......	......	......	......	W	2
28	2.30 p. m. 9.10 p. m.	8.50 p. m 10.5 p. m.	3	......	......	......	8	S.SE E	2½ 2	......	9	......	......	......	......	......	......	......	......	......
29	......	......	4	S.SE E	2½ 2	......	6	S E.SE	2 2	......	10	......	......	......	......	......	......	......	......	......
30	2 p. m. 2.50 p. m.	2.25 p. m. 3.45 p. m	2	S	1	......	10	S	2	......	1	......	......	......	......	......	......	......	W	2
31	3.30 p. m. 4.50 p. m.	4.10 p. m. 5.45 p. m.	10	SE	2	......	9	S	2	......	0	......	......	......	......	......	......	......	W	1
Mean	......	......	257	......	......	......	288	......	......	......	140	......	......	......	......	......	......	......	......	......
Total	......	......	8.3	......	......	......	9.3	......	......	......	4 5	......	......	......	......	......	......	......	......	......

HALF-HOURLY BAROMETRICAL OBSERVATIONS—*for seven days, from May* 10, 1857, *to May* 16, *inclusive.*

		6½ A. M.		7 A. M.		7½ A. M.		8 A. M.		8½ A. M.		9 A. M.		9½ A. M.		10 A. M.		10½ A. M.		11 A. M.	
			Th.		*Th.*		*Th.*		*Th*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*
May	10	23.978	59	23.980	59	23.982	59	23.983	59	23.986	59	23.935	60	23.997	61	24.000	61	*24.001	62	24.000	63
	11	.964	59	.976	59	.978	59	.983	59	.988	59	.992	60	.994	60	23.994	60	*23 996	60	23.992	61
	12	.969	60	.983	60	.992	61	24.004	61	24.010	61	24.012	62	24.016	62	*24.016	61	*24.016	61	24.010	60
	13	.973	59	.980	59	.984	59	23.988	59	23.992	59	23.998	59	24.000	59	*24.004	59	24.002	59	23.998	59
	14	.996	58	24.004	58	24.006	58	24.008	58	*24.018	58	*24.018	58	*24.018	58	24.012	59	24.012	59	24.005	59
	15	.976	58	23.986	58	23.992	58	23.996	57	24.000	57	*24.009	57	24.004	57	24 008	57	24.003	57	24.000	57
	16	.970	57	.988	57	.992	57	.996	57	24.000	57	24.002	58	24.006	58	*24.008	58	24 004	59	24.004	60
Mean..		23,975	......	23.985	......	23,989	......	23.994	......	23.999	......	24.004	......	24.005	......	*24.006	......	24.005	......	24.001	....

HALF-HOURLY BAROMETRICAL OBSERVATIONS—Continued.

		11½ A. M.		12 M.		12½ P. M.		1 P. M.		1½ P. M.		2 P. M.		2½ P. M.		3 P. M.		3½ P. M.		4 P. M.	
			Th.		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*
May	10	24.000	63	23.990	63	23.985	63	23.974	63	23.962	63	23.958	63	23.953	63	23.944	64	23.940	64	23.938	64
	11	23.988	61	.982	61	.978	62	.968	62	.960	62	.956	63	.948	63	.946	63	.940	62	.934	62
	12	24.004	60	24.000	60	.992	60	.984	60	.981	60	.976	60	.976	60	.968	60	.961	62	.956	60
	13	23.996	59	23.993	59	.988	60	.984	60	.972	60	.968	60	.964	60	.962	60	.960	60	*.956	60
	14	24.008	59	24.002	59	.994	59	.985	60	.982	60	.972	61	.968	61	.965	61	.960	61	.958	61
	15	24.000	58	23.998	58	.990	59	.983	59	.977	59	.964	59	.956	60	.955	59	.948	59	.946	59
	16	23.998	60	.990	60	.986	60	.980	61	.975	63	.963	63	.958	63	.948	62	.947	62	*.940	62
Mean...		23.999	......	23.994	......	23.988	.....	23.980	......	23.973	......	23.965	.....	23.960	......	23.955	.....	23.951	......	23.947	....

The numbers marked thus * are the maximums and the minimums of the day.

HALF-HOURLY BAROMETRICAL OBSERVATIONS—Continued.

	4½ P. M.		5 P. M.		5½ P. M.		6 P. M.		6½ P. M.		7 P. M.		7½ P. M.		8 P. M.		8½ P. M.		9 P. M.		Amplitude.
		Th.		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*		*Th.*	
May 10	*23.937	64	23.937	63	23.939	62	23.941	61	23.942	61	23.946	61	23.954	61	23.960	61	23.968	60	23.974	60	.064
11	*.932	62	.938	62	.942	62	.944	62	.950	61	.956	60	.964	60	.978	60	.983	59	.984	59	.064
12	*.953	60	.956	60	.960	59	.963	59	.970	59	.974	58	.980	58	.988	58	.996	59	24.003	58	.063
13	*.956	60	*.956	60	*.956	60	.960	60	.966	60	.978	60	.988	59	.992	59	24.004	59	24.006	59	.048
14	*.958	60	*.958	60	.959	60	.964	59	.968	59	.980	59	.982	59	.986	58	23.990	58	23.994	58	.060
15	*.945	59	.956	59	.960	58	.961	58	.965	58	.974	58	.980	58	.982	58	.992	58	23.994	58	.064
16	*.940	62	.942	61	.944	60	.948	60	.952	59	.958	59	.960	60	.974	60	.984	60	.988	60	.068
Mean..	*23.946	......	23.949	....	23.951	......	23.954	......	23.959	......	23.967	......	23.973	......	23.980	......	23.988	....	23.992	.....	.061

The numbers marked thus * are the maximums and the minimums of the day.

No. 2 *b*.

Half-hourly barometrical observations, made to find out the amount of amplitude and the precise hour at which the maximums and minimums take place, during daytime, between 9 a. m. and 5 p. m.

Date.	9 A. M.		9½ A. M.		10 A. M.		10½ A. M.		11 A. M.		3 P. M.		3½ P. M.		4 P. M.		4½ P. M.		5 P. M.		Amplitude.
	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	Barom.	Th.	
1857.																					
May 17	24.012	60	24.013	60	24.015	60	*24.016	60	24.015	60	23.965	62	23.960	61	23.958	61	*23.956	61	23.957	61	.060
18	24.026	60	*24.035	60	24.033	60	21.030	60	24.022	60	.960	61	.957	60	.957	60	.957	59	*.956	59	.079
19	24.012	59	*24.020	60	24.018	60	21.016	60	24 010	60	.956	62	.952	62	.950	62	*.948	61	.948	60	.072
20	24.018	59	24.020	59	24.022	60	*24 024	61	24 023	61	.956	61	.955	61	.952	62	*.950	61	.952	61	.074
21	24.020	59	24.022	59	24.023	60	*24.026	60	24.024	60	.968	62	.962	62	.960	62	*.958	61	.960	61	.068
22	24.022	58	24.024	59	*24.028	59	24.027	60	24.027	61	.965	61	.962	61	.958	61	*.956	61	*.956	61	.072
23	24 021	60	24.021	60	*24.022	60	24.018	60	24.016	61	.961	62	.959	62	*.956	62	.959	62	.958	62	.066
24	24.008	58	24.018	59	24.018	60	24.019	60	*24.020	61	.962	63	*.957	63	.958	63	.958	63	.958	63	.064
25	*24.022	60	24.017	60	24.016	61	24.012	62	24.010	62	.964	62	.956	61	.952	61	.952	61	*.948	61	.074
26	24.010	59	24.012	59	24.018	59	*24.022	59	24.017	59	.966	62	.961	63	.960	63	*.959	63	.960	63	.063
27	24.031	62	24.038	62	*24.040	63	24.038	63	24.032	63	.980	62	.976	61	*.969	61	.970	61	.980	61	.071
28	Barometer absent from home.....					.....	....	.....	....	.....	.960	63	.956	63	.954	63	.948	62	*.946	61	......
29	*23.992	60	23.990	60	23.998	61	23.986	62	23.984	63	.922	63	.919	63	*.914	63	.916	62	.919	62	.078
30	23.994	65	23.996	61	23.998	61	*24 003	62	24 002	64	.954	62	*.945	60	.947	60	.948	61	23.950	61	.058
31	24 021	58	24 024	59	24.024	60	*24.030	60	*24.030	60	.964	63	*.960	63	.960	63	.962	62	23.974	61	.070
June 1	21.030	59	*24.036	59	24.034	59	24.032	59	24.031	61	.964	64	.959	63	*.956	63	*.956	62	.958	62	.080
2	23.990	60	23.996	60	*23.998	60	23.992	60	23.991	60	.942	64	.939	63	.936	63	.933	62	*.932	62	.066
3	23 976	59	.988	60	*23.992	61	.987	62	.984	63	.955	63	.947	63	.946	63	*.944	63	.948	63	.048
4	24.026	60	21.027	59	*24.028	59	24.023	60	24.023	60	.968	64	.966	64	*.958	64	.962	63	.962	63	.070
5	24.015	60	21.016	61	*24.020	61	24.019	61	24.012	62	.953	64	.948	61	*.947	61	.948	63	.950	62	073
6	23.996	57	23.998	57	*24.000	57	23.999	58	23.996	57	.945	58	.940	57	.939	57	*.935	57	.936	57	.065
7	23.999	58	24.088	59	*24.010	59	24.009	59	24.009	60	.948	60	.945	60	944	60	*.942	60	*.942	60	.068
8	24.012	57	24.012	57	*21.014	58	24.014	59	24.012	59	.957	62	.954	62	.952	62	.947	61	.947	60	.067
9	23.978	57	23.981	58	23.981	58	*23.982	60	23.981	59	.943	62	.941	62	.940	62	.939	61	.938	60	.044

	Barom.	Ther.
Eighth of June has its minimum at 5½ P. M., with..................	*.946	59
Ninth of June has its minimum at 6 P. M., with..................	*.938	58

The numbers marked thus * are the maximums and minimums of the day.

No. 3.

Occurrence of rain during the different times of day, recapitulated from table No. 6 e and 6 f.

	A. M.					M.		P. M.					Total.
	6 7	8	9	10	11	12	1	2	3	4	5	6	
1856.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.
July	----	$1\frac{6}{12}$	2	3	3	$3\frac{6}{12}$	$4\frac{3}{12}$	$4\frac{6}{12}$	8	8	5	$2\frac{9}{12}$	$45\frac{6}{12}$
August	----	----	1	$2\frac{3}{12}$	3	$2\frac{9}{12}$	$3\frac{9}{12}$	$4\frac{9}{12}$	$8\frac{3}{12}$	$7\frac{6}{12}$	$7\frac{6}{12}$	$3\frac{9}{12}$	$44\frac{6}{12}$
September	---	$1\frac{3}{12}$	$1\frac{6}{12}$	$\frac{9}{12}$	----	$2\frac{6}{12}$	$6\frac{3}{12}$	$5\frac{6}{12}$	6	8	$5\frac{6}{12}$	$3\frac{6}{12}$	$40\frac{9}{12}$
October	----	---	----	$1\frac{9}{12}$	$2\frac{9}{12}$	$3\frac{9}{12}$	$5\frac{6}{12}$	$4\frac{3}{12}$	$5\frac{3}{12}$	$5\frac{6}{12}$	$6\frac{6}{12}$	$8\frac{9}{12}$	44
November	----	$\frac{6}{12}$	1	1	$\frac{1}{12}$	$\frac{9}{12}$	$3\frac{1}{12}$	$9\frac{4}{12}$	$8\frac{2}{12}$	$6\frac{2}{12}$	$3\frac{6}{12}$	3	$36\frac{7}{12}$
December	----	----	$1\frac{3}{12}$	$1\frac{3}{12}$	$2\frac{6}{12}$	2	$4\frac{6}{12}$	$10\frac{9}{12}$	$12\frac{1}{12}$	$7\frac{8}{12}$	$5\frac{6}{12}$	$5\frac{4}{12}$	$52\frac{10}{12}$
1857.													
January	----	1	1	1	1	$2\frac{6}{12}$	3	$3\frac{8}{12}$	$3\frac{3}{12}$	$3\frac{2}{12}$	$3\frac{4}{12}$	$2\frac{3}{12}$	$25\frac{2}{12}$
February	----	$\frac{1}{12}$	1	$2\frac{8}{12}$	$2\frac{11}{12}$	$4\frac{9}{12}$	$8\frac{4}{12}$	$10\frac{2}{12}$	$8\frac{7}{12}$	$8\frac{5}{12}$	$6\frac{10}{12}$	5	$58\frac{9}{12}$
Total	----	$4\frac{4}{12}$	$8\frac{9}{12}$	$13\frac{8}{12}$	$15\frac{3}{12}$	$22\frac{6}{12}$	$38\frac{8}{12}$	$52\frac{11}{12}$	$59\frac{7}{12}$	$54\frac{5}{12}$	$43\frac{8}{12}$	$34\frac{4}{12}$	$348\frac{1}{12}$
	h. m.	h m.	h. m.	h. m	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Mean	----	0 32	1 5	1 42	1 54	2 49	4 50	6 37	7 27	6 48	5 27	4 17	43 31
March	1	1	$\frac{6}{12}$	$\frac{6}{12}$	----	$\frac{6}{12}$	$\frac{3}{12}$	$1\frac{1}{12}$	1	$\frac{3}{12}$	$\frac{3}{12}$	$\frac{7}{12}$	$6\frac{11}{12}$
April	1	2	2	$\frac{7}{12}$	----	----	----	---	----	----	$\frac{2}{12}$	$\frac{3}{12}$	6
May	$4\frac{4}{12}$	$5\frac{10}{12}$	$3\frac{10}{12}$	$5\frac{4}{12}$	7	7	$7\frac{9}{12}$	$8\frac{6}{12}$	$10\frac{6}{12}$	9	$4\frac{11}{12}$	7	81

No. 4 —*Course of clouds.*

Month.	E.	E.SE.	SE.	S SE.	S.	S.SW.	SW.	W.SW.	W.	W.NW.	NW.	N.NW.	N.	N.NE.	NE.	E.NE.	
1856.																	
November	13	....	4	1	6	....	1	....	2	....	1	....	15	....	1	....	
December	21	6	11	....	....	....	1	....	....	....	....	....	6	....	4	2	
1857.																	
January	6	1	4	....	6	....	....	....	1	....	3	2	16	....	10	1	
February	11	2	8	1	9	....	....	....	....	....	....	....	11	....	1	....	
March	14	6	11	5	12	....	1	....	4	....	1	....	....	....	1	....	
April	1	....	3	....	1	....	....	1	5	....	....	1	7	1	1	....	High.
	4	2	5	4	36	....	6	....	6	....	2	....	....	....	....	....	Lower and lowermost.
May	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	High.
	5	2	10	12	27	....	....	1	....	....	....	....	....	....	....	....	Lower.
	11	3	3	2	3	....	1	....	....	....	....	....	....	....	....	....	Lowermost.
Total	86	22	59	25	101	....	11	2	19	....	7	3	55	1	18	3	
			293														

Month.	Number of days on which the sky was—						No. of rainy days.
	Free from clouds.			Entirely overcast.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1856.							
June	0	0	2	7	7	7	12
July	2	1	0	9	11	6	21
August	3	0	5	7	12	9	26
September	0	0	0	10	10	7	22
October	1	0	3	3	9	9	20
November	4	0	14	4	16	3	21
December	8	0	17	5	14	2	21
1857.							
January	12	0	22	3	7	0	10
February	4	0	9	4	13	3	20
March	4	0	8	9	14	4	9
April	0	0	7	7	4	3	6
May	0	0	1	16	18	13	25
Total	38	1	88	84	135	66	213

No. 5.

Observations on the motion of strata of clouds of different heights at Colonia Tovar.

Date.	7 A. M.		9 A. M.		12 M.		3 P. M.		6 P. M.		
	Direction.	Force.	Direction.	Force.	Direction.	Force.	Direction.	Force.	Direction.	Force.	
1857. Apl. 3	W	1	W.SW	½	....	....	....	....	W.SW	1	Cir. and very high clouds.
	....	....	....	....	N.NE	2½	N.NE	2	N.NE	2	Mid. stra. 7,500—9,000 h.
	....	....	Station	....	E	2	SE	3	....	....	Low. stra. 7,000—7,500 h.
4	....	....	....	....	....	....	....	....	Station	....	High.
	....	....	....	....	NW	2	....	....	SE	2	Middle.
	....	....	....	....	SE	3	....	....	SW	3	Lower.
5	....	....	....	....	W SW	2	....	....	....	....	High.
	....	....	....	....	....	....	....	....	....	....	Middle.
	....	....	....	....	S	3	S	3	....	....	Lower.
6	....	....	W	1½	N	1	....	....	....	....	High.
	N.NW	2	....	....	S. & N.	2	SW	2	....	....	Middle.
	S	3	N	3	S.SW	3	S	3	....	....	Lower.
7	N	1	....	....	....	....	....	....	....	....	High.
	W.SW	3	....	....	S	2	N	1	....	....	Middle.
	S	3	....	....	SW	2	S	2½	S	2½	Lower.
8	....	....	....	....	....	....	....	....	....	....	High.
	W	2	....	....	....	....	....	....	....	....	Middle.
	S.SW	3	S	3	SW	2	S	2	S	2	Lower.
9	....	....	....	....	....	....	....	....	....	....	High.
	....	....	....	....	....	....	S	3	....	....	Middle.
	S	3	S	3	S	3	SE	3	S	2	Lower.
10	....	....	....	....	....	....	....	....	....	....	High.
	....	....	W	2½	....	....	S	2	S	2	Middle.
	S	2	S	3	S	2	S	2	E	3	Lower.
11	....	....	....	....	....	....	....	....	....	....	High.
	....	....	....	....	....	....	....	....	....	....	Middle.
	E.SE, fog	1	E.SE., fog	1	E	3	E	3	S	1	Lower.
	....	....	....	....	....	....	....	....	....	....	High.
12	....	....	....	....	....	....	....	....	....	....	Middle.
	S	1	S	1	Fog, N. w'd	3	E SE	2½	E.SE	3	Lower.
13	....	....	....	....	....	....	....	....	....	....	High.
	....	....	....	....	....	....	N. & SE.	1	....	....	Middle.
	....	....	Fog	....	Fog, E.	2½	SE	2½	....		Lower.
14	....	....	....	....	....	....	....	....	NW	1	High.
	SE	2	S	2	SE	2	SE	2	SE	2	Middle.
	E	3	E	3	SE	3	S	2	S	3	Lower.
					N.NW	1					
15	....	....	W	2	NW	2½	....	....	....	....	High.
	....	....	S	2	SE	2½	S	2	S	2½	Middle.
	S	2	E	2½	S.SE	3	S	2	S	2½	Lower.
16	....	....	....	....	....	....	....	....	....	....	High.
	....	....	....	....	S.SW	2	S	2½	....	....	Middle.
	S	2	S	2½	S	3	S	3	S	2½	Lower.
17	....	....	S	2½	....	....	....	....	....	....	High.
	....	....	W	3	W	2½	SW	2	....	....	Middle.
	S	2	SE	2½	S	2½	SE	1	SE	3	Lower.
18	....	....	....	....	....	....	NW	1	....	....	High.
	SE	2	....	....	SE	2	....	....	....	....	Middle.
	SE	2	SE	2	E SE	2½	S. & E.	2½	S	1	Lower.
19	....	....	....	....	W	....	....	....	W	2	High.
	W	2½	N	1	W	....	SW	1	....	....	Middle.
	W	2½	....	....	N	....	NW	3	S	2½	Lower.
20	NW	3	....	....	....	....	....	....	....	....	High.
	....	....	W.NW	2	NW	2½	NW	2½	....	....	Middle.
	....	....	....	....	....	....	....	....	....	....	Lower.
21	....	....	....	....	N	2	W	2	....	....	High.
	....	....	SW	1	E	1	S	2	....	....	Middle.
	....	....	N	1	S	2½	E	2½	....	....	Lower.
22	....	....	....	....	....	....	....	....	....	....	High.
	S	2	S	2	S	2½	S	2½	S	2	Middle.
	....	....	....	....	....	....	....	....	SE	3	Lower.

No. 5—Continued.

	E.	E.SE.	SE.	S.SE.	S.	S.SW.	SW.	W.SW	W.	W.NW	NW	N.NW	N.	N.NE	NE.	E.NE.
High clouds	...	.....	....	......	1	......	....	3	6	1	4	......	3	.....	....	......
Middle clouds.....	1	.....	8	.....	19	1	4	1	6	1	3	1	4	3	....	......
Lower clouds.....	10	5	11	1	38	2	3	......	1	.....	1	......	3	.....	....	......
	11	5	19	1	58	3	7	4	13	2	8	1	10	3	....	......

From this we see that during the time from April 3 to April 22—

The E. and E.SE. currents have been chiefly in no other but the *lower* strata.

The SE., S., and SW. currents have been chiefly in no other but the *lower* and *middle* strata.

The W., W.SW., and N.W. currents have been chiefly in no other but the *upper* and *middle* strata.

The N. current has been in all three strata, the *upper*, *middle*, and *lower* strata.

Or expressed in another manner—

In the *upper* region occur chiefly W., NW., W.SW., N.

In the *middle* region occur chiefly S., SE., W., SW., N., NW., N.NE.

In the *lower* region occur chiefly S., SE., E., E.SE.

Colonia Tovar, Venezuela, *June* 11, 1857.

Dear Sir: Your kind letter of March 5, was received by me in due time, and a little box with eight pounds of mercury, for which I thank you very much, came to hand somewhat later, on the 3d of May.

Soon after the receipt of the mercury I went to work to fill the barometer tube according to your directions; but with every new trial I found that the mercury fell more and more below its standard height, although I was certain there could be no air above it. At first I could assign no cause for this failure; but the fact that I was losing regularly at every new trial suggested to me the idea, that in handling the mercury the latter might have taken moisture from the atmosphere. Accordingly, I placed the barometer tube containing the mercury and a Torricellian vacuum in a nearly horizontal position cautiously over a brisk charcoal fire, and in this way heated the mercury for some time, until no more bubbles were disengaged. I was hereby especially struck with the great quantity of escaping moisture, and never thought that mercury could have taken up so much from the atmosphere during the short period required for filling the tube. Can this property be due to the nitric acid, with which the mercury may have been purified, and which is known to absorb moisture from the air? Thus, by boiling, and at the same time making use of your directions, I succeeded perfectly well in bringing the level of the mercury up to its standard value. In such a damp atmosphere as this the *boiling* of the mercury seems to be indispensable.

I have now the pleasure to say, that since the 9th of May the barometer may be considered to be as correct and precise as when I first received it.

In a separate envelope accompanying my present communication, I have the pleasure of sending you besides the meteorological registers for six months, a short essay on the cause of the daily periodical variations of the barometer, and a number of tables and diagrams.

Tables No. 2 *a* and 2 *b* contain half-hourly observations on the daily periodical variation of the barometer for 31 days, made with a view to determine the precise time of maximums and minimums and the amount of daily amplitude. With regard to the latter, if we take the mean of every six days in succession, beginning with the 10th of May, we get the following mean amplitudes: .060, .070, .068, .066, .064; showing a gradual rise and fall in the numbers. The greatest mean amplitude is for the period from 16th to 21st May, so that even these additional numbers are still in accordance with the view taken with regard to the amount of amplitude for the different periods of the year, alluded to in my last letter. All the half hourly observations up to June 9, inclusive, hitherto made by me on the subject of periodical variation, which are for 56 days, prove for the occurrence of the a. m. maximum, the average time to be at 10*h.* 10½*m.* a. m., and for the p. m. minimum 4*h.* 31¼*m.* p. m., which seems to agree pretty well with the time of daily maximums and minimums found in other parts of the globe.

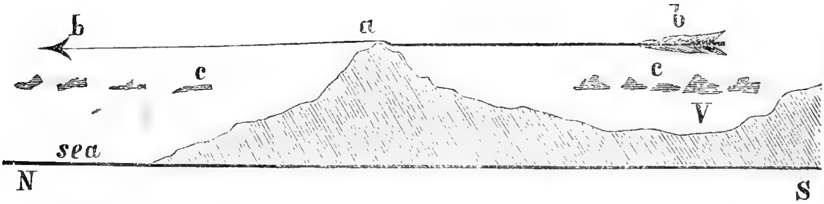
Table No. 3 is to exhibit the number of hours of rain during the different times of the day for each month from July, 1856, to May, 1857, recapitulated from tables No. 6 *e* and *f*. The vertical distance of the curve *a b c* from the base *a d* gives us the mean value of duration of rain for any given time of the day between 6 a. m. and 6 p. m. This curve is the expression of the *mean* for eight months from July, 1856, to February, 1857, and is laid down according to the mean numbers directly above it. It demonstrates very plainly that in the morning between 6 and 7 there was no rain; but with the advance of the day the rain augmented and reached its maximum between 2 and 3 p. m., whence it gradually abated towards evening. During the night it very seldom rains. Mr. Boussingault's observations, which he made in another part of South America near Marmato, prove that at that place more rain fell at night than during the day; and he says, in his Rural Economy, "every one in South America allows that it rains principally during the night." Now this is in direct opposition with my observations here, and it shows, therefore, that a certain state of the weather, especially with regard to rain, may sometimes be limited to small districts only.

From table No. 3 we also see that the month of February, which is commonly considered to be one of the dryest of the year, and properly belonging to the very centre of the dry season, has been the wettest month of the year, with the exception of May. The dryest months were March and April.

By a glance at the tables No. 6 *a* to 6 *f*, we may have a ready survey over the dry and wet months of the year and the distribution of rain in general. Here we find that the limits of the dry and the rainy seasons are not very distinct, and from May, 1854, till the end of 1855, a period of 20 months, we find no well defined dry season, the month of February, 1855, being the dryest. But with New Year's Day, 1856, there commences a dry season which lasts for five months, the longest and dryest the colonists ever enjoyed. And it was in this extraordinary dry period that the loose layer of half decomposed vegetable matter, of which I spoke in my last letter, got to be dry enough to take fire.

The dry season of the present year we recognize only in the months of March and April and a part of January. From inquiry, I learn that well defined dry seasons have also been rather rare previous to my stay in the colony.

Table No. 4 gives the course of the clouds for seven months. The most numerous direction is as usual from south and east and the points intermediate amounting to 293. As a striking feature may be noticed the increase in the number of currents from the south since January, when there are only six, while in April we find 37 and in May 31. This may well account for the fact, which captains of vessels trading between the United States and the coast of Venezuela have noticed so frequently, of meeting during the months of April and May with steady blowing southern breezes, and which I had an opportunity to notice myself on my last voyage to Laguayra. In some places east of the colony, on the back of the Cordilleras of the coast, I have experienced this steady current from the south as often as I had occasion to traverse this region on my way to Caracas, with the exception of only once. It amounts sometimes to a strong breeze. Other colonists, who frequent this road more than I do, have noticed this remarkable wind nearly at all times of the year.



Several times I had a most excellent opportunity for observing and tracing the course of this southern current to a great distance in the direction south and north. I was then standing on the very crest of the mountains of the coast, having a view towards the north upon the sea, and towards the south over a part of the fertile valleys of Aragua. Scattered masses of clouds showed plainly by their motion the direction of the current in a long line, whence it came and whither it went. The annexed figure may serve to give a somewhat clearer idea. It is to represent a vertical section of the territory from south to north, *a* the place of observation, V the valleys between the northern and southern ranges, *c c* clouds moving with the eastern trade-winds towards the west, the line *b d* the track of the high southern current, which had a velocity of about twelve miles per hour, and a somewhat sinking tendency, until it struck the northern range, where it was forced upwards for a short distance until it reached the crest, and then went on unobstructed on the other side of the mountains, in a horizontal line, apparently lowering but very little, leaving hereby the eastern trade-winds of the sea far below and undisturbed in their regular and steady course, which is nearly at right angles to that of the former. The lower clouds of the valleys showed plainly a motion from east to west, as seen against the dark background of the southern mountains. The high southern current was not indicated by clouds in those places where it was vertically over the lowest parts of the valley; but when drawing nearer to the Cordilleras, on which I stood, the vapors which it contained condensed rapidly, and became visible as drifting, incoherent clouds sweeping by, and which could still be seen on the sea-side as long as they floated over the dense primeval forest, which extends here from the mountains' tops to the very margin of the sea.

Here I may also remark that the great amount of cloudiness, which in some respects may be regarded as a disadvantage to observation, offers, with regard to the currents of the atmosphere, great advantages, the condensed vapors indicating the various motions and directions of these currents, and I have had, therefore, opportunities to observe them in most of their various forms. Sometimes I have seen the air ascend and descend vertically with considerable velocity, at other times pushed up the inclined planes of mountain flanks on one side until reaching the crest, and then gliding or flowing down on the other side somewhat like a liquid, following in its course the most depressed localities and ravines in all their windings. Sometimes the eastern currents may be seen in their gradually ascending but nearly horizontal course to meet the higher southern current at right angles, and, without mixing, to be deflected by the latter in a horizontal semicircle, or downward or upward, as the case may be. I have also seen two opposite currents meet, when each endeavored to force its antagonist back with alternate success and failure, until one got the better over the other, and at last kept undisputed sway.

At certain seasons of the year we may see extensive sheets of cloudy masses press closely over the northern or the southern range of the colony valley, and gliding down the declivity for a short distance become invisible and disappear in crossing the cultivated part of the valley, but reappear again on drawing near the opposite ridge. Frequently I have seen immense masses of clouds leaning against the northern side of the crest of the mountains, and as if stuck to them, for whole days, and while the base was gently sliding upwards towards the south, the top of the cloud, which was towering above the mountains, was bent back and moving slowly in an opposite direction.

When standing on some high mountain, especially early in the morning, I have seen dazzling white coherent masses of clouds filling up far below me whole valleys, the surface of these clouds representing immense and level snow fields, from which, in a most lovely and striking contrast, the green summits of the smaller mountains protruded as so many islets, or higher and lesser promontories of a frozen arm of the ocean. The delusion is sometimes most complete, and cannot be viewed without feelings of pleasure and surprise. The elevation of the upper surface of these clouds was between 5,000 and 6,000 feet above the level of the sea.

A striking feature in table No. 4 may be found in the prevalence of northern currents from November till February, inclusive, while they are much rarer or entirely wanting in March, April, and May.

Among the number of days free from clouds we find that at 2 p. m. throughout all the twelve months there was only one single day where the sky was entirely clear, but at 9 p. m. we had a clear sky on eighty-eight days. In the month of September the sky was during all the ninety observations made in that month more or less clouded. At 2 p. m. the sky was *entirely* overcast on one hundred and thirty-five days. In May it was *entirely* overcast during forty-seven observations. The number of rainy days is two hundred and thirteen.

Table No. 5 contains observations on the motion of strata of clouds of different heights.

Observations on the motion of the highest clouds would be very important, but in this region we are unable to make a great number of such observations on account of the cloudy state of the sky, and we have to make the best of the few opportunities we may now and then get. As April is one of the most favorable months for this purpose, I have chosen this time, and have taken peculiar pains in collecting the facts contained in table No 5. The greatest difficulty hereby exists in telling exactly which of the many different thin strata of clouds are the higher and which the lower ones. I was sometimes obliged to watch them for ten minutes right over head; but knowing that inaccurate observations are infinitely worse than none at all, I did not shun any inconvenience to arrive at the true motion of the different strata.

From this table we see that in the upper and highest regions the following winds were observed chiefly to occur: W.NW., W.SW., N.; in the middle regions, say from 7,000 to 9,000 feet above the sea, S SE., W.SW., N.NW., N.NE.; and in the lower region, say from 7,000 down to 5,000 feet and still lower, S.SE., E., E.SE.

I may here remark that, from long continued observation on the motion of the clouds, I am inclined to believe that all the easterly winds of this region are gradually *ascending* in their course towards the west, while the southern as well as the western currents are gradually *descending* in their course.

Diagram No. 7 gives a view of the curve of mean monthly temperature for Colonia Tovar compared with the curves for New Orleans, St. Louis, Missouri, and Boothia Felix. I have chosen these three latter places because they are all North American, and lying nearly under one and the same degree of longitude, but in different latitudes; Boothia Felix in north latitude 70.2°.

Diagram No. 8 contains all the mean daily heights of the barometer from November 7, 1856, to April 30, 1857, and from May 9 to June 3. A similar diagram for June to October, 1856, I have sent already with one of my former letters. At that time I remarked that a kind of periodical rising and falling in periods from four to five days was observable, but I did not then expect that this rule would hold out for the remainder of the year. But after I had finished diagram No. 8, merely to see what kind of curve these months would present to the eye, I was struck with its appearance in shape, and induced to count the days from vertex to vertex, which, commencing with November 11, gave me the following numbers: 6, 5, 2, 5, 6, 4, 4, 3, 6, 4, 6, 3

5, 3, 4. 5, 3, 7, 3, 5, 4, 5, 3, 6, 6, 4, 4, 2, 4, 6, 5, 5, 3, 7, 4, 6, 4 = 167, of which the mean is 4.5 days, as the mean period occurring between every two successive heights or vertices.

The same process applied to the former diagram of the months of June to October, 1856, gives me the following numbers: 5, 4, 5, 3, 5, 3, 4, 4, 4, 5, 6, 5, 4, 6, 3, 4, 3, 4, 3, 6, 4, 3, 4, 6, 10, (= 2 + 5,) 5, 5, 5 = 128, of which the mean number is 4.4 days. For May, 1857, commencing with the 14th, the numbers are 3, 5, 5, 5, 3.

No matter whether the barometer had a perfect vacuum or not, the features of this remarkable phenomenon are the same. The two series of the above numbers, and the coincidence of their mean value, prove beyond a doubt that they are not the result of mere accident; but that this periodical fluctuation in the pressure of the atmosphere is subject to a certain law, of which I am ignorant.

Diagram No. 9 exhibits two curves of the mean temperature for Colonia Tovar for twelve months. The upper curve is the result of noting down the mean temperature for every *third part* of the month, and presents quite a different appearance compared with the lower curve, in which are noted down the mean temperatures of the whole months only. The latter part of April and the middle of September show the highest, and the middle of January the lowest temperature. July has usually a lower temperature than the three months on either side of it. The mean temperatures of the four meteorological seasons present the curious fact that three of them, spring, summer, and autumn, have exactly the same temperature, viz: 58.9, even to a fraction. The mean temperature of the year is 58.2; difference between the coldest and warmest month, 5.3.

The temperature of the primeval forest, about two hundred yards distant from my dwelling, was, on the 25th of April, at 1*h.* 30*m.* p. m., 61°, at the margin 64°, when at my house the thermometer was 65°. In a shady ravine I stuck the thermometer four inches deep into the spongy brown vegetable mould at different times of the day, and found the temperature always 59°, pretty near the mean temperature of the year. 58° or 59° may be considered to be the *constant* temperature of this region about twelve inches below the surface of the ground in shady places.

I have often observed that, whenever the sun breaks through the clouds and has been shining for a couple of hours, the thermometer fluctuates frequently very suddenly from one to four degrees, according as it is touched by a warmer or colder current of air proceeding from the differently heated localities of the soil; but when the sky is entirely overcast such changes never take place.

It seems somewhat remakable that, at Colonia Tovar, no heavy thunder-storms occur. Thunder and lightning are seldom strong enough to deserve to be mentioned. Trusting to past experience with regard to the absence of tempests, hurricanes, and whirlwinds, I have covered the roof of my house with very thin and light shingles, not nailed down, as is done in the States, but merely hung loosely upon laths without any weather-boarding at all. And yet, for two years, they have remained in this position undisturbed by winds and weather.

The stars are here seen to scintillate on every clear evening the same as they do in higher latitudes, with the exception of a small area in the zenith of about 45 degrees, where they have their steady planetary light mentioned by Humboldt, and to be observed in lower regions. The zodiacal light I have never been able to see in the colony, although I have looked for it every clear evening.

Besides the already enumerated tables and diagrams, I have also inclosed four sheets of copies of sculptured rocks, or, as they are called in this country, "piedras pintadas," (painted stones.)

These rocks, which I have found in different regions, in low hot valleys as well as on high cold mountains, seem to be the work of one and the same race of men. The original figures are on a large scale. A few well-preserved spots, sheltered by a layer of sandy soil against the destructive influence of the atmosphere, show that the outlines of these figures are grooves, engraved or chiseled very smoothly and regularly to the depth of at least an inch in the hardest rock, and evinces a skill which would do credit to any of the civilized inhabitants now living in this country, even when aided by tools of steel There is no mere scratching about them ; they have been sculptured. They show clearly that they were worked to *last*, and to outlive full many a change in the history of nations. The delineations are in all of them, whether from the sultry and insalubrious coast of Puerto Cabello, or from the cold mountain regions of the colony, of the same kind of workmanship, consisting of grooves about an inch wide and an inch deep.

Time has worked sadly at most of these stones, and on some of them I found only traces of figures.

All these rocks I found by accident in my botanical rambles, in places where I never would have ventured to penetrate, and where I was led by necessity when strayed and trying to find my way back.

Whatever may be said of these figures, patiently worked into the rock, they were not done without a certain design. Whether they were intended to convey any peculiar meaning, or none at all, the Indians have hereby bequeathed to us the means of comparing them with similar monuments in other distant regions. So much is certain, they were worked with the intention to remain there for a *long* period of time, and to be looked at by posterity. These figures consist in images of objects, with which their makers were surrounded and acquainted, as, for instance, alligators or large lizards, snakes, tigers, canoes, sun, moon, human heads, &c., but show no signs of implements of civilization. Therefore these figures may be supposed to date anterior to the conquest of the country by the Spaniards. No record of the existence of these rocks, I suppose, has hitherto ever been made, for this region has been discovered but very lately, and none of the natives living in the neighboring valleys have known anything about them. In this case I may have been the first and only stranger who ever beheld their yet lasting works, of which they took so much pains to make a show in after years.

But how fallacious are often the most unpretending expectations of nations as well as of individuals. These Indians, as a tribe or nation, may have removed, or become extinct, or been driven away; for certain it is that they are gone, and have vanished from this region. Month after month and year after year (until amounting to centuries) went silently on over the only yet remaining witnesses of their existence. The luminaries of day and night had their glittering rays alternately reflected from the inclined and even surfaces of these rocks; the rain ran down innumerable times as from a roof and washed the figures clean. Wind and water and oxygen and heat worked slowly but effectually at the destruction of the figure-furrowed surface, and succeeded but too well. But no one came to wonder at the skill and patience of their makers. Fifty or a hundred years more would have done their destructive work completely, and these figures would have vanished and gone, probably without having been noticed even by a single individual.

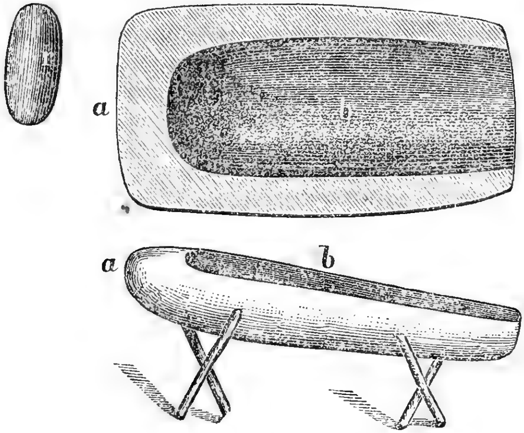
Occupied with such reflections as these, when seated near the simple memorials just spoken of, I feel myself richly remunerated for all my fatigue and the trouble to snatch them from oblivion.

That these sculptured rocks were intended to be seen and noticed is proved by the fact that they are never found in the primeval forest, but most generally in some prominent part of a savannah, bordering on the forest, although now overgrown with brushwood and reeds. Some of the figures were found in a place partly overgrown with small trees, or rather shrubs of a stunted growth, mostly of small specimens of clusia, which fact may prove how slowly a dry savannah, even when undisturbed by fire, is rechanged again into a forest; while it takes but a few years to change, by the aid of fire, a forest into a savannah.

These localities show, also, clearly enough to a person acquainted with the mode of agriculture in the mountainous districts that the Indians have subsisted on agriculture and not on the chase, for by the latter not even a dozen individuals could keep themselves alive for any length of time, much less a whole tribe.

The barometer which I carried to the region of the sculptured rocks assigns to them a height of about 5,900 feet above the ocean. When we consider the wet, cold, disagreeable, and foggy weather which prevails during the greater part of the year in this region, where the creoles, in coming up from the warmer valleys, sometimes shiver with cold, where the banana and other cultivated tropical plants seldom bear fruit, and where Indian corn can only be raised with difficulty or not at all, we may perhaps be inclined to think that the Indians chose this cold region from predilection; and in this case might probably have descended from the same stock that peopled and preferred the high regions of the Peruvian Andes. But when we afterwards find similar rocks near the hot and sultry coast of Puerto Cabello, and in other low valleys, the above inferences would have to undergo considerable modification.

A corn or maize-grinder is in general use amongst the creoles of Venezuela, which, considering its very rude and simple construction, seems not to be of European invention. It consists merely of a flat stone *a* $1\frac{1}{2}$ foot long, 14 inches wide, and 3 inches thick, somewhat convex on the lower and concave on the upper surface; the concavity *b* is flat, and 7 inches wide. The runner *r*, with which the corn is crushed, is a stone about 5 inches long, 3 inches wide, and of an oval form, so as to fit the concavity *b*. The person crushing the corn stands near the upper end of the stone, and holds the runner with both hands, and in crushing the previously soaked and somewhat pounded corn brings to bear nearly the whole weight of the upper part of the body upon the runner. The ground pulpy mass is shoved off at the lower end of the stone into some vessel. If the pulp is not fine enough it is crushed over again. This pulp, washed to remove the skins of the corn, and then baked upon hot stoves, constitutes the bread of all the creoles not living in town. The whole work of pounding and crushing is performed by females, and is a most tedious drudgery. It is really astonishing that the people here have not yet made use of the iron corn-grinders used so universally in the backwoods of the United States, although they can be bought at Caracas. The above rude corn-grinder, or rather corn-crusher, is used also to crush roasted coffee, cocoa, and salt, and has been even adopted by some German families. I have been explicit on this subject, because in Emory's "Notes of a Military Reconnaissance," page 133, I find made mention of a similar corn grinder used among the Pimos; but whether it is of the same shape as these here I have no means to learn.



Barometrical measurement shows that the river Tuy, seven or eight miles to the S SE of Colonia Tovar, is only about 3,100 feet above the level of the sea, while at Colonia Tovar it is at least 6,000 feet. This river has therefore a descent of nearly 3,000 feet within eight miles, or, on an average, a fall of 375 feet per mile. Such is the territory of the colony.

On the 28th of May I carried the barometer to the "Picacho," one of the highest peaks in the neighborhood of the colony, and found the height of the mercury at $9\frac{1}{4}$ a. m. 22,736, thermometer 69°, from which I conclude that this mountain may be only 500 or 600 feet inferior in height to the "Silla" of Caracas, the highest peak of the coast range of Venezuela.

In travelling from Victoria towards Valencia we find, about three miles west of Tarmero, right in the middle of the road, the famous "Zamang," an enormous tree, so well described by Alexander V. Humboldt. Its head, formed by enormous horizontal branches, is the most remarkable part of this giant of trees. A section of its head would present a shape as shown in the marginal figure.

I measured the head in its greatest diameter from E SE. to W.NW. most carefully, and found it to be 206 feet 11 inches, English. Fifty-seven years ago it was found by Humboldt to measure in its greatest diameter 192 feet, French measure, which would be equal to 204.48 feet, English. Hence it follows that this tree has within the last 57 years increased the horizontal diameter of its head only by 2 feet 5 inches, English. The branches are loaded with a wonderful mass of epiphytes and parasites; and it seems surprising that branches of nearly 100 feet in length, standing horizontally out from the trunk, can support for centuries, besides their own astonishing weight, such an extra load of heavy plants as Bromeliaceæ, Orchideæ, Cacteæ, Loranthaceæ, Piperaceæ, &c.

This extraordinary tree is but thinly covered with leaves; it looks as if it lacks vigor to issue new slender branchlets, for its ultimate branchlets are old, short, thick, and of stunted growth.

Setting out from Petaquire, (a place nearly as high as the colony,) on the 8th of February, in an excursion towards the sea coast, my attention was directed to some *cow-trees*. The space over which they were distributed was but very limited in the direction north and south, but extended more towards east and west, and was about 3,500 feet above the sea Their external appearance, the shape of the trunk and leaves, agreed exactly with the description given by Alexander V. Humboldt. Most of them were trees of 1 to 1½ foot in diameter, but very tall. I also found some younger ones of 5 inches diameter. In seven or eight of these trees of different age and dimensions, I made incisions, to see the milk flow. Although it was about the same season of the year when Mr. A. V. Humboldt saw the cow-tree between Valencia and Puerto Cabello, I never could elicit from them much more than 1 or 2 drops in a second of time. There was not much difference in the flow of milk between the larger and the smaller trees; and if ever I was disappointed in my expectations I certainly was on this occasion as to the quantity of milk. The milk has an agreeable, mild, rather rich taste, and becomes somewhat sticky between the fingers. People who live not far off, and have tried these cow-trees in different years, do not praise much their milk-yielding qualities. The cow-trees grow in the midst of shady, humid forests, at an elevation of about 3,000 or 4,000 feet, along the sea-fronting declivities of the high mountain range, stretching from east to west along the northern coast of Venezuela. I have neither seen the fruit nor the flowers of this tree; but in comparing its leaves with leaves of plants in my herbarium, I find the closest resemblance in shape, structure and venation with some species of fig-trees. The wood is white and of considerable hardness.

I passed the night in the midst of an immense forest, on a thin layer of dried grass, in a small, uninhabited, open shed, (a plantain leaf thatched roof, resting upon six isolated posts,) near to which a tiger was said to have his range. Towards evening torrents of rain poured down; but the night was still and undisturbed, except by the rushing mountain-stream at some distance off, which appeared to the watchful ear like the hollow rustling of a forest in a gale of wind. One solitary bird near by made the spot still more melancholy by its mournful notes, which it sent forth from time to time throughout the night, unanswered by anything living.

These damp and shady primeval forests, especially when fronting the sea, are also to be noted for the great amount of ferns, with regard to species as well as to individuals. This beautiful class of plants, of which I have already collected 489 species within a comparatively small part of the country, loves moisture, shade, and *stagnant* air, and rarely ever succeeds in a climate or region which lacks these three great necessary conditions. With regard to number of individuals, the different heights show no marked effect. I found them in masses equally dense at 1,500 and 6,500 feet elevation; and I have descended and ascended the flanks of the coast-chain in five different regions. The only difference we see is the change of species in different heights, and even here we find many species to extend over a great area of different elevation; but most species are rather of a local habit.

We can, therefore, from the amount of ferns which occurs in any given place, not very well deduce the mean temperature of that place, as is sometimes done in geology, in conjectures about the temperature of the earth's surface at the time of deposition of the coal fields, unless we know what temperature belongs to the luxuriant growth of that very species which we wish to draw conclusions from. The yearly mean temperature of the fern region may vary from 56° to 80° F.

Colonia Tovar, Venezuela, *January* 10, 1858.

Dear Sir: Under date of June 11, 1857, I sent you a letter, together with some meteorological registers and a number of tables and diagrams, which you probably will have received in due time. Inclosed I send you now—

No. 1. Registers of meteorological observations for seven months, viz: from June to December, 1857, inclusive.

No. 2. A table showing by the length of horizontal lines at what time of the day it rained at Colonia Tovar for each day from June to December, 1857, inclusive.

No. 3. A table containing a recapitulation of the occurrence of rain expressed in number of hours, for all the months from July, 1856, to December, 1857, from 6 a. m. to 10 p. m. This table also shows by the length of straight lines the comparative value for each *month*, as regards the number of hours of rain; and in another diagram the mean rain value for each *hour* from 6 a. m. to 10 p. m.

It may not be uninteresting here to see what a symmetrical figure the curve *a b c* represents; how it rises gradually from 6 a. m. to the hour between 2 and 3 p. m., and then sinks to 10 p. m. nearly as gradually as it rose.

No. 4. A table giving the course of the clouds of the higher, middle, and lower strata for the months of June to December, 1857. The motion of the clouds from the E., E.SE., SE., S.SE., and S. is by far the most prevailing, amounting to 415, while the motions from all the other eleven points amount only to 133. November and December show, as usually, a preponderance over the eight preceding months with regard to motion of the clouds from the northern regions. The motions from the west, with only one exception, took place in the highest regions of the atmosphere. This puts me in mind of the fact that, while at Santa Fé, New Mexico, the steady course of the higher clouds from the west had frequently attracted my attention.

No. 5 gives a view of the fluctuation of the mean daily heights of the barometer for seven months. My remarks in a former letter about the falling and rising of the mean daily height of the barometer, which from one maximum to another requires, on an average, 4½ days, still hold good, as will be seen by the following series of numbers, which are the number of days counted from one maximum height to the next following one.

Beginning with my earliest barometrical observations, counting from the 14th of June, 1856, and ending with the 30th of October, 1856, the day on which the barometer got out of order, we have: 5, 4, 5, 3, 5, 3, 4, 4, 4, 5, 6, 5, 4, 6, 3, 4, 3, 4, 3, 6, 4, 3, 4, 6, 10, 5, 5, 5 = 128 days, of which the mean is 4.57 days.

Beginning again, when the barometer was put into use, with the 12th of November, 1856, and ending with the 30th of April, 1857, the day on which the barometer was taken apart to be mended, we get: 6, 5, 2, 5, 6, 4, 4, 3, 6, 4, 6, 3, 5, 3, 4, 5, 3, 7, 3, 5, 4, 5, 3, 6, 6, 4, 4, 2, 4, 6, 5, 5, 3, 7, 4, 6, 4, 2 = 169 days, of which the mean is 4.45 days.

Beginning again, when the barometer was in good order, with the 13th of May, 1857, and ending with the 31st of December, 1857, we get: 2, 3, 5, 5, 5, 3, 4, 5, 4, 4, 3, 3, 3, 2, 4, 8, 4, 4, 5, 3, 4, 7, 2, 5, 4, 4, 5, 6, 5, 4, 5, 2, 4, 4, 2, 5, 3, 7, 7, 5, 4, 4, 5, 6, 4, 5, 10, 8, 6, 6, 3 = 230 days, of which the mean is 4.51 days.

The mean of all these three series is 4.51 days.

No. 6 contains the half-hourly observations on the daily periodical variations of the barometer for 157 days, which, together with those made from the 10th of May to the 10th of June, amount to 186 days, including more than 2,000 half-hourly observations of the barometer. During these seven months I was, if I may use the expression, "living under the clock;" for I had to keep a continual lookout for the arrival of the moment when one half hour after another would be up.

How often was I interrupted in my out-door manual labors in order to attend to these observations! And but the desire to help carry a few useful materials towards the building ground of the great structure of meteorology, which no doubt one day will be reared in all its perfection, could keep me at work with patience unwearied. I should have continued these half-hourly observations still longer, but my other engagements multiplied so much that I found it utterly impossible to do so. The clock I used is a first rate time-piece, and was compared, from time to time, with the meridian line laid down by observation of the north star.

No. 7 contains the *mean* barometrical heights of all the half-hourly observations made in 1857, recapitulated chiefly from table No 6, to which are added the monthly means of the barometer at 7 a. m., 2 p. m., and 9 p. m. These latter means are not the means of the *whole* months, but of those days only on which half-hourly observations have been made.

No. 8 exhibits the curves of mean height of the barometer in its course from 7 a. m. to 9 p. m., laid down according to the numbers in table No. 7. We find these curves to be much more regular, and more gradually and smoothly rounded off in proportion to the number of days, of which they are the mean result. So is, for instance, the curve *c*, resulting from the mean of eight months, more smoothly rounded than the curve of the month of August or that of May; and these again more smoothly rounded than the curves resulting from single days, which I have sent in my previous communications to you, and which are more or less angular.

The curve *c* in diagram No. 8 may therefore serve to illustrate the true and normal course of the periodical rise and fall of the barometer from 7 a. m. to 9 p. m. Its rise and fall from 9½ to 11 a. m., and from 4 to 5 p. m., are very inconsiderable; but from 1 to 2½ p. m., and from 7 to 9 a. m., far more rapid. There exists also a difference in the shape of the curve of the month of August compared with that of the month of May.

No. 9 contains the *mean* amplitudes of the barometer, calculated from table No. 6, for periods from six to six successive days; also, the mean amplitudes for periods from 12 to 12 days, and likewise those for the different months. All these mean amplitudes are laid down in diagram No. 10, in their proper position, according to their numerical value.

No. 10. The monthly means in the first curve exhibit a pretty regularly rounded curve. The second curve, that is, the curve of the twelve daily means, is somewhat more irregular. The third, or six daily curve, is still more irregular, exhibiting many projecting corners. The fourth and lowermost, which can no longer be called a curve, and of which, to save time, I have given only a small portion, exhibits in a striking manner the great fluctuation of the daily amplitudes.

At first view there seems to be not the least tendency in them to follow a certain law with regard to their mean value. This law, however, becomes apparent, when we look at the next curve above, and still more so in the two uppermost curves. The third curve shows, also, that the nature of the curve of mean amplitudes is not the same in every year; in 1857, for instance, it is much higher from October to December than it was in 1856. All this indicates plainly enough that the daily amplitudes of the barometer are subject to great disturbances by some cause or other.

Great as the irregularities caused by such disturbances are in the above curve, they do not invalidate the view I advanced in a former letter about the nature of this curve, as it ought to be in its normal value. In their main features both coincide, if we make due allowance for the short period during which these observations have been continued. The curve in diagram No. 10 having its first maximum near the 18th of May, its minimum near the 8th of July, and its second maximum near the 27th of October, and if we were to draw a mean line between the heights of 1856 and 1857, the second maximum would be near the 3d instead of the 27th of October.

No. 11. In order to compare the course of the morning temperature of Colonia Tovar with that of some place of the southern part of the United States, I have in diagram No. 11 laid down in dotted line the course of the temperature at 7 a. m. for the different days of March, 1852, as observed by me at Memphis, Tennessee, with the same thermometer with which I made my first observations at Colonia Tovar. The other line is the course of temperature at 7 a. m. for the different days of March, 1857, at Colonia Tovar.

Besides the regular observations specified above, I have made from time to time, just as occasion offered, memoranda on many other meteorological subjects which came under my observation. These memoranda were made either at the time of observation or immediately after. They are rather numerous, and for want of time I am unable at present to arrange them properly, or to make a selection from among them.

I may, however, afford so much time as to give the following:

July 27. In preparing for a journey to La Victoria, I rose early in the morning. At 4½ a. m. there was a dense fog. Intending to step out, and opening the kitchen door which leads into the open air, I saw the sprightly burning kitchen fire reflected from the fog as from a white, smooth, and solid wall; and, besides this, a halo of about twenty feet diameter, as plain and well defined as I ever saw around the moon. This halo, with the reflected fire in its centre, appeared to be close before me in a vertical plain, and it changed its position whenever I changed mine, either to the right or to the left.

At a first superficial glance upon the map it may seem as if the northern coast of Venezuela, on account of its great distance, can have nothing to do with the climate of the United States, or that the meteorology of the two countries can have no feature common to both; but observation proves it to be otherwise. And if we take a more comprehensive view of this vast region, we see that the Mexican gulf, together with the Caribbean sea, is nothing more than a great inland sea basin with numerous and spacious entrances to the northeast and east. Five States of the Union forming its northern shore; Venezuela, New Grenada, and Central America, its opposite or southern shore. Here I may also remark about the Venezuelan mountain range of the coast, that its northern declivity towards the sea is generally very steep, and in many places near its crest bearing marks of immense masses of its body having sunk on that side far below its original level, while on the other or southern side, no such marks are visible.

If we want to study in Venezuela the mutual influence of atmospheric currents of these two opposite shores, viz: The southern coast of the United states, and the northern of Venezuela, we must not try to do it on that low and extremely narrow strip of land, which, bordering the sea, stretches along the foot of the mountain chain running east and west, parallel with the seashore. This low and narrow strip of land has a climate of its own widely different from that of the United States. But when we take our abode on or near the top of the mountain ridge where we are above the steady eastern trade winds, and find ourselves in quite a different set of atmospheric currents, and if we then pay particular attention to the more violent northerly winds, which now and then blow in this region, and to the great southerly current, which lowers gradually in its course, reaches the surface of the sea somewhere between latitude 16° and 26° north, and generally blows steady during a great part of the summer and fall of the year up the Mississippi valley, even beyond latitude 39° north;* we then will recognize in the moisture-laden southeastern, as well as in the dry and chilling northwestern, by their very peculiarities, their namesakes of the United States.

It is but five or six times a year that I am fortunate enough to get hold of a few newspapers in these mountain solitudes, and it is seldom that they contain anything regarding the weather of the United States. However, I have read, only a few days ago, in a New York paper of August 22, 1857, the following:

"A private letter from New Orleans states that up to the 18th instant, it had rained there every day for thirty-eight days consecutively, and was still raining."

Now, by referring to my register of meteorology I find a singular coincidence between the occurrence of rain at New Orleans and Colonia Tovar. The inclosed table No. 2 exhibits this more strikingly, for we see here at once, that of all the seven months there is no other equally long period that can compare with the period from July 18, to August 20, with regard to the number of rainy hours.

The following sentence from the Weekly Herald of September 5, 1857:

"From New Mexico. The season has been unusually dry and cold, and the crops look very badly. So little rain has fallen that the little stream near Santa Fé is dried up," shows that the rain-spending southeast current of the atmosphere, which soaked in the month of August the soils of Colonia Tovar and New Orleans, never was felt at Santa Fé, New Mexico; and that there is a closer correspondence between the aëreal strata of the coast of Venezuela and the lower ones of Louisiana, than between those of Louisiana and those of Santa Fé, although the distance in a straight line between the two former places is more than double the distance between New Orleans and Santa Fé.

Again, we find in the Weekly Herald of January 17, 1857:

"A terrific hurricane swept over the city and harbor of Vera Cruz on the 20th of December," and "a heavy northerly gale had prevailed for several days previous to the 25th of December (at Havana.")

My meteorologicul register of Colonia Tovar shows, on the 17th of

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* While living at St. Louis, Missouri, I had a good opportunity to notice, during several years, in July, August, and September, a steady southerly breeze almost day after day. In some years, however, this wind blows less regular than in other years.

December, 1856, at 7 a. m., north wind, 4.; on the 19th, at 7 a. m., clouds from the north, 4.; on the 20th, at 7 a. m., clouds from the north, 3.; at 9 p. m., clouds from the north, 4. Number 4, as an indication of force attached to the winds or the clouds is extremely rare in the register for Colonia Tovar, and therefore denotes something extraordinary. The mean barometer height was remarkably low on the 19th, 20th, and 23d of December, vid: diagram of mean barometer height for 1856.

I could, no doubt, cite many more instances of this kind if I had the means to know what is going on in other parts of the world.

To make observations in this country about the higher strata of the atmosphere and their motions, no place, I should think, would be more adapted than the mountains of Merida, which are said to reach the line of perpetual snow. There we have a gigantic range of snow-capped mountains stretching from southwest to northeast. Its base is washed on one side by the warm waters of the gulf of Maracaybo, that great arm of the sea, which runs far inland, and expands in a vast basin near the mountains. On the other side lie, in near approach, those immense, level, grassy plains, the Llanos of Venezuela, which are but slightly elevated above the level of the sea, and entirely bare of forest.

When in the dry season the sun, unobstructed by clouds, acts upon the extensive sheet of the already very warm water of the gulf, with all the power of its nearly vertical rays, the quantity of vapor carried into the air by evaporation must be immense, while at the same time, on the opposite side of the mountains, the rarified strata of the atmosphere vibrate over the dry and burning hot surface of the llanos as over a heated furnace.

The phenomena which the different strata of air under such circumstances must exhibit would, I think, form a worthy and highly interesting subject of study for the meteorologist, and tend to advance the cause of his science. Happy he who has the means and the mind to do so!

In connection with the foregoing, I will mention only one phenomenon, near the lake of Valencia, which may show some of the effects of evaporation with regard to its disturbance of the atmosphere.

As often as I have visited Valencia in the dry season I have observed a violent northerly wind, amounting sometimes to a very stiff breeze, blowing there late in the afternoon till 10 or 11 o'clock at night. I found this same wind also in other parts of the valley of Aragua near the lake of Valencia, as, for instance, in Cagua and San José.

By inquiry I learned that this is a regular wind, commencing and ending with the dry season, returning every year as regularly as the season itself; that it rises every afternoon, continues till late at night, and is very annoying to the inhabitants by the dust it raises.

By referring to Humboldt's Travels I find the following sentence, where he speaks about the site of the town of Valencia: "But there is an opening on the meridian of Nueva Valencia, which leads towards the coast, and by which a cooling sea breeze penetrates every evening into the valleys of Aragua. This breeze rises regularly two or three hours after sunset."

Now, here we see that this phenomenon was as regularly exhibited fifty-seven years ago as it is now, and no doubt has been going on from time immemorial. The same causes that were then at work are still at work as forcibly as ever. While at Valencia the slapping of the doors, the columns of dust that came sweeping by, and other signs of a violent rush of wind indicated to me with unfailing certainty that it was after 3 or 4 p. m. Travellers and muleteers, in going from Valencia to Puerto Cabello, are especially annoyed on the first six miles of their road by the dust, so that they have to cover their faces or shut their eyes most of the time.

It was natural for me to reflect upon the probable cause of this phenomenon, and a circumstance soon presented itself to help me towards the solution of this problem.

For on the 11th of March the sky was densely clouded, all day, over Valencia, and the whole valley of Aragua, including the lake, and it looked as if it was going to rain. In the evening, the usual regular wind failed to make its appearance altogether.

To account for the alternating daily land and sea breezes of the coasts in general, there exists a well-known explanation, based upon the rarefaction of the air by the heated surface of the land or water. This explanation, however, will not do in the above case; for at Valencia the wind begins to blow from the seaside not in the morning, when the land becomes heated, but, on the contrary, in the afternoon when the land begins to cool again.

When in equatorial regions the direct rays of the sun act for some time upon a widely spread mass of water, surrounded by land, as, for instance, a lake, they evaporate powerfully the water from its surface; that is, they convert a liquid into an aëriform fluid. In this latter state the water requires several hundred times more room and exerts a certain pressure which added to the pressure of the atmosphere,* with which this vapor is mixed, overpowers the surrounding *dryer* atmosphere, and spreads or shoves the latter outward in all directions to make room for itself. In such an atmosphere, saturated with invisible vapor, its permanent gases are much more attenuated than when in a dry state; but they nevertheless exert, by the aid of the invisible vapor, an overwhelming outward pressure.

That amount of pressure, however, which the vapor exerts, can be easily annihilated by condensation, and thereby a partial vacuum be produced, into which the external air will strive to rush with great force.

Now, in the surrounding bottom lands of the lake, the air loses towards evening, in the dry season, by radiation against an unclouded sky, more caloric than it receives.

It therefore seems highly probable, that the *gradual decrease of temperature*, by which the vapors of the air above the lake of Valencia lose part of their tension, is the cause of the regular breeze which

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* According to the great fundamental principle, that in any given space, the power of tension of two or more mixed aëriform bodies is equal to the sum of all those tensions which each of these aërial bodies would exert, if it was to occupy the whole space by itself.

blows as long as the temperature of the air falls: that is, till 10 or 11 o'clock at night. It is easy to imagine what a hurricane would blow if the cooling and condensing of the vapors were to be very sudden. What interesting barometrical and other observations could be made in the neighborhood of this lake!

Very frequently at night or evening, throughout the rainy season, we may observe, at Colonia Tovar, favored by the absence of daylight, flashes of lightning unaccompanied by any audible noise of thunder. This noiseless discharge of electricity shows itself also frequently in the daytime; but of all the many discharges of lightning during a three and a half years' residence I have heard only once or twice thunder loud enough to be compared with those of the United States.

Register of meteorological observations for Colonia Tovar, Venezuela, from June, 1857, to December, 1857, inclusive, by A. Fendler.

Date.	Rain.		Clouds.												Well defined winds.					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direct'n.	Force.	Direct'n.	Force.	Direct'n.	Force.
1857. June 1	3.50 p. m.	4.10 p. m.	3	SE.	2	......	7	S.SE. E.	2 2	......	5	......	......	......	......	......	......	......	......	......
2	......	......	9	S.SE.	2½	......	5	S.SE.	2½	......	7	SE.	3	......	......	......	......	......	......	......
3	6.5 p. m.	6.10 p. m.	6	S.SW. S.	1 1	High Low.	5	SE.	2	......	6	S.	1	......	......	......	......	......	S.	2
4	8.40 a. m. 9.30 a. m. 3.55 p. m. 4.40 p. m.	9.10 a. m. 9.40 a. m. 4.20 p. m. 6.15 p. m.	8	E.	1	......	6	SE.	2½	......	6	E.	2	......	......	......	......	......	......	......
5	10.55 a. m. 2.45 p. m. 4.40 p. m.	11.30 a. m. 2.55 p. m. 5.15 p. m.	7	E.SE.	2½	......	7	S. E.	2 2	......	10	SE.	2	......	......	......	......	......	......	......
6	5.50 a. m. 7.40 a. m.	6.30 a. m. 5.10 p. m.	10	......	......	Fog.	10	N.	3	Fog.	9	E.SE.	3	......	N. descend	4 ing.	N.	3½	......	......
7	......	......	10	SE.	2½	......	8	S.SE.	2½	......	0	......	......	......	......	......	N. in gusts.	3	......	......
8	......	......	1	SE.	2½	......	6	S. NE.	2½ 2	......	1	......	......	......	......	......	......	......	W.	1
9	......	......	1	S.SE.	2	......	3	E.SE.	2	......	8	E.SE.	2½	......	......	......	......	......	......	......
10	4.55 p. m.	5.30 p. m.	3	E.SE.	2½	......	7	SE. E.	2½ 2½	......	0	......	......	......	......	......	......	......	......	......
11	10.45 a. m. 6.40 p. m.	11.15 a. m. 8.10 p. m.	4	...... E.	...... 2½	...... Low	10	NE.	2	....	5	....	....	....	....	....	....	....	S.	2 ......
12	6.25 a. m. 10.45 a. m. 4.5 p. m.	7.30 a. m. 11.10 a. m. 5.15 p. m.	10	...... E.	...... 2½	...... Low	10	SE.	2	....	10	....	....	....	....	....	....	....	....	....
13	At night 11.15 a. m. 1 p. m.	6.30 a. m. 12.10 p. m. 1.40 p. m.	10	E.	2	......	10	E.SE.	2½	......	4	......	......	......	......	......	......	......	W.	2
14	......	......	3	S.	2	......	7	E.	2½	Low.	0	......	......	......	......	......	......	......	......	......
15	......	......	10	E.NE.	2	......	5	S. E.	2½ 2½	......	0	......	......	......	......	......	......	......	W.	1
16	......	......	1	W.	2	High	3	S. & SE.	2½	......	3	......	......	......	......	......	......	......	W.	1
17	......	......	10	......	......	......	5	SE.	2½	......	9	......	......	......	......	......	......	......	......	......
18	......	......	10	S.	2½	......	7	SE.	2	......	0	......	......	......	......	......	......	......	W.	2
19	......	......	10	SE.	2	......	10	SE.	2	......	10	......	......	......	......	......	......	......	......	......

20	5.10 a. m.	8.20 a. m.	10	S.	2½	Fog	10	S.	2½		0								W.	1
								E.	2											
21	10.30 a. m	3.20 p. m.	10	S.	2½	Fog	10	SE.	2½		10									
22			3	SE.	2		6	E SE.	1		3								W.	1
23	7.20 a. m.	7.50 a. m.	10	SE	2		9	SE.	2		10								NE.	2½
	5.20 p. m.	8.30 p. m.																		
24			7	S	2		7	E.	1		5									
				E.	2			S.	1											
								E.	2											
25	2.40 p. m.	2.55 p. m.	10				8	E	2½		5								W.	1
	8.15 p. m.	8.25 p. m.		E.SE.	2½	Low														
26	6.35 a. m.	8.30 a. m., mist.	10				10	S.	2½		4	E.SE.	2½							
	9.40 a. m.	12.15 p. m., mist.		E.SE.	1	Fog & mist.		E.SE.	2½											
	12.15 p. m.	1.30 p. m.																		
27	5 p. m.	5.15 p. m.	9								8								W.	1
	5.40 p. m.	6.5 p. m.		E.SE.	2	Low	7	E.SE.	2½	Low										
28	10.30 a. m.	11.20 a. m.	10				10				9								W.	2
	1.30 p m.	3.10 p. m.		E.	2	Fog		E.	2	Low										
	5 p. m.	7.30 p. m.																		
29	11.30 a. m.	12.50 p. m.	8	S.	2		10				4				N.	2			SW.	2½
	1.45 p. m.	4 p. m.		E.	1			E.	2	Low		SE.	2½							
30	3.5 p. m.	3.30 p. m.	10	SE.	2½		9	E.SE.	2½		10	E.SE.	2							
	5.30 p. m.	6.50 p. m.																		
	7 20 p. m.	8.30 p. m.																		
Total.			223				227				171									
Mean			7.4				7.6				5.7									

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857.																	
June 1	23.994	23.979	24.000	58	63	59	60	68	57	61.7		The same as thermometer in open air.		58	62½	55	
2	.976	.958	23.976	58	62	60	58	64	58	60.0				56½	60	57	
3	.960	.974	.992	57	63	59	57	65	57	59.7				52	59	54½	
4	24.004	.988	.996	58	64	59	57	64	57	59.3				55	59	55	
5	23.998	.972	.984	59	64	59	59	65	57	60.3				57	61	57	Thunder at 5¾ p. m.
6	.978	.954	.980	57	58	55	55½	57	55	55.8				55	57	53½	
7	.976	.960	.966	55	61	57	54	60	55	56.3				54	56	52	
8	.982	.985	.982	55	63	57	55	62	55	57.3				52	56	53½	
9	.960	.950	.970	56	62	59	58	64	56	59.3				55	56	55	
10	.948	.946	.936	57	64	57	58	67	56	60.3				55	61	53½	
11	.921	.910	.906	58	63	59	57	62	56	58.3				54	59	55	Barometer unusually low in the afternoon. Strong gusts of wind from the E. at 7¼ p. m.
12	936	.940	.962	57	60	57	55	60	55	56.7				55	59	55	
13	.982	.960	.956	57	61	55	56	61	52	56.3				55	60	49	
14	.952	.964	.952	55	62	56	55	63	54	57.3				54	58	51	
15	.948	.944	.946	57	63	55	56½	64	52	57.5				56	59	51½	
16	.950	.968	.974	55	64	60	55½	64	57	58.8				50	57	56	
17	.982	.986	.988	57	63	59	57	64	56	59.0				54	58	53	
18	.964	.956	.946	55	61	57	56	61	54	57.0				48	56	52	
19	.962	.946	.978	57	61	59	56	61	57	58.0				55	58	56	
20	24.010	.984	24.016	56	58	57	53	59	56	56.0				53	57	54	
21	.020	.996	.016	56	58	57	56	60	55	57.0				55	58	55	
22	.000	.974	23.976	56	62	56	56	63	54	57.7				54	57	53	
23	23.960	.956	.964	56	62	59	55	65	57	59.0				54½	60	57	
24	.960	.966	.960	57	62	59	57	65	60	60.7				54½	59	54	
25	.964	.951	.970	57	63	60	55	66	58	59.7				54½	60	57	
26	.960	.948	.964	58	61	58	57	62	57	58.7				56½	60	56	
27	.976	.985	.974	58	64	60	57	65	59	60.3				55	59	57	
28	.966	.960	.966	59	60	57	58	59	57	58.0				57½	58½	53	
29	.970	.952	.956	57	58	56	56	58	56	56.7				55	57	52	
30	23.966	23.952	23.968	56	62	60	55	64	58	59.0				54½	60	57	
Total.....	119.125	1.864	119.120	....	....	....	1690½	1882	1683	1.7517	....	....	....	1634½	1737	1629½	
Mean.....	23.971	23.962	23.971	....	....	....	56.3	62.7	56.1	58.4	....	....	....	54.5	58.5	54.3	
		23.968						58.4							55.8		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds, (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. July 1			7	S.	2		9				3									
								E.SE.	2	Low										
2*			3	E.SE.	2½		5	W.	1	High	3									
								E.SE.	2½	Low		E.SE.	3							
3			8	S.	1	High	9				7									
				S.SE.	2½	Low		E.SE	2											
4	7.45 p. m.	8.10 p. m.	5	SE	2	High	6	SE	2		7									
				E.SE.	1	Low		E.SE.	2½			E.SE.	2½							
5	1 p. m	1.45 p. m.	10	SE.	2		8	S.SE.	2		10									
	3.5 p. m.	3.30 p. m.						S.SE	2½											
	3.50 p. m.	4.10 p. m.																		
6	4 a. m.	4.30 a. m.	10	S.SE	2		10	SE.	2		3								W.	2
	7.15 a. m.	11.30 a. m.																		
	2.30 p. m.	3.15 p. m.																		
	7.15 p. m.	7.30 p. m.																		
7	8.15 a. m.	10.20 a. m.	10			Mist & fog.	10				10				NE.	1				
	4 p. m.	4.45 p. m.						E.SE.	2	Low										
	5.30 p. m.	7.45 p. m.																		
8			10	S.SE	2½		8	S.	1		8									
								SE.	2											
9			7	W	2	Cirr.	6	W	2	Cirr.	1								W.	1
				S.SE.	2			E.	2	Middle										
10			2	W.	2½	Cirr.	9	S.	2½		8								W.	1
				S.	2½	Low		E.SE.	2½											
11	11.15 a. m.	1.30 p. m.	9	E.	1	Middle	10	Stationary			10									
	2 p. m.	2.45 p. m.						N.	1	Low										
	7.15 p. m.	8 p. m.																		
12	During the	night.	10	S.SE.	3		10				9									
	12.10 p. m.	1.30 p. m.						NE.	3	Low										
	3.15 p. m.	5 p. m.																		
13			6	E.	2	Middle	5	S.SW.	2½	Middle	4								W.	1
				S.	2½	Low		S.SE.	2½	Low										

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds, (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. July 14			10	S.	2	Low	7	S. & SE.	2	Low	0								W.	1
				and SE.	2	Low.														
15			0	Calm			7	S.	1	Middle.	0								W.	1
								E.	2½	Low										
16			0				8	N.NE.	2	High	0								W.	2
								S. & E.	2½	Low										
17			3				6	S.SE.	2	Middle	1									
				E.	2	Low		E.	2	Low										
18	3.55 p. m.	6 p. m., heavy.	3	S.	2	Middle.	9		2½		5								W.	2
								S.SE. & E	2	Low										
19	12 30 p. m.	12.45 p. m.	7	S.SW.	1	High	10	E.NE.	2	Low	2								W.	2
	1.30 p. m.	3.40 p. m.																		
20	12.30 p. m.	1.15 p. m.	1	E.	1		10	S.	1		3									
	1.30 p. m.	2.5 p. m.																		
	3.50 p. m.	4.15 p. m.																		
21	9.15 a. m.	10.40 a. m.	10	SW.	2	Middle.	9	S.	2		10			Fog						
								and E.	2											
	12.30 p. m.	3.10 p. m.																		
	8 p. m.	8.45 p. m.																		
22	4.30 a. m.	5 a. m.	6	SE.	2	Middle.	8	S.	1		10									
	3 p. m.	3.5 p. m.		SE.	2½	Low.		S. & E.	2½											
									2											
23	8.50 a. m.	9. a. m.	10				10	E.NE.	2½		8									
	1.20 p. m.	5.50 p. m.		SE.	2															
24	7.5 a. m.	7.45 a. m.	10				9	S.SE.	1		7									
	9 a. m.	11.15 a. m., mist.		E.	2	Fog.		SE.	2											
25			3	E.SE.	2		7				1								W.	1
								E.	2											
26	7.35 a. m.	7.45 a. m.	10	SE.	2		9	S SE.	2½		10									
27	7 a. m.	2.30 p. m., mist.	10			Fog.	10	SE.	2		3								W.	1
28	12.15 p. m.	3.10 p. m.	5				8	SE	2		10									
				E.	2															

29	6.15 a. m.	7.45 a. m.	10				7				5								W.	1
	9.15 a. m.	9.50 a. m.		E.	2	Fog		E.SE.	2½											
	3.15 p. m.	4.20 p. m.																		
30	3.25 p. m.	3.45 p. m.	6	Stationary			9				9								W	2
	3.55 p. m.	4.15 p. m.						E.SE.	2			E.SE.	1							
	4.30 p. m.	5.10 p. m.																		
31	12.30 p. m.	12.40 p. m.	10			Fog	10	S.SW.	1		2	N.	2						W.	2
	1 p. m.	3.10 p. m.																		
Total			211				258				169									
Mean			6.8				8.3				5.4									

* Gusts of strong wind alternately from E., NE., S., and W., till 7 a. m. July 3; barometer high from 9 a. m. to 1 p. m.

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857. July 1	23.940	23.949	23.973	57	62	58	57	62	57	58.7		The same as thermometer in open air.		53	59	55	
2	.966	.968	.960	57	62	57	58	64	56	59.3				55	58	53	
3	.950	.942	.932	54	61	57	54	65	55	58.0				51	58	53	
4	.908	.920	.938	56	64	60	56	66	55	59.7				51	59	56	
5	.946	.942	.968	59	61	59	57½	63	59	59.8				57	60	58	
6	.966	.945	.966	58	61	59	57	62	56	58.3				56	60	55	
7	.944	.920	.938	58	62	57	57	61	56	58.0				57	58	55½	
8	.932	.940	.934	56	62	59	56	64	56	58.7				55	59	55	
9	.926	.942	.944	56	62	56	56	64	55½	58.5				55	57	52	
10	.944	.960	.962	57	63	58	57	65	55	59.0				55	60	53	
11	.958	.956	.984	55	61	59	56	60	57	57.7				51	60	55	
12	.928	.970	.994	56	58	56	54	59	55	56.0				52	58	54	
13	24.009	.994	.998	58	61	57	57	62	55	58.0				56	58	54½	
14	.010	24.020	24.006	57	65	59	56	68	56	60.0				55	62	55	
15	.010	.011	23.994	56	64	56	58½	68	54	60.1				54½	61	52	
16	23.978	23.968	.976	56	63	59	58	65	56	59.7				55	60	55	
17	.968	.972	.964	55	62	59	56	65	55	58.7				54½	58	54	
18	.977	.960	.978	58	63	56	57	65	54	58.7				55	60	53	Thunder.
19	.964	.970	.956	56	60	55	56	57	53	55.3				54	57	51	
20	.942	.944	.962	56	61	58	58	59	56	57.7				54½	57	55	
21	.938	.928	.943	56	61	61	55	62	58½	58.5				55	59	58½	
22	.944	.942	.948	57	63	60	56	64	59	59.7				55	60	58	
23	.935	.932	.950	59	62	57	57	59	56	57.3				56	58	54	
24	.940	.955	.962	56	60	58	55	60	56	57.0				55	58	54	
25	.958	.977	.956	56	63	56	55	62	57	58.0				53	57	56	
26	.976	.975	.980	57	63	61	55½	64	59	59 5				54	58½	58	
27	.992	.982	.984	57	63	60	56	63	56	58.3				55	61	55	
28	.980	.974	.974	57	64	60	57	66	58	60.3				55	61	57	
29	.978	.992	.996	59	63	58	56	65	55	58.7				56	60	54	
30	.988	.992	24.016	57	64	60	58	65	58	60.3				55	60	57	Thunder, very faint, at 5 p. m.
31	24.000	.976	23.984	58	59	59	57	59	56	57.3				57	58	55	
Total....	122.849	122.818	123.020	....	....	....	1749½	1953	1742	181.48	....	....	....	1692½	1829½	1700½	
Mean....	23.963	23.962	23.968	....	....	....	56.4	63.0	56.2	58.5	....	....	....	54.6	59.0	54 9	
		23.964						58.5							56.2		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds, (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Aug. 1	2.45 p. m.	4.5 p. m.	9	....	....	....	7	....	....	....	7	....	....	....	....	....	....	....	....	....
	4.30 p. m.	6.25 p. m.	....	SE	2	Low	....	E	2	....	....	E	1	....	....	....	....	....	....	....
2	12.45 p. m.	1.30 p. m.	3	E	1	....	6	SE	2	....	10	....	....	Mist.	....	....	....	....	....	....
	4 p. m.	5.35 p. m.	....	E	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	1.45 p. m.	4.25 p. m.	3	SE	1	....	10	....	....	....	10	NE	1	....	....	....	....	....	....	....
	6.45 p. m.	8.30 p. m.	....	....	....	....	....	E	1	....	....	....	....	....	....	....	....	....	....	....
4	10.30 a. m.	10.50 a. m.	9	E	1	....	10	From W.	Top.	} of lower	5	....	....	....	....	....	....	....	....	....
								From E.	Base	} clouds.	....	E.	1	....	....	....	....	....	....	....
5	6.15 a. m.	7.10 a. m.	10	....	....	....	10	E.SE	2	....	9	Station'y	....	....	....	....	....	....	....	....
	9.20 a. m.	12.15 p. m.	....	E	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	1.30 p. m.	1.45 p. m.																		
	2.5 p. m.	4.15 p. m.																		
6	5.10 p. m.	5.20 p. m.	1	....	....	....	7 }	SW S.	2½ 2	High Middle	} 10	....	....	....	....	....	....	....	....	....
	5.35 p. m.	6.15 p. m.																		
7	11.45 a. m.	6.5 p. m.	9	....	....	....	10	SE	2	....	9	....	....	....	....	....	....	....	W	1
	7.50 p. m.	8.40 p. m.	....	E	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	8.30 a. m.	10 a. m.	9	E.SE	2	....	10	E.SE	2	....	10	....	....	Fog	....	....	....	....	....	....
	12.10 p. m.	12.30 p. m.																		
	1.15 p. m.	1.30 p. m.																		
	2.30 p. m.	3 p. m.																		
	5 p. m.	8.30 p. m.																		
9	12.35 p. m.	3.30 p. m.	10	E.SE	1	Fog	10	....	....	....	0	....	....	....	....	....	N.NE	2½	W	2½
								E	2	Fog	....	....	....	....	....	....	....	....	....	....
10	4.30 p. m.	4.40 p. m.	10	E.	2	....	10	....	....	....	10	S.SE	2	....	....	....	....	....	....	....
				SE	2	....	....	E.SE	....	....	....	E	2	....	....	....	....	....	....	....
11	....	....	8	....	....	....	5	E SE	1	....	3	....	....	....	....	....	....	....	W	1
								E.SE	2	....	....	....	....	....	....	....	....	....	....	....
12	3.30 p. m.	5.50 p. m.	6	....	....	....	9	NE. & SE.	2	....	10	....	....	....	....	....	....	....	W	2
	6.45 p. m.	9 p. m.	....	E	2½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	12.30 p. m.	2.30 p. m.	9 }	NE. S SE	1 2 }	....	10	SE	2	....	10	....	....	....	....	....	....	....	....	....
	7.50 p. m.	8.5 p. m.																		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds, (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Aug. 14	12.20 p. m.	12.30 p. m.	9	E.SE	1	......	10	NE.&E.SE	1	......	2	......	......	......	......	......	......	......	W	2½
	1.5 p. m.	1.55 p. m.																		
	2.10 p. m.	3 p. m.																		
15	1.55 p. m.	3 45 p. m.	3	SW	2	......	10	......	......	......	10	......	......	......	......	......	......	......	......	......
	8.45 p m.	9.30 p. m.	......	......	......	......	......	E	1	......	......	......	......	......	......	......	......	......	......	......
16	7.30 a m.	9 a. m.	10	NE. & SE	2	......	10	......	......	......	6	......	......	......	......	......	......	......	W	2½
	9.15 a. m.	1.30 p. m.																		
	2.30 p. m.	4 p. m.																		
	4.30 p. m.	5.30 p m.																		
17	7.30 a. m.	11 a. m.	10	NE and E.SE	2 2	Mist	10	S.SW and E	2 2	......	1	......	......	......	......	......	......	......	W	2
	12.15 p. m.	1.50 p. m.																		
	3.5 p. m.	4 p. m.																		
18	2.30 p. m.	2.40 p. m.	8	W.E E	1 2	High Middle	7	E.NE E S	1 2½ 2½	High Middle Low	8	......	......	......	......	......	......	......	E.NE	2
19	9.15 a. m.	11.30 a. m.	10	NE and E.SE	1 1	High Middle	10	E	1	......	10	......	......	......	......	......	......	......	......	......
	11.45 a. m.	8.30 p. m.																		
	10 p. m.	12 p. m.																		
20	12.30 a. m.	6 a. m.	10	......	......	Fog	10	SW and S.SE.	2 2	......	7	......	......	......	......	......	......	......	W	2
	6.10 a. m.	8 a. m.																		
21	5 p. m.	7.15 p. m.	10	SE	2	......	7	S.	2½	......	10	......	......	......	......	......	......	......	......	......
22	3.45 p. m.	5 p. m.	5	SE	2½	......	10	S.SE	2½	......	10	......	......	Mist	......	......	......	......	......	......
23	2.45 p. m.	4.15 p. m.	10	......	......	Fog	10	E	2½	......	10	......	......	......	......	......	......	......	W	1
24	......	......	10	N	2½	Fog	8	E and SE	2½ 2½	......	7	......	......	......	......	......	......	......	......	......
25	......	......	3	E	2	Middle	7	E	2	Middle	3	......	......	......	......	......	......	......	W	1
26	1.15 p. m.	1.30 p. m.	1	N NE air unusually dry	2 2½	High Middle	10	SE	1	......	10	......	......	......	NE., in gusts.	3	......	......	......	......
27	4.30 a. m.	6.15 a. m.	10	SE	2	Middle	10	S.SE S	2 2½	High Middle	8	S	2½	......	......	......	......	......	......	......

28	6.50 a. m..	7.30 a. m..	4	S...	3	....	5	S.......	3		2									
29	....	....	7	S........	3	....	10	S	3	....	9	S.SE ...	2½	....	....	......	....	......	....	......
								E	2½	....	......	....	......	....	....	......	....	......	....	......
30	4 p. m.....	5.15 p. m..	7	S .... S SE.....	1 2½	Cirr ... Middle	8	NE...... SE......	2 1	High ... Middle ..	4	Station'y	......	....	....	......	....	......	....	......
31	1.30 p. m..	2 p. m.....	8	W ...... E	1 2	Cirr ... Middle	10	....	......	....	4	....	.....	....	....	......	....	......	W	1
	2.25 p. m..	3.50 p. m..	....	....	......	....	......	E	2	Low	......	....	......	....	....	......	....	......	....	......
Total...	....	....	231	....	......	....	276	....	......	....	224	....	......	....	....	......	....	......	....	......
Mean...	....	....	7.5	....	......	....	8.9	....	......	....	7.2	....	......	....	....	... .	....	......	....	......

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857. August 1	23.976	23.972	23.992	58	63	59	58	64	56	59.3		The same as thermometer in open air.		56	60	55	
2	.948	.954	.976	56	62	60	55½	65	59	59.8				54	61	58	
3	.952	.992	.978	59	63	61	59	60	59	59.3				57½	59	58½	Thunder at 4*h*.30 p. m.
4	.952	.940	.958	59	63	60	58	64	57	59.7				56	62	57	
5	.930	.928	.939	59	60	58	57	61	55	57.7				57	59½	55	
6	.924	.936	.960	56	62	60	58	61	58	59.0				55	58	58	Thunder at 9 p. m.
7	.948	.940	23.966	60	60	58	58	58	57	57.7				57	57	56	
8	.968	.968	24.000	58	62	61	56	64	59	59.7				56	63	58	
9	23.986	23.994	.008	59	60	56	57	58½	55	56.8				57	58	53	
10	24.004	24.004	.008	57	62	59	57	62	57	58.7				54	60½	57	
11	23.986	23.996	.006	57	63	58	57	66	57½	60.2				56	59	56½	
12	24.022	.998	.042	58	64	58	57	66	55	59.3				55	61	54	Thunder at 6 p. m.
13	24.002	.988	24.023	58	60	59	56	60	56	57.3				55	59	55½	
14	24.000	.990	23.992	57	59	56	56	56	55	55.7				55	56	53	
15	23.956	.942	23.970	56	61	60	56	60	57½	57.8				55	59½	57	Thunder at 8*h*.45 p. m.
16	23.968	23.966	24.008	59	59	57	56	58	56	56.7				55	57	55	
17	24.008	24.002	24.000	57	59	56	55	58	55	56.0				55	56	54	
18	23.986	24.002	24.004	57	63	58	59	65	57	60.3				55	60	54	
19	.952	23.908	23.942	57	60	58	56	58	55½	56.5				55	57½	55½	
20	.972	.980	.994	56	58	56	54	58	56	56.0				54	57	54	
21	.992	.984	.996	57	62	59	57	66	57	60.0				55	64	57	
22	.980	.984	23.990	57	62	59	57	64	57	59.3				56	62	57	
23	.984	23.990	24.018	57	60	59	56	60	56	57.3				56	59	56	
24	24.020	24.038	.056	57	61	60	55	64	58	59.0				55	60	57	
25	.046	.052	.042	58	63	59	60	65	56	60.3				56½	60	52	
26	.022	.016	.032	57	61	59	57	61	57	58.3				51	57	56½	
27	.024	.008	.028	59	63	60	56	66	56	59.3				56	64	56	
28	.022	.012	.014	56	63	59	56	63	56	58.3				54	58	55	
29	.022	.010	.042	58	61	60	57	63	59	59.7				55½	60	57½	
30	24.041	24.022	24.022	59	65	59	59	65	55	59.7				57	59	53	
31	23.995	23.962	23.966	57	63	58	58	61	55	58.0				53	60	53	
Total....	123.588	123.478	123.972	....	....	....	1763½	1920½	1754½	181.27	....	....	....	1714½	1843	1724	
Mean....	23.987	23.983	23.999	....	....	....	56.9	62.0	56.6	58.5	....	....	....	55.3	59.5	55.6	
		23.990						58.5							56.8		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Sept. 1	1.20 p. m.. 3.45 p. m..	1.40 p. m.. 4 p. m.....	2	W	1	H	9	N	2	....	5	....	......	......	....	....	....	......	....	......
2	10.45 a. m 2.45 p. m.. 6.45 p. m..	12 m ..... 3.20 p. m.. 8.30 p. m..	3	S	1	....	10	E.NE.... S	2½ 2	M......	10	S	2	....	NE....	2½	....	......	....	......
3	....	....	10	SE......	2½	....	5	E SE.....	2	....	1	....	......	....	....	......	....	......	S	1
4	4.10 p. m..	4.35 p. m..	10	SE......	2	....	6	SE......	2½	....	3	....	......	....	....	......	....	......	W	2
5	4.30 a. m.. 2.45 p m.. 4 p. m.. ..	5 a. m..... 3.5 p. m... 6.15 p. m..	7	SE.....	2	....	9	S.SE ... and N...	1 1	....	9	....	......	....	....	......	....	......	W	1
6	....	....	2	E.NE....	1	H	7	E SE	2½	....	10	....	......	....	....	......	....	......	W	1
7	1.25 p. m.. 5.10 p. m.. 6.25 p. m..	2.30 p. m.. 5.30 p. m.. 7.15 p. m..	6	S.SE.....	2½	....	10	S.SE ...	1	....	10	....	......	....	....	......	....	......	N	2½
8	....	....	9	SE......	3	....	4	S.SE.... S.SE....	1 3	H	6	....	......	....	....	......	....	......	....	......
9	....	....	1	W	1	Cirr ...	5	S	3	....	4	....	......	....	W	2	....	......	W	2
10	....	....	7	SE......	2½	....	5	S.SE....	2	....	10	....	......	....	....	......	....	......	....	......
11	....	....	1	Stationary	......	....	8	SE ...... and S.SE.	2 2½	M......	0	....	......	....	....	......	....	......	W	2
12	....	....	1	....	......	....	5	SE......	2	....	0	....	......	....	....	......	....	......	W	2
13	....	....	9	S	1	....	7	S .... and E ...	2½ 1	....	10	....	......	....	....	......	....	......	....	......
14	3.15 a. m.. 5 p. m.....	3.45 a. m. 5.30 p. m..	10	NE......	2	Fog ...	10	SE......	2	....	3	....	......	....	....	......	....	......	W	2
15	....	....	5	SE......	2	....	5	S	2½	....	3	....	......	....	....	......	....	......	W ...	2
16	....	....	3	....	......	....	5	S	2½	....	10	....	......	....	....	......	....	......	....	......
17	....	....	7	....	......	....	7	E NE....	1	....	10	....	......	....	....	......	....	......	....	......
18	1.30 p. m..	2.25 p. m..	10	SE.....	2	....	10	NE. & SE	2½	M.......	2	S	1	....	....	......	NE . .. in gusts.	3	W	2½
19	....	....	8	Stationary	......	....	10	S .... and E ...	2 2	....	5	....	......	....	....	......	....	......	W	2

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Sept. 20	11.55 a. m. 1.40 p. m. 4.40 p. m. 7.15 p. m.	1.10 p. m. 2.45 p. m. 5 p. m. 8.45 p. m.	5	W ... S ...	1 2	H ... M ...	10	Stationary	...	...	6	...	...	...	...	...	...	...	W ...	2
21	...	...	1	...	...	...	9	S ... E ...	3 2	...	0	...	...	...	...	...	...	...	W ...	1
22	12.30 p. m.	1.30 p. m.	2	N ...	1	H ...	9	S ... and E.SE	2 2	M ...	10	...	...	...	...	...	...	...	...	...
23	3.50 p. m. 1 p. m. 4.30 p. m.	4.30 p. m. 3.5 p. m. 5.10 p. m.	8	N ...	1	H ...	10	SE ...	1	...	5	...	...	...	...	...	...	...	W ...	1
24	...	...	5	W ...	1	H ...	7	SE ...	2	...	8	...	...	...	...	...	...	...	...	...
25	8.30 a. m. 10.35 a. m. 1.30 p. m.	8.45 a. m. 12.10 p. m. 4.50 p. m.	7 ...	W.SW ... SE ...	2 2	Cirr ... M ...	10 ...	S ... E ...	2 1	...	10	...	...	...	...	...	...	...	...	...
26	Greater part of last night till 6.30 a. m.		10	S.SE ...	2	...	10	SE ...	2	...	3	...	...	...	...	...	...	...	W ...	1
27	...	...	3	W ...	2	H ...	9	S ...	2	...	4	E ...	2	...	...	...	...	...	W ...	2
28	...	...	3	...	...	...	10	SE ...	2	...	5	...	...	...	...	...	...	...	W ...	2
29	8.30 p. m.	9.15 p. m.	3	...	...	...	9	SE ...	2	...	10	...	...	...	...	...	...	...	...	...
30	1 p. m. 3 p. m. 5.50 p. m.	2.35 p. m. 3.15 p. m. 7 p. m.	10	Stationary SE ...	... 1	H ... M ...	10	E ...	1	...	9	...	...	...	...	...	...	...	...	...
Total ...	...	...	168	...	...	...	240	...	...	...	181	...	...	...	...	...	...	...	...	...
Mean ...	...	...	5.6	...	...	...	8.0	...	...	...	6.0	...	...	...	...	...	...	...	...	...

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer att.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857.																	
Sept. 1	23.946	23.942	23.938	56	63	55	57	62	55	58.0		The same as thermometer in open air.		51½	60	51	
2	.930	.942	978	56	61	58	56	61	56	57.7				55	59	56	
3	.954	.976	.980	57	61	59	57	66	59	60.7				56½	61	55	
4	.972	.974	.988	59	65	59	57	66	56	59.7				56	61	55	Thunder at 4*h*.15 p. m.
5	24.000	.994	21.004	60	65	59	57	67	57	60.3				57	62	55	Thunder and lightning more energetic than usual at 5 p. m.
6	23.973	.976	23.992	57	65	61	59	68	59	62.0				56	61	58	
7	.970	.968	.988	59	63	59	59	62	57	59.3				57½	60	56	
8	.985	.985	24.004	58	62	58	56	64	57	59.0				56	57	54	
9	.980	.988	24.012	57	63	59	58	66	57	60.3				54	61	55	
10	24.016	24.012	24.038	58	64	61	58	67	59	61.3				56	60	58	
11	21.028	24.004	23.992	58	65	58	60	66	55	60.3				54	62	49	
12	23.950	23.952	.956	58	64	56	57	69	53	59.7				50	61	52	Temp. at sunrise, 51°.
13	.940	.934	.976	58	64	60	56	65	59	60.0				55	61	58	
14	.970	.970	.988	59	61	59	56	61	57	58.0				55	59	55	
15	.964	.970	.980	59	61	60	58	68	56	60.7				56	61	55	
16	.950	.938	.964	57	66	61	58	68	59	61.7				54	60	57	
17	.948	.942	.950	56	64	61	58	70	57	61.7				54	62	56	
18	.956	.944	.972	59	60	58	57	57	57	57.0				56½	56	53	
19	.960	.960	.968	58	63	59	58	63	57	59.3				55	60	55	
20	.947	.948	.980	59	64	59	59	62	58	59.7				57	61	55	Thunder at 5*h*.45 p. m.
21	.972	.972	.972	58	65	60	59	66	56	60.3				57	61	55	
22	.958	.962	.974	55	64	61	55	65	59	59.7				50½	61	58	Temp. at sunrise, 49°.
23	.944	.938	.960	58	63	60	59	62	56	59.0				57	60	55	
24	.924	.944	.956	57	63	60	60	67	58	61.7				55	60½	56	
25	.964	.936	.993	59	60	58	59	60	58	59.0				57	59	57	
26	.968	.946	.960	57	61	59	56	62	56	58.0				54	58	55	
27	.940	.939	.960	56	63	57	57	64	54	58.3				54	60	52½	
28	.950	.966	.974	54	63	58	57	64	56	59.0				53	60	54	
29	.968	.954	.976	58	65	62	59	67	59	61.7				55	60	58	Thunder at 8*h*.15 p. m.
30	.962	.946	.975	60	64	61	59	63	59	60.3				57	61	57½	Lightning at 6*h*.15 p. m.
Total	118.889	118.822	119.348	....	....	....	1731	1938	1711	1793.4	....	....	....	1651½	1805½	1656	
Mean.....	23.963	23.961	23.978	....	....	....	57.7	64.6	57.0	59.8	....	....	....	55.0	60.2	55.2	
		23.967						59.8							56.8		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Course.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857.																				
Oct. 1	....	....	10	E.SE...	1	....	8	E.SE. ...	2	....	3	....	......	....	....	......	....	......	W.....	2
2	5.45 p. m..	6.10 p. m..	3	SW ..... SE	1 2½	High .. Middle.	7	E.S.E....	2½	....	6	S........	2	....	....	......	....	......	W.....	1
3	....	....	4	Station'y	......	....	9	S........	1	....	5	S.E......	2	....	....	......	....	......	W.....	2
4	11.55 a. m. 3.10 p. m.. 5.10 p. m..	12.15 p. m. 4.30 p. m.. 7.30 p. m..	7	E.SE....	1	....	9	.... E........	...... 2½	.... High	8	S........	1	....	....	......	....	......	W.....	2
5	12.20 p. m. 3 p. m.....	1.15 p. m.. 3.40 p. m..	9	S........	2	....	9	S........ and E ...	2½ 2	....	3	....	......	....	....	......	....	......	W.....	2½
6	....	....	5	Stat'n'ry S........	1	Cir. Middle.	7	S.SE....	2	....	10	....	......	....	....	......	....	......	W.....	2
7	7.35 a. m.. 9.15 a. m.. 3.15 p. m.. 6 p. m.....	7.50 a. m.. 12.40 p. m. 4.5 p. m... 7.15 p. m..	9	S.&SE...	2	....	7	S.SE....	2½	....	7	....	......	....	....	......	....	......	W.....	1
8	2.30 p. m..	3.40 p. m..	10	S........ E........	2½ 2	....	9	S........ E........	2 2	....	0	....	......	....	....	......	....	......	....	......
9	3.25 p. m...	4 p. m.....	2	S.SE.....	2	....	7	S........	2½	....	9	....	......	....	....	......	....	......	....	......
10	....	....	0	....	......	....	3	SE......	2	....	3	....	......	....	....	......	....	......	....	......
11	....	....	2	....	......	....	8	N.	1	....	0	....	......	....	....	......	....	......	....	......
12	....	....	0	N........	2 at 10 and 11 a.m.		8	S........	1	....	4	....	......	....	....	......	....	......	W.....	1
13	5.5 p. m...	7.10 p. m..	0	....	......	....	7	SE	1	....	8	....	......	....	....	......	....	......	....	......
14	1.10 p. m.. 5.30 p. m..	2 p. m..... 6.15 p. m..	1	....	......	....	7	SW......	2	....	3	....	......	....	....	......	....	......	SW....	2½
15	4 50 p. m.. 6.30 p. m..	5.10 p. m.. 9.30 p. m..	1	NE. high. SE. mid..	at 10	and 11 a.m.	9	N .... and S ...	1 2	....	9	....	......	....	....	......	....	......	....	......
16	3.15 p. m..	3.25 p. m..	2	....	......	....	7	S........	2	....	3	S........	2	....	....	......	....	......	....	......
17	4.30 p. m..	5.10 p. m..	9	S........ And E...	2 2	....	10	....	......	....	5	....	......	....	....	......	....	......	W.....	2
18	11.15 a. m. 3.30 p. m..	3 p. m..... 6.15 p. m..	3	SE,......	2	....	9	S E......	2	....	3	....	......	....	....	......	....	......	W.....	2
19	1.30 p. m..	3.15 p. m..	10	S........	1	....	10	S........ and E ...	1 1	....	9	....	......	....	....	......	....	......	....	......

20	10.50 a. m.	3.45 p. m.	10	S.	1	......	10	S.	2½	......	10	......	......	Fog	......	......	......	......	......	......
	7.30 p. m.	8.10 p. m.						and E.	1	......										
	8.45 p. m.	9.30 p. m.																		
21	3.30 a. m.	4.15 a. m.	10	......	......	Fog	10	N.	2	......	10	......	......	......	......	......	......	......	......	......
	8 a. m.	11.15 a. m.						E.	1	......										
	11.50 a. m	3.30 p. m.																		
22	2.25 p. m.	3.50 p. m.	10	......	......	......	9	S.	2	......	3	S.	1	......	......	......	......	......	......	......
	4.15 p. m.	5.10 p. m.		E.	1	Fog														
23	5.15 p. m.	5.30 p. m.	10	SE	2	......	6	E.S.E.	2½	......	4	......	......	......	......	......	......	......	......	......
24	12.35 p. m.	6.20 p. m.	4	N.	1	High	10	S.E	1	......	3	......	......	......	......	......	......	......	W.	1
25	12.20 p. m.	12.35 p. m.	1	......	......	......	9	S.	2	......	8	E.SE	2	......	......	......	......	......	......	......
	7.40 p. m.	7.55 p. m.						E.	2											
26	2.50 p. m.	3.10 p. m.	3	SE	2	......	9	S.S.E.	2	......	10	......	......	......	......	......	......	......	W.	1
	4.20 p. m.	4.50 p. m.						E	2	......										
27	......	......	10	E.	2½	Fog	6	S.E.	2½	......	9	S.	2½	......	......	......	......	......	......	......
28	11.30 a. m.	12.10 p. m.	3	SE.	2	......	9	S.E.	2	......	7	Station'y	......	High	......	......	......	......	......	......
	1 p. m.	1.45 p. m.																		
	1.55 p. m.	3.40 p. m.																		
29	......	......	3	W.	1	High	6	S.E.	2	......	2	......	......	......	......	......	......	......	......	......
				S.	2	Middle.														
30	4.10 p. m.	4.30 p. m.	3	E.S.E	2	High	8	S.E.	2½	......	7	S.	3	......	......	......	......	......	......	......
31	12.20 p. m.	12.40 p. m.	6	S.SE.	1	......	9	S.E	2	......	3	......	......	......	......	......	......	......	......	......
	2.55 p. m.	3.50 p. m.																		
Total	......	......	160	......	......	......	251	......	......	......	174	......	......	......	......	......	......	......	......	......
Mean	......	......	5.2	......	......	......	8.1	......	......	......	5.6	......	......	......	......	......	......	......	......	......

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry Bulb.			Wet bulb.			
	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Mean.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	
1857.																	
October 1	23.964	23.952	23.972	59	64	59	58	67	57	60.7		The same as thermometer in open air.		57	63	55	
2	.960	.946	.954	58	64	60	59	65	58	60.7				55	60	55	
3	.948	.948	.978	58	65	61	58	66	57	60.3				56	60	56	
4	.962	.956	.973	59	65	60	59	66	57	60.7				56	63	55	
5	.972	.962	.992	59	63	57	58	63	57	59.3				57	61	54	
6	24.002	.984	24.016	57	63	60	58	64	57	59.7				54½	61	56	
7	24.006	.978	24.012	58	62	59	58	67	56	60.3				57	62	55	
8	24.000	.996	24.015	57	61	58	56	61	56	57.7				55	60	55	
9	24.022	24.014	24.022	57	64	60	58	64	59	60.3				56	60	58	
10	23.978	23.988	23.988	55	66	61	59	68	58	61.7				53	57	57	
11	.950	.958	.944	55	65	57	56	66	56	59.3				52	61	48	Thunder at 4 p. m.
12	.934	.943	.945	55	64	58	58	64	58	60.0				51½	59	56	Temperature at 6*h*.15, a.m., 51°.
13	.933	.932	.934	56	65	61	58	67	57	60.7				55	61½	57	
14	.926	.910	.922	56	62	56	56	62	55	57.7				55	60½	51	
15	.916	.923	.943	57	64	59	59	67	56	60.7				53	61	55	Thunder at 7 p. m.
16	.943	.953	.972	56	63	60	57	65	57	59.7				55	61	56	
17	.956	.936	.968	57	62	57	58	60	55	57.7				57	59	54	
18	.930	.920	.930	56	60	57	56	63	55	58.0				55	60	53	
19	.928	.912	.946	57	59	58	57	60	56	57.7				55	59	55	
20	.940	.912	.951	58	59	58	56	58	57	57.0				55	58	57	
21	.943	.912	.956	57	58	57	56	56	56	56.0				56	56	56	
22	.952	.939	.962	57	61	57	56	61	55	57.3				56	59	53	
23	.972	.972	.976	57	64	59	56	66	57	59.7				55	56	56	
24	.959	.920	.940	56	60	58	57	59	56	57.3				54	58	54½	Thunder at 3*h*.30 p. m.
25	.932	.916	.938	56	61	61	57	64	58	59.7				55	60	57	
26	.934	.922	.959	57	66	60	59	64	57	60.0				57	61	56½	
27	.956	.952	.980	60	64	61	57	66	59	60.7				57	61	58	
28	.983	.962	24.000	58	63	60	59	65	58	60.7				57	64	56	
29	.980	.954	23.986	57	64	59	58	66	56	60.0				56	61	55	
30	.966	.940	.956	59	64	61	61	65	60	62.0				59	62	59	
31	.947	.931	.952	59	63	59	62	64	55	60.3				60	62	54	
Total.......	122.694	122.343	122.982	....	....	....	1790	1979	1761	1843.6	....	....	....	1722	1867	1713	
Mean.......	23.958	23.947	23.967	....	....	....	57.7	63.8	56.8	59.47	....	....	....	55.5	60.2	55.3	
		23.957						59.43							57.0		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Nov. 1	8.5 a.m.	8.25 a. m.	10	SE	2	....	7	SE	2	....	1	....	......	....	....	......	....	......	W	1
2	12.20 p. m. 1.40 p. m. 2.15 p. m.	1.10 p. m. 1.55 p. m. 4.5 p. m.	1	....	......	....	10	.... E.SE	 2	....	9	S.	2	....	....	......	....	......	W	1
3	6.10 p. m.	6.35 p. m.	1	S	2	....	7	S. E	2 2	....	4	S.	2½	....	....	......	....	......	....	......
4	2.35 p. m.	2.50 p. m.	10	S.	2	....	8	S.	2½	....	5	S.	2	....	....	......	....	......	W	2
5	1.25 p. m.	1.45 p. m.	5	SE 1 a m.SE	2 2	....	7	S.SE	2½	....	3	....	......	....	....	......	....	......	....	......
6	....	....	3	W	1	High	6	SE	2½	....	7	....	......	....	....	......	....	......	....	......
7	....	....	0	....	......	....	7	S. E	2½ 2	....	1	....	......	....	....	......	....	......	W	2
8	3.45 p. m.	5.30 p. m.	2	NW	1	High	8	SW	2	....	2	....	......	....	....	......	....	......	W	2
9	....	....	3	S.	2	....	8	W.SW S.	1 2	High Mid.	3	....	......	....	....	......	....	......	W	2
10	3.10 p. m.	3.40 p. m.	8	W	2	....	10	N E	1 2	Mid. Low	5	....	......	....	....	......	....	......	....	......
11	4.20 p. m.	5.5 p. m	4	W	1	Cir.	6	SE	1	....	1	....	......	....	....	......	....	......	W	2
12	....	....	4	W	2	Cir.	6	SE	2½	....	0	....	......	....	....	......	....	......	W	2
13	11.40 a. m.	2.40 p. m.	1	W	2	Cir	8	NW NW	1 2	Mid. Low	0	....	......	....	....	......	....	......	W	2
14	1.25 p. m.	2.40 p. m.	3	SW	1	....	10	SE	1	....	3	....	......	....	....	......	....	......	W	2
15	11 a. m.	12.10 p. m.	4	....	......	....	7	S.	2	....	4	....	......	....	....	......	....	......	....	......
16	1.15 p. m.	3.10 p. m.	8	SE	2	....	10	N & E.	1	....	3	....	......	....	....	......	....	......	W	1
17	2.20 p. m. 3.20 p. m.	2.30 p. m. 4.5 p. m.	4	W	2	Cir	9	N SE	1 1	Mid	9	....	......	....	....	......	....	......	....	......
18	11.45 a. m.	1 p. m.	4	W E	1 2	Cir Low	10	.... E	 1	.... Low	10	....	......	....	....	......	....	......	....	......
19	8.15 a. m.	9 a. m.	10	NE E	1 1	Mid. Low	8	SSE	2½	....	0	....	......	....	....	......	....	......	W	1
20	....	....	3	E.NE	1	High	9	E.NE S.	2½ 2½	Mid Mid	0	....	......	....	....	......	....	......	W	2½

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined·)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Nov. 21			1	N	3		4	N	2		2	N	3							
22	12.40 p. m. 2.50 p. m. 4.45 p. m.	12.50 p. m. 4 p. m. 5.30 p. m.	1	NW N	2½ 3	High Mid.	6	NE NE	2 3	High Mid	8	NE	2							
23	3.5 p. m.	3.20 p. m.	6	N	3		8	N E. SE	1 2½	Mid	0									
24			1				9	S	2½		8	S	2							
25	2.35 p. m.	3.30 p. m.	2	S	2	High	10	Stat. &N.	1	Mid	1								W	1
26			2				10	S E	2 2½	Mid Low	2								W	2
27			9	N	2		6	W N & E	1 1	High Mid	5									
28			7	W	2	High	8	SE	2		2	NE	1							
29			0				5	SW S	2½ 2	High Mid	0				W	2			W	2
30			7	S	2		10	SE	2½		9	S	2							
Total			124				237				107									
Mean			4.1				7.9				3.6									

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857.																	
Nov. 1	23.954	23.940	23.946	58	64	58	56½	67	56	59.8		The same as thermometer in open air.		56	61½	55	Temp. at 1 a. m. 51°.
2	.938	.922	.936	55	63	60	57	62	57	58.7				55	60½	57	Temp. at 6¼ a m. 53°.
3	.920	.918	.938	58	63	61	58	64	58	60.0				57	59½	57	Temp. at 6½ a. m. 55°.
4	.934	.920	.954	59	64	59	57	68	57	60.7				56	62	56	
5	.959	.936	.938	59	64	58	58	65	56	59.7				56	60	55	
6	.926	.916	.922	57	64	60	57	64	57	59.3				55	58½	57	
7	.910	.914	.908	56	64	59	56	66	56	59.3				54	60½	55	Temp. at sunrise 51°.
8	.910	.902	.898	57	64	57	58	64	54	58.7				55	61	53½	Thunder at 2*h*.30 p. m. 3*h*.30 p. m.
9	.904	.898	.938	57	64	60	55½	66	57	59.5				55	59	55	
10	.952	.932	.946	58	65	59	58	65	57	60.0				55½	61	52	
11	.916	.912	.904	58	64	58	60	65½	54	59.8				49	60	53	
12	.898	.876	.876	58	65	57	56	64	55	58.3				54	59	53	
13	.878	.874	.876	57	61	56	57	61	53	57.0				54	59	52	Thunder at 1*h*.45 p. m.
14	.894	.894	.920	56	62	58	54	60	56	56.7				53	59	55	
15	.936	.934	.978	59	62	60	57	64	58	59.7				56	59	57	
16	.952	.940	.958	58	62	57	58	60	56	58.0				56	60	55	
17	.936	.919	.948	56	63	59	56	62	57	58.3				55	60	57	
18	.940	.934	.949	57	62	60	58	62	59	59.7				56	61	58	
19	.972	.984	.994	59	63	59	56	64	54	58.0				56	60	52	
20	24.002	24.016	24.008	55	64	56	55	66	52	57.7				54	62	50	
21	23.996	24.006	23.982	54	62	56	55	62	53	56.7				51½	55	52	Temp. at 6*h*.15 a. m. 53°; N.W. winds.
22	.948	23.958	.954	54	63	57	54	62	54	56.7				50	56	53	
23	.940	.936	.960	56	63	56	55	67	53	58.3				53	61	51	
24	.954	.972	.995	55	62	60	55	62	59	58.7				53	58½	58	
25	.976	.973	.988	57	64	58	56	64	56	58.7				54½	59	53	Thunder at 3 p. m.
26	.978	.978	.980	56	65	58	55	62	56	57.7				54	61	55	
27	.946	.958	.948	54	62	57	53	63	54	56.7				49	56	52½	
28	.936	.945	.936	54	63	55	53	66	52	57.0				50	59	51	Temp. at sunrise 51°.
29	.916	.934	.954	50	61	55	49	60	53	54.0				45	55	50	Temp. at 6*h*.25 a. m. 46°, W. wind.
30	.958	.958	.978	54	60	59	55	60	57	57.3				53	58	56	
Total.....	118.179	118.099	118.410	....	......	....	1678	1907.5	1666	1750.7	....	....	....	1610.5	1781	1626	
Mean.....	23.939	23.936	23.947	....	....	....	55.9	63.6	55.5	58.3	....	....	....	53.7	59.4	54.2	
		23.941						58.3							55.8		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1857. Dec. 1	9.15 a. m.	1.30 p. m.	10			Fog	10	SW	2		4								W	2
2			10	E	2		7	SE.	2		5								W	1
3			3	SE	2		9	SE	2½		9									
4			8	SE	2		9	NE	1	H	5								E	3
								E.SE.	2	L.										
5	11.20 a. m.	1.10 p. m.	9	E	2½		10	E	2½		6								E	2
6			1	S	2		4	NE	2½	H	0									
								S	2½	M										
7	3.25 p. m.	3.40 p. m.	1	N	2		7	N.NE.	2	M	0									
								SE. below N.NE.												
8	2.15 p. m.	2.25 p. m.	4	E.NE.	2½		10				0								W	1
	2.40 p. m.	3.10 p. m.						E.	2	L.										
9			1	NE	1		8	NE	2		0								W	2
								E	2											
10	9.15 a. m.	12.30 p. m.	8	E	2½		10	SE	2		4									
	1.15 p. m.	3.10 p. m.																		
11	1 p. m.	1.20 p. m.	10	SE	2½		10	S.SE.	2		9									
	2.5 p. m.	2.25 p. m.																		
12	10.35 a. m.	12.10 p. m.	7	E	2 }	M	10	E.	1	Fog.	3								W	1
	1.15 p. m.	2.40 p. m.		S	1 }															
	6.55 p. m.	7.20 p. m.																		
13	2.10 p. m.	2.20 p. m.	4	W	1	H.	10	S	2		0								W	2
				S	1	M.		E	2											
14			10	SE	1		9	SE	1		3								W	2
15			1				10	S.SE	2		5								S W.	2
16			1	S	2		8	S	2		4								W	1
17			7	W	1	H	9	SE	2		1								S	2
18			1				10	S	2		0								W	2
19	2.25 p. m.	3.30 p. m.	2				8	S.SE.	2		2								W	1
20			7	N	2		10	NE	2		0								W	2½
21			2	W	2	Cirr.	8	SE.&NE. intermingling.	2	M	1									
				N	2	M.														
22	12.40 p. m.	1 p. m.	8	NE. & N.	2½	M.	10	N.	2		0								W	2
								E.SE.	2½											

23	2.15 p. m.. 4.30 p. m..	2.30 p. m.. 4.40 p. m..	1	N.	1	....	10	SE.......	2	....	0	....	......	....	....	......	....	......	....	.....
24	....	....	6	E.NE....	2	....	8	E.NE....	2	....	4	E.........	2¼	....	....	.....	....	......	....	......
25	11.50 a. m. 12.55 p. m. 3.35 p. m..	12.5 p. m.. 2 p. m..... 4.40 p. m..	4	NE.......	2½	....	10	E	2	Fog......	5	N.........	1	....	....	......	....	......	W.....	2
26	....	....	1	....	......	....	8	S. & E...	2	....	0	....	.....	....	....	.....	....	......	W.....	2
27	....	....	2	W........	1	Cirr. ..	7	SE.	2	....	8	N..	2½	....	....	......	....	......	....	......
28	8.30 a. m.. 10.40 a. m. 5 p. m.....	10 a.m.mist 4 p m. rain. 5.30 p. m..	8	N..	2½	....	10	N. & E..	2	....	9	N.NE....	3	....	....	......	....	......	....	.....
29	....	....	0	....	......	....	4	NE......	2	....	0	....	......	....	N.W..	2	....	......	....	......
30	....	....	8	W.......	2	H.	8	W....... NE......	1 3	H .... M.......	0	....	.....	....	....	......	....	......	W.....	2
31	....	....	7	W....... N	1 2	H. .... M....	8	W....... S........	2 2	H. .... M......	4	....	......	....	....	......	....	......	....	......
Total...	....	....	152	....	......	....	269	....	......	....	91	....	......	....	....	......	....	......	....	......
Mean...	....	....	4.9	....	......	....	8.7	....	......	....	2.9	....	......	....	....	......	....	......	....	......

Register of Meteorological Observations—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1857.																	
Dec. 1	23.982	23.984	23.968	58	57	55	56	55	55	55.3		The same as thermometer in open air.		56	55	53	
2	.974	.984	24.016	56	60	59	54	61	57	57.3				54	59	55	
3	24.000	24.014	24.024	56	64	60	56	64	59	59.7				54	60	55	
4	24.020	24.016	24.020	57	64	59	58	65	59	60.7				54	60	54	
5	24.023	24.010	24.021	57	61	59	57	61	57	58.3				55	58	56	
6	23.993	24.024	24.024	56	65	55	54	63	52	56.3				49	56	48	
7	24.000	23.996	23.992	54	65	56	53	68	56	59.0				50	60	49	
8	23.982	.951	.956	58	62	54	59	62	50	57.0				54	59½	45	
9	.936	.959	.944	53	63	55	53	63	52	56.0				49	58	48	
10	.940	.926	.963	55	58	57	55	58	55	56.0				53	56	54	
11	.974	.961	.988	56	58	58	54	58	57	56.3				53	57	56	
12	.974	.974	.990	56	60	57	57	59	55	57.0				54	59	55	
13	.980	.990	.982	56	62	58	57	61	55	57.7				54½	59	54	
14	.956	.941	.944	57	60	55	57	62	53	57.3				56	59	52	
15	.948	.940	.949	54	60	58	54	61	57	57.3				51	59	56	
16	.929	.942	.948	57	64	59	56	63	55	58.0				54	57	55	
17	.930	.916	.930	56	64	57	55	65	54	58.0				53	62	51	
18	.908	.914	.919	55	63	55	53	63	53	56.3				49	59	50	
19	.916	.928	.916	54	63	56	52	62	53	55.7				51	60	52	
20	.906	.910	.905	55	62	55	55	59	52	55.3				54	58	45	Clouds at 5 p. m.; N. 2.
21	.902	.910	.918	52	62	55	52	65	52	56.3				47	59	50	Temp. at sunrise, 49°.
22	.914	.906	.914	55	59	56	54	58	51	54.3				53	57	50	
23	.910	.917	.932	53	62	55	53	57	54	54.7				51	60	50	
24	.932	.943	.954	55	64	58	55	63	56	58.0				53	59	55	
25	.956	.956	.946	58	59	55	56	57	53	55.3				54	57	52	
26	.938	.958	.942	54	62	54	55	62	51	56.0				50	58	48	Temp. at 6.40 a. m., 49°.
27	.934	.906	.970	51	62	55	51	62	54	55.7				45	56	53	Temp. at 6.40 a. m., 48°; clouds at 5 p. m; N. 1.
28	.962	.964	.964	57	62	57	57	61	55	57.7				56	60	54	
29	.930	.924	.918	52	65	55	54	65	53	57.3				39	58	49	Clouds at 8 p. m.; NE 2.
30	.900	.910	.920	54	63	55	55	61	54	56.7				42	53	50	Temp. at 6.45 a. m., 51°.
31	.918	.958	.970	52	63	56	51	60	53	54.7				45	56	52	Temp. at 6.45 a. m., 48°.
Total....	122.467	122.492	122.767	......	......	......	1698	1904	1682	1762.2	......	......	......	1592.5	1803.5	1606	
Mean....	23.9506	23.9514	23.960	......	......	......	54.8	61.4	54.3	56.8	......	......	......	51.4	58.2	51.8	
		23.954						56.8							53.8		

No. 3.

Recapitulation of the occurrence of Rain during the different hours of the day from 6 a. m. to 10 p. m. for all the months from July, 1856, to December, 1857, inclusive.

			A. M.				M.				P. M.						
	6 7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	Monthly total.
1856.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.
July	----	$1\frac{6}{12}$	2	3	3	$3\frac{6}{12}$	$4\frac{3}{12}$	$4\frac{6}{12}$	8	8	5	$2\frac{9}{12}$	$2\frac{6}{12}$	$1\frac{3}{12}$	$\frac{3}{12}$	1	$50\frac{6}{12}$
August	----	----	1	$2\frac{3}{12}$	3	$2\frac{9}{12}$	$3\frac{9}{12}$	$4\frac{9}{12}$	$8\frac{3}{12}$	$7\frac{6}{12}$	$7\frac{6}{12}$	$3\frac{9}{12}$	$2\frac{3}{12}$	$3\frac{4}{12}$	$2\frac{9}{12}$	$\frac{3}{12}$	$53\frac{1}{12}$
September	----	$1\frac{3}{12}$	$1\frac{6}{12}$	$\frac{9}{12}$	----	$2\frac{6}{12}$	$6\frac{3}{12}$	$5\frac{6}{12}$	6	8	$5\frac{6}{12}$	$3\frac{6}{12}$	$1\frac{3}{12}$	$\frac{3}{12}$	----	----	$42\frac{3}{12}$
October	----	----	----	$1\frac{9}{12}$	$2\frac{9}{12}$	$3\frac{9}{12}$	$5\frac{6}{12}$	$4\frac{3}{12}$	$5\frac{3}{12}$	$5\frac{6}{12}$	$6\frac{6}{12}$	$\frac{9}{12}$	$6\frac{3}{12}$	$5\frac{5}{12}$	$2\frac{6}{12}$	1	$59\frac{2}{12}$
November	----	$\frac{6}{12}$	1	1	$\frac{1}{12}$	$\frac{9}{12}$	$3\frac{1}{12}$	$9\frac{4}{12}$	$8\frac{2}{12}$	$6\frac{2}{12}$	$3\frac{6}{12}$	3	$\frac{3}{12}$	----	----	----	$36\frac{10}{12}$
December	----	----	$1\frac{3}{12}$	$1\frac{3}{12}$	$2\frac{6}{12}$	2	$4\frac{6}{12}$	$10\frac{9}{12}$	$12\frac{1}{12}$	$7\frac{8}{12}$	$5\frac{6}{12}$	$5\frac{4}{12}$	$2\frac{8}{12}$	1	----	----	$56\frac{6}{12}$
1857.																	
January	----	1	1	1	1	$2\frac{6}{12}$	3	$3\frac{8}{12}$	$3\frac{3}{12}$	$3\frac{2}{12}$	$3\frac{4}{12}$	$2\frac{3}{12}$	----	----	----	----	$25\frac{2}{12}$
February	----	$\frac{1}{12}$	1	$2\frac{8}{12}$	$2\frac{11}{12}$	$4\frac{9}{12}$	$8\frac{4}{12}$	$10\frac{2}{12}$	$8\frac{7}{12}$	$8\frac{5}{12}$	$6\frac{10}{12}$	5	$1\frac{9}{12}$	1	1	$\frac{6}{12}$	63
March	1	1	$\frac{6}{12}$	$\frac{6}{12}$	----	$\frac{6}{12}$	$\frac{3}{12}$	$1\frac{1}{12}$	1	$\frac{3}{12}$	$\frac{3}{12}$	$\frac{7}{12}$	$\frac{2}{12}$	----	----	----	$7\frac{1}{12}$
April	1	2	2	$\frac{7}{12}$	----	----	----	----	----	----	$\frac{2}{12}$	$\frac{3}{12}$	$\frac{9}{12}$	----	----	----	$6\frac{9}{12}$
May	$4\frac{4}{12}$	$5\frac{10}{12}$	$3\frac{10}{12}$	$5\frac{4}{12}$	7	7	$7\frac{9}{12}$	$8\frac{6}{12}$	$10\frac{6}{12}$	9	$4\frac{11}{12}$	7	$4\frac{8}{12}$	$4\frac{3}{12}$	$3\frac{1}{12}$	$1\frac{11}{12}$	$94\frac{11}{12}$
June	3	$3\frac{4}{12}$	$2\frac{2}{12}$	$1\frac{8}{12}$	$3\frac{7}{12}$	$5\frac{6}{12}$	4	$3\frac{11}{12}$	$4\frac{5}{12}$	$3\frac{2}{12}$	$3\frac{6}{12}$	$4\frac{11}{12}$	$3\frac{7}{12}$	$3\frac{2}{12}$	$1\frac{4}{12}$	----	$51\frac{3}{12}$
July	1	$3\frac{4}{12}$	$2\frac{11}{12}$	$5\frac{1}{12}$	4	$2\frac{6}{12}$	5	$7\frac{8}{12}$	$6\frac{10}{12}$	$5\frac{1}{12}$	$5\frac{3}{12}$	$2\frac{6}{12}$	1	2	$\frac{11}{12}$	----	$55\frac{1}{12}$
August	2	$2\frac{8}{12}$	$2\frac{6}{12}$	$4\frac{2}{12}$	$4\frac{4}{12}$	3	$5\frac{8}{12}$	$8\frac{1}{12}$	$9\frac{6}{12}$	$10\frac{9}{11}$	$7\frac{10}{12}$	$7\frac{9}{12}$	$4\frac{3}{12}$	$4\frac{7}{12}$	$3\frac{6}{12}$	$\frac{6}{12}$	$81\frac{1}{12}$
September	----	----	$\frac{9}{12}$	$\frac{3}{12}$	$\frac{8}{12}$	$2\frac{1}{12}$	$1\frac{8}{12}$	$4\frac{11}{12}$	$4\frac{11}{12}$	$2\frac{1}{12}$	$3\frac{7}{12}$	$2\frac{2}{12}$	$2\frac{1}{12}$	2	$1\frac{9}{12}$	$\frac{3}{12}$	$29\frac{2}{12}$
October	----	$\frac{3}{12}$	1	$1\frac{9}{12}$	$2\frac{2}{12}$	$3\frac{9}{12}$	$5\frac{9}{12}$	$6\frac{5}{12}$	$7\frac{4}{12}$	$9\frac{2}{12}$	$4\frac{10}{12}$	$5\frac{3}{12}$	$4\frac{6}{12}$	$2\frac{8}{12}$	$1\frac{5}{12}$	1	$57\frac{3}{12}$
November	----	----	$1\frac{1}{12}$	----	----	$1\frac{7}{12}$	3	$3\frac{1}{12}$	$4\frac{1}{12}$	$4\frac{4}{12}$	$2\frac{1}{12}$	$1\frac{1}{12}$	$\frac{5}{12}$	----	----	----	$20\frac{9}{12}$
December	----	----	----	$1\frac{6}{12}$	$2\frac{9}{12}$	$4\frac{10}{12}$	$4\frac{2}{12}$	$4\frac{6}{12}$	$4\frac{6}{12}$	$2\frac{6}{12}$	$\frac{10}{12}$	$\frac{6}{12}$	$\frac{1}{12}$	$\frac{4}{12}$	----	----	$26\frac{6}{12}$
Total	$12\frac{4}{12}$	$22\frac{9}{12}$	$25\frac{6}{12}$	$34\frac{6}{12}$	$39\frac{9}{12}$	$53\frac{3}{12}$	$75\frac{11}{12}$	$101\frac{1}{12}$	$112\frac{8}{12}$	$100\frac{9}{12}$	$76\frac{11}{12}$	$66\frac{4}{12}$	$38\frac{5}{12}$	$31\frac{3}{12}$	$18\frac{6}{12}$	$6\frac{5}{12}$	$816\frac{4}{12}$
	h. m	h. m.	h. m.	h m.	h m	h. m.	h. m	h. m.	h. m.	h. m	h. m	h. m	h. m.	h. m.	h. m.	h. m.	h. m.
Mean	0. 41	1. 16	1. 25	1. 55	2. 12	2. 57	4. 13	5. 37	6. 16	5. 36	4. 16	3. 41	2. 8	1. 44	1. 2	0. 21	45. 21

Course of the Clouds at Colonia Tovar.

Month.	E.	E SE.	SE.	S.SE.	S.	S.SW.	SW.	W.SW.	W.	W.NW.	NW.	N.NW.	N.	N.NE.	NE.	E.NE.	
1857.																	
	1	......	......	......	......	1	......	......	1	......	......	......	......	......	......	......	High.
June	4	10	18	6	14	......	......	......	......	......	......	......	1	......	1	1	Middle.
	14	5	1	......	1	......	......	......	......	......	......	......	......	......	1	......	Low.
	......	......	1	......	2	1	......	......	4	......	......	......	......	1	......	......	High
Jul	5	2	7	7	8	2	1	......	......	......	......	......	1	......	......	2	Middle.
	11	12	6	5	6	......	......	......	......	......	......	......	1	......	1	......	Low.
	......	......	......	1	1	......	1	......	1	......	......	......	1	......	4	1	High.
August	11	8	12	6	8	1	2	......	......	......	......	......	1	......	6	......	Middle.
	14	2	2	1	1	......	......	......	......	......	......	......	......	......	......	......	Low.
	......	......	......	1	......	......	......	1	5	......	......	......	2	......	......	1	High.
September	1	3	19	7	14	......	......	......	......	......	......	......	2	......	2	2	Middle.
	5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Low.
	......	1	......	......	......	......	1	......	1	......	......	......	2	......	1	......	High.
October	......	6	17	5	25	......	1	......	......	......	......	......	2	......	......	......	Middle.
	12	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	Low.
	......	......	......	......	1	......	1	1	8	......	2	......	1	......	1	1	High.
November	2	1	12	2	18	......	2	......	1	......	1	......	11	......	4	1	Middle.
	7	1	......	......	......	......	......	......	......	......	1	......	......	......	......	......	Low.
	......	......	......	......	......	......	......	......	8	......	......	......	......	......	2	......	High.
December	11	......	13	3	10	......	1	......	......	......	......	......	12	2	7	3	Middle.
	3	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Low.
	1	1	1	2	4	2	3	2	28	......	2	......	6	1	8	3	High.
Total	34	30	98	36	97	3	7	......	1	......	1	......	30	2	20	9	Middle.
	66	22	9	6	8	......	......	......	......	......	1	......	2	......	2	......	Low.
	101	53	108	44	109	5	10	2	29	......	4	......	38	3	30	12	
			415														

No. 6.

Half-hourly Barometrical Observations, made with a view to find out the amount of Daily Amplitude, and the precise hour at which the maxima and the minima take place.

The numbers marked thus (*) are the maxima and the minima of the day.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M.	Ther.	11½ A. M.	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857.																													
	36.022	....	36.062	....	36.077	..	36.057	..	36.039	..	....	..	....	.	35.575	..	35.539	..	35.517	..	35.506	..	35.513	..	....	..	....	..	.581
June 10	23.966	56	23.972	58	23.978	59	*23.983	60	23.981	61	....	..	....	..	23.924	62	23.918	62	23.912	62	23.909	62	*23.908	61	23 908	60	....	..	.075
11	* .920	60	.920	61	.917	61	.917	62	.919	62	23.916	63	....	..	.898	63	.896	62	.888	63	.884	63	* .880	62	23.884	62	....	..	.040
12	23 968	61	23 975	61	23.980	61	23.981	61	* .984	61	23.980	61	....	..	.940	62	.939	61	.936	61	* .934	61	.936	61	....	..	....	..	.050
13	*24.005	58	24.005	59	24.004	59	24.003	59	.996	59	....	..	....	..	.948	60	.943	60	.940	60	* .936	60	.940	60	....	..	....	..	.069
14	23.980	59	23.988	60	*23.990	60	23.988	60	.988	62	....	..	....	..	.949	62	.942	61	.939	60	* .935	60	.936	60	....	..	....	..	.055
15	.962	67	.968	58	.969	59	* .973	60	.970	63	....	..	....	..	.936	63	.930	63	* .924	62	.925	61	.925	60	....	..	....	..	.049
16	.970	58	.976	59	.982	60	* .989	61	.988	62	....	..	....	..	.954	64	.953	63	.950	63	.945	62	* .940	62	....	..	....	..	.049
28	.976	59	.985	59	* .989	59	.984	60	.983	60	....	..	....	..	* .935	60	* .935	60	.940	60	.944	59	.948	59	....	..	....	..	.054
29	.990	57	.993	57	* .995	57	.993	58	.990	59	....	..	....	..	.952	58	.940	58	* .932	58	* .932	58	.933	57	....	..	....	..	.063
30	.980	58	.982	59	.984	59	* .985	60	.985	61	....	..	....	..	.937	63	.934	63	.928	63	* .924	63	.925	62	....	..	....	..	.061
Total......	75.739	....	75.826	..	75.865	..	75.853	..	75.823	..	....	..	....	..	74.948	..	74.869	..	74.806	..	74.774	..	74.784	..	....	..	....	..	1.146
Mean......	23.9863	....	23.9908	....	*23.9929	..	23.9923	..	23.9907						23.9446	..	23.9405	..	23.9372	..	*23.9352	..	23.9360	..	....	..	....	..	.0603

No. 6.—*Half-hourly Barometrical Observations*—Continued.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M	Ther.	11½ A. M	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857.																													
July 1	23.962	58	23.963	58	23.963	58	*23.967	58	23.967	59	23.964	60	....	..	23.928	60	*23.924	60	23.924	59	23.930	58	23.932	57	....	..	....	..	.043
2	.995	59	24.004	61	*24.011	62	24.010	62	24.010	62	....	..	....	..	.947	63	.936	62	.932	61	.927	61	*.925	60	23.930	60	....	..	.086
3	.970	59	23.972	60	*23.973	61	23.973	62	23.972	62	....	..	....	..	.932	64	.930	64	.927	63	*.922	63	.922	61	....	..	....	..	.051
4	.935	58	.938	59	.939	60	.940	60	*.943	62	23.940	62	....	..	.903	62	.896	62	.894	62	.891	62	*.889	61	....	..	....	..	.054
5	.963	59	23.964	60	.962	59	.961	59	*.968	60	....	..	....	..	.924	62	.923	62	*.922	62	.923	62	.926	62	....	..	....	..	.046
6	.996	58	*24.001	58	.996	58	.993	58	.992	58	....	..	....	..	.932	61	*.928	60	.932	61	.932	61	.932	61	....	..	....	..	.073
7	.958	59	23.959	59	*.960	59	.953	60	.954	60	....	..	....	..	.909	61	.904	60	.903	60	*.900	60	.902	60	....	..	....	..	.060
8	.950	58	.954	58	*.962	59	.962	60	.959	59	....	..	....	..	.922	62	.916	62	.910	61	.908	61	*.906	61	23.907	61	....	..	.056
9	.946	58	.948	59	.950	59	*.954	60	.953	60	....	..	....	..	.926	62	.924	61	.923	61	.922	61	.920	61	23.916	61	*23.914	60	.040
10	.960	59	.970	60	.971	60	.978	61	*.980	61	....	..	....	..	.944	64	.936	64	*.932	63	.932	62	.934	62	....	..	....	..	.048
11	.982	61	.988	62	.991	62	*.996	61	.988	61	....	..	....	..	.950	61	.945	61	.942	61	.940	61	*.936	61	23.940	61	....	..	.060
12	23.996	56	23.996	57	*23.998	57	23.996	57	23.994	57	....	..	....	..	.960	59	*.948	59	.952	59	.952	59	.952	58	23.958	58	....	..	.050
13	24.022	59	24.025	58	*24.026	58	24.024	59	24.024	60	....	..	....	..	23.980	62	23.976	61	23.968	61	*23.966	61	.968	61	....	..	....	..	.060
14	.036	59	.040	60	.040	60	.043	61	.043	62	*24.045	63	24.043	64	24.010	63	24.006	63	24.000	63	24.002	63	.996	62	*23.992	61	23.996	60	.053
15	24.036	60	24.038	61	24.041	62	*24.042	63	24.040	63	....	..	....	..	23.988	63	23.984	63	23.979	63	23.978	62	*.974	62	.976	61	....	..	.068
16	23.992	62	23.994	62	*23.996	62	23.995	61	23.995	61	....	..	....	..	.957	63	.951	63	.952	63	.952	63	.950	62	*.947	62	23.950	62	.049
17	24.000	58	24.003	59	24.002	60	24.004	60	*24.005	60	24.000	60	....	..	.946	62	.942	62	.937	63	*.935	62	.936	62	23.940	62	....	..	.070
18	23.996	59	24.002	61	24.008	62	*24.010	62	*24.010	62	....	..	....	..	.944	64	.941	64	.940	63	*.935	62	.940	62	....	..	....	..	.075
19	.994	59	23.996	59	*23.996	59	23.996	59	23.994	60	....	..	....	..	.952	58	.946	59	.941	59	.938	59	*.937	59	23.940	59	....	..	.059
20	.972	59	.974	61	*.975	61	*.975	61	.972	61	....	..	....	..	.936	60	.932	61	.924	60	.923	60	.922	60	*.920	60	23.924	59	.055
21	.966	59	.968	59	.971	59	*.972	59	.966	59	....	..	....	..	.920	62	.916	62	.910	62	.908	62	*.905	62	23.906	62	....	..	.067
22	.960	58	.966	59	*.966	59	.966	59	.963	60	....	..	....	..	.928	62	.918	62	*.916	62	*.916	62	.917	62	....	..	....	..	.050
23	.954	59	.954	59	.960	61	*.962	61	.962	62	23.959	62	....	..	.921	61	.914	61	.910	59	.910	59	.910	58	*23.908	57	23.909	57	.754
24	.962	57	.972	58	.980	58	.984	58	23.983	58	*23.986	58	23.982	58	.936	61	.930	61	.928	61	.922	60	*.912	60	.912	59	....	..	.074
25	23.984	59	23.990	60	23.994	60	23.996	61	24.000	62	*24.002	62	24.000	62	.956	63	.948	63	.942	62	.938	61	*.932	61	23.934	61	....	..	.070
26	24.000	58	24.002	59	24.006	60	*24.005	60	.006	60	24.003	60	....	..	.954	63	.945	63	*.936	63	.940	62	.940	62	....	..	....	..	.070
27	.004	58	.004	59	.004	59	*.012	60	.008	61	....	..	....	..	.970	63	.966	63	.960	63	*.950	62	.952	62	....	..	....	..	.062
28	.008	59	.012	60	.015	60	*.016	61	.014	62	....	..	....	..	.962	63	.952	63	.947	62	*.945	62	.948	62	....	..	....	..	.071
29	.004	59	.002	59	.004	59	.007	59	.006	59	*24.010	60	24.007	60	.980	63	.974	62	.971	61	.970	61	*.962	59	23.964	59	....	..	.048
30	.021	59	.024	60	*.025	60	.024	61	.024	61	24.021	62	....	..	.980	64	.976	64	.974	64	.973	63	.972	63	*23.970	61	23.980	61	.055
31	.022	60	*.025	60	*.025	60	.020	61	.020	62	....	..	....	..	.964	60	.954	60	*.947	60	.948	60	.952	60	....	..	....	..	.078
Total......	123.546	....	123.618	....	123.710	..	123.737	..	123.715	..	....	..	....	..	122.361	..	122.181	..	122.075	..	122.028	..	122.001	..	....	..	....	..	1.855
Mean......	23.985	....	23.9886	....	23.9906	..	23.9915	..	23.9908	..	....	..	....	..	23.9471	..	23.9413	..	23.9379	..	23.9364	..	23.9355	..	....	..	....	..	.0598

No. 6.—*Half-hourly Barometrical Observations*—Continued.

Date.	9 A.M.	Ther.	9½ A.M.	Ther.	10 A.M.	Ther.	10½ A.M.	Ther.	11 A.M.	Ther.	11½ A.M.	Ther.	12 M.	Ther.	3 P.M.	Ther.	3½ P.M.	Ther.	4 P.M.	Ther.	4½ P.M.	Ther.	5 P.M.	Ther.	5½ P.M.	Ther.	6 P.M.	Ther.	Amplitude.
1857.																													
Aug. 1	24.006	60	21.012	60	24.012	61	*21.075	61	*24.015	61	24 014	61	....	..	23.954	63	23 945	62	23.911	61	*23.941	61	23.944	60	....	..	....	..	.074
2	23.976	59	23.976	59	23.983	59	23.986	60	*23.989	61	*23.989	61	23 984	62	.942	63	.937	63	.934	63	.928	62	*.928	62	23.928	62	23.934	61	.061
3	.984	61	.985	63	.988	64	*.993	64	.992	63	.992	64	.986	64	.921	62	.928	62	*.924	62	*.924	62	.924	61	23.926	61	....	..	.069
4	.976	61	.983	61	.990	61	*.993	62	.990	61	....	..	....	..	.930	64	.931	64	*.924	64	.924	63	.928	63	...	..	....	..	.069
5	.968	59	.972	60	.976	59	*.979	59	.976	60	....	..	....	..	.916	61	.916	60	.910	60	*.908	60	.909	60	23.920	59	....	..	.071
6	.954	60	.965	61	.963	61	.972	61	*.978	61	23.976	61	....	..	.924	62	.920	62	.916	62	.912	62	*.908	62	23.914	61	....	..	.070
7	.965	60	.976	60	*.982	60	.980	60	.973	62	....	..	....	..	.932	60	.928	60	*.928	61	.930	61	.932	61	....	..	....	..	.054
8	23.993	59	23.995	60	23.988	60	21.001	60	21.002	61	*24.003	61	23.998	61	.948	63	.944	62	*.942	62	.945	62	.946	62	....	..	....	..	.061
9	24.020	59	24.032	60	24.033	60	*.034	60	.031	61	.028	61	....	..	.993	60	.986	60	.984	60	.982	59	*.980	59	23 980	58	23.984	58	.054
10	.020	59	.022	59	.026	60	.032	61	*.033	61	*24 033	61	24.032	61	.992	62	.984	62	.980	62	.980	60	.964	60	*.962	60	.966	60	.071
11	.016	59	.020	59	.025	60	*.026	61	*.026	61	.024	62	24.021	62	.987	63	.980	63	.974	63	.973	62	*.970	61	*23.970	61	23.972	60	.056
12	.038	60	.046	61	.052	62	*.055	63	*.055	63	24.048	63	....	..	.974	65	.974	65	*.968	64	.968	63	.972	62	....	..	....	..	.087
13	.023	59	.026	60	.030	60	*.034	60	.030	61	....	..	....	..	.974	60	.966	60	*.960	61	.966	6	.968	60	....	..	....	..	.074
14	.030	59	.030	60	*.631	60	*.031	60	.028	60	....	..	....	..	.971	58	.962	59	.950	59	*.960	59	.960	59	23.963	59	....	..	.071
15	23.990	59	23.990	59	23.990	59	*23.991	59	23.938	59	....	..	....	..	.928	60	.924	61	.921	61	*.923	61	.924	61	....	..	....	..	.068
16†	23.994	58	23.996	58	23.998	58	*24.000	58	*21 005	58	23.996	58	....	..	.950	59	.945	59	*.943	58	.944	58	.944	58	23.944	58	23.944	58	.062
17	24.036	57	24.044	57	24.046	57	*24.018	58	24.043	58	....	..	....	..	.984	59	.980	59	.970	59	.968	59	*.968	59	.958	59	.978	59	.080
18	24.022	59	24.027	60	*24.030	60	*24.030	60	24.030	61	24.025	61	....	..	.980	63	.972	63	.961	63	.959	62	*.959	62	23.959	62	23 964	62	.071
19	23.970	59	*23.974	59	23.967	59	23.961	59	23.956	60	....	..	....	..	.892	59	.888	58	*.888	58	.888	58	.890	58	....	..	....	..	.086
20	23.996	57	23.997	58	.997	58	24.000	57	*21.003	57	21.001	57	....	..	.962	57	.958	58	.956	58	.953	58	*.952	58	23.954	58	....	..	.051
25	24.085	60	24.086	60	.089	61	*.090	61	*.090	61	.090	62	24.084	62	24.040	63	24.033	63	24.028	63	*24.024	63	24.025	63	24.025	63	24.025	62	.066
26	.062	59	.066	60	*.067	60	.067	61	.066	62	24.064	63	....	..	23.996	62	23 992	62	23.988	62	23.983	62	*23.982	62	23.986	62	..	..	.085
27	.046	60	*.052	61	*.052	61	.049	60	.046	60	....	..	....	..	.989	63	.989	62	.984	62	*.980	62	.986	62	....	..	....	..	.072
28	.050	62	.059	60	.059	60	*.064	61	.061	62	....	..	....	..	23.994	63	.988	63	.986	63	*.985	63	*.985	63	23.985	6	23.988	62	.079
29	*.056	59	.055	60	.054	60	.054	61	.052	61	24.059	61	....	..	24.000	61	23.999	62	.996	62	*.992	62	.995	61	....	..	....	..	.064
30	.053	60	*.069	61	.068	61	.067	61	.067	61	.064	62	....	..	24 010	65	24.004	65	996	64	*.993	64	.994	64	....	..	....	..	.076
31	.016	60	.019	61	*24.021	62	.019	63	.018	63	.014	64	....	..	23.950	62	23.944	62	23.942	61	*23.935	62	23.935	62	23.936	62	23.944	61	.086
Total	103.357	....	108.474	....	108.532	..	108.574		108.543	..	....	..	....	.	107.036	..	106.916	..	106.801	..	106.768	..	106.772	..	....	..	....	..	1.8 8
Mean .. .	24.0132	....	24.0176	....	24.0197	..	*24.0213	..	24.0201	..	....	..	....	..	23.9643	..	23.9600	..	23 9558	..	*23.9544	..	23.9545	..	....	..	....	..	.0699

† 6½ p. m., 23.952; ther. 58.

No. 6.—*Half-hourly Barometrical Observations*—Continued.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M.	Ther.	11½ A. M.	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857. Sept. 1	23.970	60	23.978	61	23.986	62	*23.989	62	23.989	63	23.986	63	....	..	23.933	62	23 924	61	23.920	60	23.917	59	*23.916	58	*23.916	58	23.921	57	.073
2	.961	59	.964	60	23.974	60	*23 976	60	23.972	59	....	..	....	..	.925	60	.922	60	* .918	60	.923	60	.920	59	.920	59	23.930	59	.056
3	23.992	59	23.996	59	24.006	61	*24.010	61	24.008	62	....	..	....	..	.959	64	.947	64	* .944	64	.948	64	.948	64	....	..	....	..	.066
4	24.003	60	24.010	61	.020	62	.021	63	.020	63	*24.025	64	24.021	64	.968	65	.960	65	* .954	64	.954	63	.955	63	23.958	62	....	..	.071
5	.028	61	* .039	62	* .039	62	.038	62	.034	6	....	..	....	..	.984	65	.980	64	.976	64	.973	64	* .972	63	.984	61	....	..	.067
6	.014	61	.019	63	.022	63	.025	63	* .030	64	24.027	64	....	..	.968	65	.962	65	.953	64	.953	64	* .948	63	.952	63	....	..	.082
7	.000	59	.002	59	.010	60	* .012	61	.008	62	....	..	....	..	.952	63	.948	63	* .948	63	.948	63	.950	62	.954	62	....	..	.064
8	.008	58	.010	59	.018	59	.021	59	.021	60	*24.022	62	....	..	.978	63	.972	63	970	62	.968	62	* .962	61	.964	61	....	..	.060
9	.010	60	.024	61	* .032	61	* .032	61	.032	62	.032	63	24.031	63	23.980	63	23.978	63	23 976	63	.972	63	* .971	62	23.975	62	....	..	.061
10	.042	61	.045	62	.048	62	* .054	62	* .054	62	24.051	63	....	..	24.006	64	24.005	64	*24.000	64	*24.000	64	24.002	62	24.002	62	....	..	.054
11	24.054	62	*24.058	64	* .058	65	.055	64	.052	65	....	..	....	..	23.986	64	23.980	64	23 972	64	23.972	64	*23.970	63	23.970	62	23.975	61	.088
12	23.993	60	23.994	60	24.000	62	*24.002	6	24.000	64	23.994	64	....	..	.940	64	.938	64	.930	63	.930	63	* .928	62	....	..	....	..	.074
13	.965	61	.966	61	23.970	62	23.972	62	*23.973	62	.970	63	....	..	.919	63	.916	63	.916	63	.915	6	* .914	63	23.916	63	....	..	.059
20	23.980	61	23 988	62	23.992	63	23.996	63	*23.998	63	23.996	62	....	..	.942	64	.938	64	* 932	64	.934	64	.936	63	.942	63	....	..	.066
21†	24.008	62	24.016	63	*24.018	64	*24 018	64	24.012	64	....	..	....	..	.958	65	.952	65	.948	65	* .945	65	* .945	65	.945	64	.945	63	.073
22	24.000	61	24.013	62	24 014	63	*24.018	63	24.016	63	24.012	64	....	..	.944	63	.942	63	.937	63	* .934	63	* .934	63	.934	62	.934	61	.084
23	23.978	62	23.986	63	23.988	63	*23.990	63	23.989	64	23.989	64	23.980	64	.926	64	.918	63	.916	63	.912	63	.912	63	* .910	63	.911	62	.080
24‡	.972	61	23.980	62	.984	62	.985	62	.987	63	23.986	63	....	..	.928	64	.922	64	.922	64	.920	63	.918	63	.916	63	* .914	62	.073
25	.992	60	*24.000	60	.994	60	.992	60	.988	60	....	..	....	..	.930	61	.926	61	* .918	61	.920	61	.920	60	....	..	....	..	.082
26	.991	58	23.994	58	* .996	58	.995	59	.990	58	....	..	....	..	.936	61	.930	61	.923	61	* .920	61	.922	61	.924	61	....	..	.076
27	.984	60	23.988	61	.995	61	* .997	61	.996	61	....	..	....	..	.930	62	.926	62	.926	62	.924	62	.922	61	* .921	61	.923	60	.076
Total...	83.948	....	84.070	....	84.164	..	84.198	..	84.169	..	....	..	....	..	82.992	..	82.886	..	82.802	..	82.782	..	82.765	..	....	..	....	..	1.485
Mean...	23.997	....	24.003	....	24.0078	..	24.0094	..	24.0080	..	....	..	....	..	23.952	..	23.947	..	23.913	..	23.9420	..	23.9412	..	....	..	....	..	.0707

† 6½ p. m., 23.948; ther. 63.

‡ 6½ p. m., 23.9 ; ther. 62.

No. 6.—*Half-hourly barometrical observations*—Continued.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M	Ther.	11 A. M.	Ther.	11½ A. M	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857.																													
Oct. 2	23.994	61	24.000	62	24.002	62	*24.005	63	24.002	64	....	..	....	..	23 932	65	23.925	63	23.925	65	23.924	65	*23.924	64	23.926	64	....	..	.081
3	23.985	62	23 992	63	*23.997	64	23.997	65	23.992	65	....	..	....	..	.926	65	.924	65	* .918	64	.920	64	.920	64	....	..	....	..	.079
4	24.006	63	24.016	64	*24.026	65	*24.026	65	24.022	65	....	..	....	..	.934	64	.932	64	* .929	64	.931	64	.933	64	....	..	....	..	.097
5	.005	60	.015	61	* .022	62	* .024	62	.022	62	....	..	....	..	* .948	62	.959	61	.958	61	.926	61	.955	60	23.955	60	23.955	60	.076
																											† .960	60	
6	.024	60	.032	61	* .033	61	.033	62	.033	62	24.030	63	....	..	.966	64	.961	63	.958	65	* .958	63	.957	63	*23.957	63	23.962	61	.076
7	.030	63	.037	63	* .037	59	.036	59	.028	60	....	.	....	..	.970	62	.960	61	* .960	61	.960	61	.965	60	....	..	....	..	.077
8	.032	57	* .038	58	* .038	58	.036	59	.034	59	24.030	59	....	..	23.976	61	.968	61	* .965	61	.970	61	.968	60	....	..	....	.	.073
9	.056	61	.060	61	.061	61	* .066	62	.062	63	....	..	....	..	24 000	63	.996	63	.996	63	.996	63	.994	62	*23.993	62	23.996	62	.073
10	.033	61	.036	61	* .040	62	.036	63	.032	63	....	..	....	..	23.964	65	.964	65	.962	65	.960	65	.958	64	.958	63	* .957	62	.083
																											†23.960	62	
11	23 996	61	24.000	62	24.009	64	*24.010	65	24 004	65	....	..	....	..	.940	64	* .936	64	* .936	63	.939	63	.938	63	.938	62	....	..	074
12	.975	60	23.980	61	23 986	62	*23.987	62	23.982	64	....	..	....	..	.930	65	.928	65	.921	64	.920	64	* .918	63	.920	62	....	..	.069
13	.975	61	.986	62	* .990	63	.988	64	.984	64	....	..	....	..	.905	64	.900	63	.897	63	.897	63	* .895	63	* .895	63	23.898	63	.095
14	.968	60	.972	62	.976	63	* .978	63	.976	65	....	..	....	..	.900	63	• .895	63	.893	63	.892	63	* .890	65	.892	62	.892	61	.088
15	.951	60	23.963	61	23.963	61	*23.966	63	.962	64	....	..	....	..	.904	64	.893	64	.890	64	.889	63	.884	63	*23.882	62	23.884	61	.084
16	.993	60	24.002	60	*24.004	61	*24.004	61	.997	63	....	..	....	..	.924	62	.921	62	* .918	62	.920	62	.920	62	....	..	....	..	.086
18	.976	58	23.978	58	*23.982	58	23.978	58	.970	59	....	..	....	..	.904	59	.896	58	* .896	58	* .896	58	.896	58	23.902	57	....	..	.086
19	.966	58	.974	59	* .981	59	.976	59	.972	59	....	..	....	..	.898	60	* .896	59	* .896	59	.897	59	.897	59	23.898	59	....	..	.085
20	.972	58	.980	59	* .984	59	.980	59	.975	60	....	..	....	..	.904	59	.898	59	.896	60	* .895	60	.900	59	....	..	....	..	.089
21	.964	57	.968	57	* .972	57	.969	58	.960	58	....	..	....	..	.908	57	.900	57	* .898	57	* .898	57	.900	57	....	..	....	..	.074
22	.980	57	.989	57	* .994	57	* .994	57	.992	59	....	..	....	..	932	59	.931	59	* .930	59	.932	59	.936	59	....	..	....	..	.064
23	24.014	58	24.018	59	*24.026	61	24.024	61	24.021	61	....	..	....	..	.954	64	.950	64	.948	62	.946	62	.944	62	*23.943	62	*23.943	61	.083
																											†23.944	61	
24	23.991	61	23.996	64	*24.002	64	23.998	64	23.996	65	....	..	....	..	.922	61	.928	61	.922	60	.920	60	* .918	59	23.920	59	....	..	.084
25	.970	60	.976	60	23.980	61	.981	62	.974	63	....	..	....	..	.904	63	.901	63	.901	62	* .900	62	.901	62	....	..	....	..	.081
26	.976	60	23.982	61	23.984	62	23.982	62	.978	63	....	..	....	..	.905	64	.904	64	.904	63	* .903	63	.906	62	....	..	....	..	.081
27	23.997	60	24.004	61	*24.010	61	24.008	61	24.006	62	....	..	....	..	.932	64	.928	64	* .924	62	* .924	62	.925	62	....	..	....	..	.086
28	24.024	61	* .030	61	.028	62	.026	63	.020	63	....	.	....	..	* .936	62	* .936	62	.940	62	.944	62	.947	61	....	..	....	..	.094
29	24.016	62	.020	62	*24.022	63	24.020	63	24.014	63	....	..	....	..	.942	65	* .934	64	.938	64	.936	64	* .934	63	23.936	62	....	..	.088
30	23.998	60	*24.002	60	23.999	61	23.997	63	23.992	63	....	..	....	..	.916	65	.910	65	* .906	64	* .906	64	.908	65	....	..	....	..	.096
31	23.984	61	23.990	62	*23.992	62	23.990	64	23.985	64	....	..	....	..	.924	63	.920	63	.916	63	.912	65	* .902	62	* .902	62	.906	62	.090
Total......	115.854	....	116.036	....	116 140	..	116.115	..	115.987	..	....	..	....	..	114.000	..	113.894	..	113 841	..	113.811	..	113.833	..	....	..	....	..	2.392
Mean	23.995	....	24.001	....	*24.005	..	24.004	..	23.9995	..	....	..	....	..	23.931	..	23.927	..	23.9256	..	*23.9245	..	23.9253	.	....	..	....	..	.0825

† 6½ p. m.

No. 6.—*Half-hourly Barometrical Observations*—Continued.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M.	Ther.	11½ A. M.	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857.																													
Nov. 1	23.979	59	23.986	59	*23.993	59	23.990	60	23.989	60	......	..	......	..	23.916	64	23.911	64	23.910	64	23.906	63	*23.905	62	23.908	62	......	..	.088
2	.980	60	* .986	61	.986	62	.980	62	.976	62	......	..	......	..	.904	62	.896	62	* .892	62	.893	62	.894	62	......	..	......	..	.091
3	.962	59	.968	60	* .973	61	.970	62	.966	62	......	..	......	..	.900	63	* .897	63	.897	62	.898	62	.898	62	23.898	61	......	..	.076
4	.965	60	.972	60	* .976	61	.976	62	.974	62	23.968	63	......	..	.904	64	* .901	63	.901	62	.902	62	.908	62	......	..	......	..	.075
5	.986	59	.992	60	* .993	61	.992	61	.986	63	......	..	......	..	.923	64	.923	64	.922	6	.920	62	* .918	62	23.919	62	23.920	62	.075
6	.959	59	.965	60	* .974	63	.971	63	.968	63	......	..	......	..	.898	64	.895	64	.893	64	.893	64	* .892	63	.892	62	......	..	.082
7	.944	62	.952	62	* .954	62	.954	63	.952	64	......	..	......		.898	64	.898	64	.892	63	.892	63	.892	62	.890	61	*23.888 † .890	60 60	.066
8	.942	61	.948	62	.953	63	.956	65	* .958	63	23.948	64	......	..	.890	63	.885	63	.892	63	.892	61	.886	61	* .884	61	23.886	60	.074
9	.936	60	.940	61	* 943	61	.940	62	.934	63	......	..	......	..	.884	64	.878	64	* .874	64	.876	64	.877	63	23.880	62	......	..	.069
10	.988	62	.988	63	.994	65	* .997	65	.994	65	23.988	64	......	..	.924	64	.915	63	* .915	64	.917	63	.920	63	......	..	......	..	.082
11	.948	60	.956	61	.958	62	* .960	63	.960	64	.958	64	......	..	.899	64	.895	64	.892	64	.896	62	.894	61	23.889	61	23.887 †23.888	60 59	.073
12	.930	60	* .934	61	* .934	61	.930	63	.929	63	23.920	64	......	..	.862	63	.860	64	* .852	64	.856	63	.856	62	23.857	61	......	..	.082
13	.916	60	.920	61	.928	63	* .934	61	.930	61	......	..	......	..	.858	63	.852	63	.852	63	* .850	62	.852	62	......		......	..	.084
14	.948	61	.952	62	* .956	63	.949	63	.947	63	......	..	......	..	.880	63	.868	62	* .864	62	.864	61	.868	61	......	..	......	..	.092
15	.980	60	.982	61	* .986	61	23.984	61	.983	61	......	..	......	..	.918	62	.912	62	* .911	62	.912	62	.916	62	......	..	......	..	.075
16	.988	58	.994	59	.999	61	*24.000	61	.997	61	......	..	......	..	.922	62	.918	6	* .914	62	.920	62	.922	62	......	..	......	..	.086
17	.980	58	* .983	59	.982	61	23.982	61	.974	61	......	..	......	..	.904	62	* .899	62	* .898	62	* .898	62	.900	61	......	..	......	..	.085
18	.984	58	.986	59	* .995	61	*23.995	61	.992	61	......	..	......	..	.923	62	.922	62	.917	62	* .916	62	.919	62	......	..	......	..	.079
19	24.006	58	24.013	58	24.019	59	*24.021	59	24.020	59	24.018	60	......	..	23.976	63	23.966	63	.964	63	.959	63	* .957	62	23.959	62	......	..	.064
20	.047	60	.052	61	* .058	60	.058	61	.053	61	......	..	......	..	24.006	64	24.002	63	.997	62	.997	62	.996	61	* .994	60	23.996	60	.064
21	24.049	59	.050	59	.052	61	.054	61	* .055	61	24.050	61	......	..	23.984	63	23.980	63	.978	63	.976	62	.972	61	.970	59	* .960 †23.962	58 58	.095
22	23.985	57	24.000	59	24.010	61	24.010	61	*24.011	61	24.006	61	......	..	.912	62	.939	62	.934	60	.933	60	* .932	59	.935	59	......	..	.079
23	23.986	60	23.988	60	*23.991	60	23.991	61	23.991	61	23.984	61	......	..	.924	63	* .922	62	.923	61	.924	61	* .922	61	23.924	61	......	..	.069
24	24.005	59	24.010	60	*24.014	60	24.014	61	21.014	61	24.011	61	......	..	.966	63	.958	62	.955	62	* .950	6	.952	62	......	..	......	..	.064
25	.014	61	.014	61	.012	61	012	63	* .018	65	24.015	65	24.010	65	.964	63	.954	63	* .943	63	.946	63	.944	62	23.948	61	......	..	.075
26	24.012	60	24.018	60	21.021	61	*24.026	62	.020	61	......		......	..	.956	65	.954	64	.954	64	* .953	63	.954	63	.956	63	......	..	.073
27	23.993	56	23.997	57	23.999	57	23.999	58	*24.000	58	23.995	59	......	..	.939	62	.934	62	.930	62	* .930	61	.930	6	.932	61	23.934	60	.070
28	.974	57	.980	59	.984	58	* .990	60	24.988	61	......	..	......	..	.932	63	.925	62	.924	62	.922	61	.922	59	*23.918	59	23.920	58	.072
29	23.970	57	23.970	57	23.974	58	*23.978	59	23.974	59	......	..	......	..	.920	61	.912	6	* .916	61	.912	61	.914	60	......	..	......	..	.068
30	24.002	56	24.002	56	*24.004	57	*24.004	57	24.000	57	......	..	......	..	.946	61	.938	61	.936	61	.932	60	* .930	60	23.936	60	......	..	.074
Total......	119.358	....	119.498	....	119.615	..	119.617	..	119.553	..	......	..	......	..	117.662	.	117.512	..	117.436	..	117.435	..	117.442	..	......	..	......	..	2.304
Mean	23.978	....	23.983	...	*23.9872	.	*23.9872	..	23.985	..	......	.	......	..	23.922	..	23.917	..	*23.9145	..	*23.9145	..	23.9147	..	......	..	......	..	.0768

† 6½ p. m.

No. 6.—*Half-hourly Barometrical Observations*—Continued.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M.	Ther.	11½ A. M.	Ther.	12 M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	6 P. M.	Ther.	Amplitude.
1857.																													
Dec. 4	24.054	60	*24.056	61	*24.056	61	24.056	[illegible]	24.054	65	....	..	....	..	23.990	64	23.983	63	23.980	63	*23.974	63	23.980	63	....	..	....	..	.082
5	.064	61	.068	61	.067	62	* .069	[illegible]	.062	63	....	..	....	..	23.990	60	23.990	61	23.986	61	*23.982	61	23.981	61	....	..	....	..	.087
6	.058	59	.065	60	* .069	62	* .069	62	.066	63	....	..	....	..	*24.006	63	24.006	62	24.006	62	24.008	61	24.009	60	....	..	....	..	.063
7	.036	59	.040	60	.040	60	* .041	[illegible]	.039	63	....	..	....	..	23.983	61	23.980	62	*23.978	61	23.980	61	23.982	60	....	..	....	..	.063
8	*24.008	59	24.007	60	24.006	61	24.003	[illegible]	24.001	61	....	..	....	..	.944	63	.944	63	* .942	62	.942	61	.942	61	23.945	61	....	..	.066
9	23.975	59	23.983	61	*23.986	62	23.985	[illegible]	23.982	61	....	..	....	..	.934	63	* .926	62	.929	62	.929	62	.930	62	....	..	....	..	.060
10	23.976	56	*23.980	56	*23.980	56	23.975	57	23.970	56	....	..	....	..	.922	57	.921	57	* .920	58	.921	58	.924	57	....	..	....	..	.060
11	24.004	56	24.010	56	24.015	58	*24.016	[illegible]	24.011	58	....	..	....	..	.950	58	.946	59	* .946	59	.946	59	.950	59	....	..	....	..	.070
12	24.016	59	24.022	59	*24.024	59	24.023	[illegible]	24.021	59	....	..	....	..	.960	60	.958	59	.954	59	* .953	59	.956	58	....	..	....	..	.071
Total	36.191	....	36.231	....	36.243	..	36.237	..	36.206	..	....	..	....	..	35.679	..	35.654	..	35.641	..	35.635	..	35.657		....	..	....	..	.622
Mean	24.021	....	24.026	....	*24.027	..	24.026	..	24.023	..	....	..	....	..	23.964	..	23.9616	..	23.9601	..	*23.9594	..	23.962	..	....	..	....	..	.0691

No. 7.

Mean Barometrical Heights of all the half-hourly Observations made in 1857, *compiled chiefly from table No.* 6.

	7 A. M.	9 A. M.	9½ A. M.	10 A. M.	10½ A. M.	11 A. M.	2 P. M.	3 P. M.	3½ P. M.	4 P. M.	4½ P. M.	5 P. M.	9 P. M.
1857.													
May..	23.986	24.011	24.0135	*24.0145	24.0143	24.0115	23.971	23.959	23.954	23.9515	*23.9501	23.953	23.994
June..	.967	23.9863	23.9998	*23.9929	23.9923	23.9907	.958	.9446	.9405	.9372	* .9352	9360	.967
July..	.963	23.985	23.9886	23.9906	*23.9915	23.9908	.962	.9471	.9413	.9379	.9364	*.9355	.968
August..	.986	24.0132	24.0176	24.0197	*24.0213	24.0201	.981	.9643	.9600	.9558	*.9544	*.9545	.997
September..	.965	23.997	24.003	24.0078	*24.0094	24.0080	.963	.952	.947	.943	.9420	*.9412	.981
October..	.958	23.995	24.001	*24.005	24.004	23.9995	.947	.931	.927	.9256	*.9215	.9253	.967
November..	.939	23.978	23.983	*23.9872	*23.9872	23.985	.936	.922	.917	*.9145	*.9145	.9147	.947
December..	.982	24.021	24.026	*24.027	24.0263	24.023	.976	.964	.9616	.9601	*.9594	.962	.989
Total..	31.746	191.9865	192.0235	192.0447	192.0463	192.0286	31.694	191.5840	191.5484	191.5256	191.5165	191.5222	31.810
Mean..	23.968	23.9983	24.0029	24.0056	*24.0058	24.0036	23.962	23.9480	23.9435	23.9407	23.9396	23.9403	23.976

No. 9.

Mean Amplitudes of the Barometer, computed from table No. 6, for periods from six to six successive days.

	Days of the month.						Mean amplitude.	Mean.		M'thly mean amplitude.
May	10	11	12	13	14	15	.060	.0600	May	.0666
	16	17	18	19	20	21	.070	.0690		
	22	23	24	25	26	27	.063			
	29	30	31	1	2	3	.066	.0650		
June	4	5	6	7	8	9	.064		June	.0603
	10	11	12	13	14	15	.0563	.0580		
	(16)	(17)	(18)	(19)	(20)	(21)	....			
	(22)	(23)	(24)	(25)	(26)	(27)	....			
	28	29	30	1	2	3	.0597			
July	4	5	6	7	8	9	.0548	.0555	July	.0598
	10	11	12	13	14	15	.0563			
	16	17	18	19	20	21	.0625	.0629		
	22	23	24	25	26	27	.0633			
	28	29	30	31	1	2	.0645	.0651		
August	3	4	5	6	7	8	.0657		August	.0699
	9	10	11	12	13	14	.0688	.0692		
	15	16	17	18	19	20	.0696			
	(21)	(22)	(23)	(24)	25	26	.0755	*.0710 †.0701		
	27	28	29	30	31	1	.0750			
September	2	3	4	5	6	7	.0677		September	.0707
	8	9	10	11	12	13	.0660			
	(14)	(15)	(16)	(17)	(18)	(19)	....	.0763		
	20	21	22	23	24	25	.0763			
	26	27	(28)	(29)	(30)	(1)	.0760	.0785		
October	2	3	4	5	6	7	.0810		October	.0825
	8	9	10	11	12	13	.0779	.0818		
	14	15	16	(17)	18	19	.0858			
	20	21	22	23	24	25	.0792	.0842		
	26	27	28	29	30	31	.0892			
November	1	2	3	4	5	6	.0817	.0780	November	.0768
	7	8	9	10	11	12	.0743			
	13	14	15	16	17	18	.0835	.0780		
	19	20	21	22	23	24	.0725			
	25	26	27	28	29	30	.0720	‡.0746		
December	(1)	(2)	(3)	4	5	6	.0773	§.0733	December	.0691
	7	8	9	10	11	12	.0650	.0650		

* When computed from the four *mean* amplitudes.
† When computed from the twenty *single* amplitudes.
‡ When computed from the two *mean* amplitudes.
§ When computed from the nine *single* amplitudes.

Note.—The days in parentheses are days on which I was unable to make observations for want of time, or days on which I was absent from home.

Caracas, *July* 16, 1858.

Under date of January 10, I sent you my meteorological registers for Colonia Tovar, for seven months ending with the last day of December, 1857, besides some other observations on the meteorology of that region.

The inclosed registers, which I send you this time, extend from the 1st of January to the 5th of June, 1858, for Colonia Tovar, and from the 16th to the 30th of June for Caracas.

On the 6th of June, after having sold my little property, I left Colonia Tovar, the place where I had lived for more than four years, and moved to Caracas. I am very sorry to say that on this journey, in endeavoring to measure some of the highest points of the difficult and dangerous mountain road, the barometer was accidentally broken, and hence the barometrical observations end with the 5th of June.

In February last I attempted to make a complete set of *half-hourly* barometrical observations, but after proceeding with this task for seven days I was compelled to leave off for want of time. The pressure of business at present also prevents me from sending anything more on meteorology this time.

A. FENDLER

Register of Meteorological Observations for Colonia Tovar, *Venezuela, from January* 1, *to June* 5, 1858.

Date.	Barometer.						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	2 A. M.	2 P. M.	9 P. M.	*Mean.*		7 A. M.	2 P. M.	9 P. M.	
1858. Jan. 1	23.976	23.980	24.024	55	65	55	54	64	52	56.7	....	52	61	49	Temp. at 6¾ a. m. 50°.
2	.998	988	24.006	53	61	58	53	59	55	55.7	....	46	58½	55	
3	.984	.972	23.974	56	60	54	56	59	51	55.3	....	53	52	49	
4	.964	.970	.978	52	64	56	51	63	53	55.7	....	47	52	48	
5	.962	.982	.992	54	64	55	55	63	52	56.7	....	52	52	49	
6	.998	.976	.998	55	63	57	53	60	55	56.0	....	51½	59	53	
7	.980	.972	.996	53	60	56	55	61	53	56.3	....	46	57	51	Temp. at 6½ a. m. 51°.
8	.960	.984	.974	53	60	50	53	59	47	53.0	....	48	55	37	
9	.950	.950	.982	50	61	54	49	64	50	54.3	....	46	58	48	Temp. at 6½ a. m. 48°.
10	.960	.980	.988	50	61	56	48	65	53	55.3	....	47	59	52	Temp. at 6½ a. m. 48°.
11	.970	.976	.970	52	59	53	51	57	53	53.7	....	47	55	42	Temp. at 6.40 a. m. 48°.
12	.944	.978	.982	50	61	54	50	60	52	54.0	....	48	57	48	Temp. at 6.40 a. m. 48°.
13	.960	.972	.972	50	62	55	49	61	52	54.0	....	46	56	49	Temp. at 6.40 a. m. 47°.
14	.950	.970	.956	49	62	53	49	63	50	54.0	....	42	56	44	
15	.930	.966	.960	51	64	53	49	65	49	54.3	....	45	58	44	
16	.935	.964	.976	49	64	54	48	63	51	54.0	....	43	55	48	Temp. at 6.40 a. m. 45°.
17	.942	.952	.958	53	59	57	51	59	53	54.3	....	49	55	52	
18	.912	.912	.950	54	59	56	54	58	52	54.7	....	52	55	51	
19	.956	.950	.974	54	61	58	54	60	56	56.7	....	52	53	55	
20	.984	.980	24.000	56	60	59	55	61	57	57.7	....	54	58	57	
21	24.028	24.020	24.022	58	63	59	59	62	58	59.7	....	56	57	57	
22	24.002	23.990	23.995	57	63	59	55	64	56	58.3	....	54	57	55	
23	23.968	.974	.990	56	65	59	57	67	57	60.3	....	52	55	54	
24	.956	.956	.980	56	65	57	60	67	54	60.3	....	49	57	51	Temp. at 6.30 a. m. 51°.
25	.968	.964	.974	56	64	54	56	64	52	57.3	....	44	57	46	
26	.966	.956	.966	53	60	55	52	57	51	53.3	....	50	55	49	Thunder at 7 p. m.
27	.958	.970	.978	52	60	54	53	61	51	55.0	....	49	56	48	
28	.962	.956	.966	52	61	55	52	62	53	55.7	....	49	58	51	
29	.956	.950	.982	53	62	59	53	64	56	57.7	....	51	58	55	
30	.968	.978	.990	55	62	56	54	63	50	55.7	....	52	58	49	
31	.962	.976	.972	53	61	55	53	61	52	55.3	....	48	55	49	
Total...	122.939	123.104	123.425	....	....	....	1641	1916	1636	1731.0	....	1520.5	1744.5	1545	
Mean...	23.966	23.971	23.981	....	....	....	52.9	61.8	52.8	55.8	....	49.0	56.3	49.8	
		23.973						55.8					51.7		

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds.					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858.																				
Jan. 1			1				9	SE.	2		0								W.	2
2	12.25 p. m 2 50 p. m. 6.10 p. m.	1 15 p. m. 5.5 p. m. 7.15 p. m.	2	W.	1	Higher.	10	SE.	2	Fog.	10									
3	11 a. m.	12.15 p. m.	4	NE.	2		2	NE.	2		0									
4			2	W.	2	Higher.	4	E.	2		0								W.	2
5			5	NE.	2		4	NE.	2		0									
6	2.40 p. m.	3.10 p. m.	2	NE.	2		10	N. & E.	2		3								W.	2
7	10.45 a. m. 12.20 p. m.	11.30 a. m. 1.10 p. m.	3	NE.	2		9	N. & E.	2		1									
8			1	W	1	Higher.	9	N. & SE.	2	Middle	0								W.	2½
9			2	N.	1		9	NE.	1		1									
10			1	E.NE.	2		8	E.NE,	2		4									
11			4	E.NE	2½		9	SE. & NE.	2		0									
12			0				7	S.	2		0								W.	2
13			0				10	SE.	2		0								W.	1
14			0				8	N. NE.	1 2		0								W.	2½
15			0				5	SE	2		0				W.	2				
16			0				3	NE. E.SE	2½ 2½		0								SW.	2
17			0				7	SW. SE.	2 2	Higher. Middle.	2								W.	1
18			2	SE	2		8	SE.	2		2								W.	2
19			1				3	SE.	3		10									
20			10	SE.	3		10	SE.	3		10								W., fog	2
21			6	SW. SE	2 3	Higher. Middle	9	SE	3		9	SE.	3							
22			5	W. SE	2 2½	Higher. Middle.	7	W. SE.	2 2½	Higher. Middle.	9	SE.	2½							
23			6	W.	2	Higher.	5	W.	2	Higher.	8	SE.	2½							
24			8	W.SW	2	Higher	7	W. SE	2 2½	Higher. Middle.	3								W.	1

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds.					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. Jan. 25			8	W	2	Higher.	5	SE.	2½		2								W.	2
26	2 15 p. m.	2.35 p. m.	8	N.	2		10				6								W.	2
	6 p. m.	6.20 p. m.						E.	2											
27			4	SE	2		6	SE.	2½		1								W.	2
28			5				7	SE.	2½		1								W.	2
				E.	2															
29			1				5	SE.	2		5								W.	1
30			1				7	SW.	1		1								W.	2
31			10				8	S.	2		0								W.	2
Total.			102				220				88									
Mean.			3.3				7.1				2.8									

Register of Meteorological Observations—Continued.

Date.	Barometer.						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.		7 A. M.	2 P. M.	9 P. M.	
1858. Feb. 1	23.980	23.992	24.020	54°	62°	58°	55°	61°	56°	57.3	....	51°	53°	53°	
2	24.020	24.012	24.006	55	63	53	56	63	49	56.0	....	54	56	42	
3	23.998	24.016	24.030	52	65	55	53	64	54	57.0	....	41	55	50	
4	24.013	24.018	24.048	54	60	56	53	60	53	55.3	....	52	51	51	
5	24.035	24.023	24.024	55	60	54	53	62	51	55.3	....	52	55	49	
6	24.002	24.018	23.996	53	63	55	54	63	53	56.7	....	50	52	48	
7	23.975	23.980	23.997	54	61	55	54	62	52	56.0	....	52	58	50	
8	.972	.966	23.994	58	62	59	58	62	58	59.3	....	54	57	56	
9	.980	.990	24.008	57	63	60	58	63	58	59.7	....	56	59	57	
10	.978	.977	23.978	58	64	58	58	65	55	59.3	....	56	61	54	
11	....	....	....	....	....	....	54	62	56	57.3	....	52	58	53	
12	....	....	....	....	....	....	53	63	53	56.3	....	50	60	51	
13	....	....	....	....	....	....	55	65	54	58.0	....	52	61	53	
14	....	....	....	....	....	....	56	62	52	56.7	....	51	57	48	
15	....	....	....	....	....	....	54	60	51	55.0	....	48	56	46	
16	....	....	....	....	....	....	53	59	52	54.7	....	42	52	48	
17	....	....	....	....	....	....	54½	61	55	56.8	....	50	55	52	
18	....	....	....	....	....	....	53	63	55	57.0	....	49	60	53	
19	....	....	....	....	....	....	55	64	55	58.0	....	52	59	52	
20	....	....	....	....	....	....	57	63	58	59.3	....	53	59	56	
21	....	....	....	....	....	....	54	63	55	57.3	....	49	60	48	
22	....	....	....	....	....	....	57	68	51	58.7	....	46	60	45	
23	....	....	....	....	....	....	55	64	51	56.7	....	48	56	46	
24	....	....	....	....	....	....	52	69	52	57.7	....	44	57	45	Temp. at 6½ a. m. 48°.
25	....	....	....	....	....	....	61	68	53	60.7	....	44	57	50	
26	....	....	....	....	....	....	58	66	52	58.7	....	42	59	50	
27	....	23.924	23.918	50	65	57	51	66	55	57.3	....	47	55	50	
28	23.904	23.906	23.910	54	61	55	55	60	51	55.3	....	51	55	49	
Total...	....	....	....	....	....	....	1539.5	1771	1500	1603.4	....	1388	1593	1405	
Mean...	....	....	....	....	....	....	55.0	63.2	53.6	57.3	....	49.6	56.9	50.2	
							57.3					52.2			

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. Feb. 1			5	S.	2		4	S.	2		4								W.	2
2			1				5				0								W.	2
3			0				4	E.	2½		1				N.W.	2½			S.	2½
4			10	E.S.E.	2		3	SE.	2		0								W.	2
5			9	E.S.E.	2		8	SE.	2½		1								W.	2
6	6 a. m. 11 a. m.	6.20 a. m. 11.30 a. m.	1				3	SE.	2		0								W.	2
7			0				9	S.	2½		3								W.	2
8			0				7	S.	2½		10									
9			4	S.S.W.	2		10	SE.	2		7									
10			2	N.N.W.	1		9	SE. & S.	2 2½	M.	2								W.	1
11			0				8				0									
12			0				9	S.	2½		0									
13			6				8	S.S.E.	2½		0								W.	1
14			0				9	S.S.E.	2		0								W.	1
15			2	SW.	2	M. H.	9	SW.	1		0								W.	2
16			6	Very dry. W.	2	H. cirr cum.	10	SE.	1	M.	5								W.	2
17			0				9	S.S.E.	1		1	S.	1							
18			1				8				0									
19			0				10	NW.	2		0								W.	2
20			1				10	SE.	2		1								W.	2
21			10	NW.	2		10	SE.	2½		7									
22			6	SW.	1	H.	8	N.	2	M.	4								W.	2
23			6	Station.		H.	9	E.S.E.	2		8	Station.		H. thin					SW.	2
24			2	Station.		H.	4	S. E.	2½ 2½	M.	0								W.	2
25			0				5	N. E.S.E.	2 2	M.	1	Station.		H.	NW. Extraordinarily dry.	1				

26			8	S.	2	H.	8	N.	2	M.	4	N.	2		NW.	2				
27			1	Station'y		H.	5	S. W	2 2	M.	0									
28			3				7	S. W	2 2	M	0	N.	3							
Total			84				268				59									
Mean			3.0				7.4				2.1									

Register of Meteorological Observations—Continued.

Date.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1858. March 1	23.896	23.900	23.912	53	61	58	52	60	55	55.7	....	....	....	49	55	53	Temp. at 6¼ a. m. 49°.
2	.890	.900	.930	52	60	55	54	56	53	54.3	....	....	....	48	53	45	
3	.898	.909	.922	53	61	55	54	61	51	55.3	....	....	....	44	55	48	
4	.912	.916	.914	53	63	61	57	63	54	58.0	....	....	....	43	55	42	Temp. at 6¼ a. m. 50°.
5	.892	.912	.908	51	68	57	54	66	54	58.0	....	....	....	42	54	48	
6	.918	.935	.948	55	65	58	55	69	55	59.7	....	....	....	50	59	52	
7	.934	.930	.944	56	63	58	58	65	56	59.7	....	....	....	52	57	52	
8	.944	.914	.982	57	64	60	57	63	59	59.7	....	....	....	54	57	56	
9	.994	24.000	24.042	59	68	63	58	69	59	62.0	....	....	....	55	60	56	Thunder at 4¾ p. m.
10	24.028	24.024	24.022	59	66	60	59	64	58	60.3	....	....	....	55	58½	54	
11	23.994	24.002	23.978	57	67	55	56	68	51	58.3	....	....	....	51	60	43½	
12	.976	23.952	.951	56	66	60	57	65	56	59.3	....	....	....	53	59	53	
13	.924	.916	.926	55	62	57	57	61	54	57.3	....	....	....	53	57	50	
14	.907	.906	.910	55	64	57	57	67	55	59.7	....	....	....	48	56	61	
15	.900	.904	.906	55	62	58	54	64	56	58.0	....	....	....	51	57	54	
16	.900	.896	.922	56	61	58	57	59	56	57.3	....	....	....	54	56	52	
17	.916	.926	.938	55	60	57	53	59	54	55.3	....	....	....	47	56	52	
18	.948	.949	.970	55	57	56	50½	55½	54	53.3	....	....	....	49	55	53	
19	.956	.966	.967	55	60	58	53	61	56	56.7	....	....	....	53	56	54	
20	.938	.930	.940	57	66	60	57	69	58	61.3	....	....	....	53	61	55	
21	.916	.912	.932	56	62	59	58	60	56	58.0	....	....	....	54	59	53½	
22	.940	.952	.956	58	64	56	59	64	53	58.7	....	....	....	55	57	45	
23	.956	.976	.990	56	66	59	58	69	58	61.7	....	....	....	54	56	54	
24	.980	.994	.990	56	65	58	57½	67	56	60.2	....	....	....	54	55	51	
25	.982	.974	.972	57	65	59	59	65	56	60.0	....	....	....	49	60	52½	
26	.948	.963	.960	55	67	58	55	67	56	59.3	....	....	....	49	59	48	
27	.966	.962	.980	57	65	62	58	66	59	61.0	....	....	....	54	56	56½	Clouds at 10 a m. W. 2 higher; SE. 3 middle.
28	.970	.964	.976	58	66	61	59	70	59	62.7	....	....	....	53	58	55	
29	.960	.968	.976	57	65	63	58	66	61	61.7	....	....	....	55	59	59	
30	.959	.949	.948	60	68	63	59	69	60	62.7	....	....	....	56	59	57½	
31	.944	.946	.954	59	66	59	60	67	56	61.0	....	....	....	57	57	52	
Total.....	122.186	122.277	122.566	....	....	....	1750	1994.5	1734	1826.2	....	....	....	1594	1771.5	1617.5	
Mean.....	23.941	23.944	23.954	....	....	....	56.5	64.3	55.9	58.9	....	....	....	51.4	57.1	52.2	
	23.946						58.9							53.6			

Register of Meteorological Observations—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2. P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. April 1	......	......	1	N.	3	......	9	S. N.	2 2	} M.	2	Station.	......	......	......	......	......	......	......	......
2	......	......	0	......	......	......	10	SE. NW.	2 3	M., H. M.	0	......	......	......	......	......	......	......	NW.	2½
3	......	......	0	......	......	......	7	S. NW.	2½ 3	M. Below M	0	......	......	......	N.	2	NW.	2½	W.	2
4	......	......	0	......	......	......	9	S. N.	2 2½	M. Below M	0	......	......	......	N.NW.	3	......	......	N.NW.	2½
5	......	......	3	SW.	2	H., cirr.	8	SW. S.	2½ 2½	H. M.	5	......	......	......	......	......	......	......	SW.	2
6	......	......	2	SW.	1	H.	8	SW.	2	M., H.	3	......	......	......	......	......	......	......	......	......
7	......	......	0	......	......	......	8	S.	2	......	0	......	......	......	......	......	......	......	......	......
8	......	......	2	SE.	2	M.	9	S. SE.	2 2	M. M.	4	......	......	......	......	......	......	......	......	......
9	......	......	2	SW.	2	......	8	E.	2½	......	2	......	......	......	......	......	......	......	W.	1
10	......	......	4	N.NE.	3	......	8	SSE. N.	2½ 2	} M.	0	......	......	......	......	......	......	......	......	......
11	......	......	2	NE. N.	3 3	M., H. M.	7	E.NE.	2	......	0	......	......	......	NW.	2½	......	......	W.	1
12	......	......	5	E.NE. S.	2 2	M., H. M.	9	SE.	2½	M.	0	......	......	......	......	......	......	......	......	......
13	......	......	1	......	......	......	10	SE. N.	1 2	M. Below M.	0	......	......	......	......	......	......	......	W.	2
14	......	......	0	......	......	......	7	S SE.	1	......	0	......	......	......	W.	1	......	......	W.	2
15	......	......	3	SW.	2	H.	8	SW. SE.	2½ 2	H. M.	6	......	......	......	......	......	......	......	......	......
16	A few drops p. m.	of rain at 4	7	SW.	2	H.	10	S. N.	2 2	M. M.	10	......	......	......	......	......	......	......	......	......
17	7.25 a. m. 12.10 p. m.	9 a. m. 1 p. m.	10	W.	1	M., H.	10	S.SE.	2	M.	10	......	......	......	......	......	......	......	W.	2
18	6.40 a. m. 8.5 a. m. 10 a. m. 1.25 p. m.	7.40 a. m. 8.50 a. m. 11 a. m. 4.15 p. m.	10	SW. SE.	1 1	H. M.	10	...... E SE. Fog	 1	...... L.	9	......	......	......	......	......	......	......	......	......

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. April 19	......	......	10	S. E.	2 2½	M. L.	9	W. SE. E.	2½ 2½ 3	Cirr. M. L.	10	......	......	......	......	......	......	......	......	......
20	......	......	10	N.NE.	1	M.	8	E.SE.	2½	M.	6	......	......	......	......	......	......	......	......	......
21	1.45 p. m. 3.40 p. m. Mist.	2.30 p. m. 5.15 p. m.	1	....	....	....	10	...... E.	 1	...... L.	5	W.	2	Cirr. Cumul.	......	......	......	......	W.	2
22	......	......	5	S. SE.	2½ 2½	} M.	10	S.SE.	2	M.	0	......	......	......	......	......	......	......	SW.	2
23	......	......	3	W.	2	H.	4	W SW. SE.	1 2	H. M.	4	S.	2	M.	......	......	......	......	SW.	2
24	......	......	2	SW.	1	H.	6	SE.	2	M.	1	......	......	......	......	......	......	......	SW.	2
25	......	......	2	S.SW.	2	H.	8	NE.	2	M.	0	......	......	......	......	......	......	......	W.	1
26	......	......	2	......	......	......	10	SE.	2	M.	0	......	......	......	......	......	......	......	SW.	2
27	......	......	2	SE.	3	M.	8	SE.	3	M.	4	S.	2½	M.	......	......	......	......	E.	2
28	......	......	2	SW.	2	M., H.	3	SE.	2½	M.	3	......	......	......	......	......	......	......	W.SW.	2
29	......	......	4	W.SW.	1	H.	10	S SE.	2½	M.	10	S.	2	M.	......	......	......	......	......	......
30	......	......	5	SE	2½	M.	7	SE.	2½	M.	7	S.	2	M.	......	......	......	......	......	......
31	......	......	6	SW. NE.	1 2	H. M.	9	S.SE.	2	M.	2	......	......	......	......	......	......	......	SW.	2
Total...	......	......	106	......	......	......	257	......	......	......	103	......	......	......	......	......	......	......	......	......
Mean...	......	......	3.4	......	......	......	8.3	......	......	......	3.3	......	......	......	......	......	......	......	......	......

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.		7 A. M.	2 P. M.	9 P. M.	
1858.				°	°	°	°	°	°	°		°	°	°	
April 1	23.968	23.982	23.972	59	67	63	57	66	60	61.0	....	55	59	58	
2	.974	.948	.998	61	63	62	62	62	59	61.0	....	59	59	57	
3	.948	.950	.972	59	65	61	58	64	60	60.7	....	56	58	57	
4	.972	.984	.984	58	64	62	56	68	60	61.3	....	55	61	57	
5	.982	.968	.968	58	65	62	58	65	60	61.0	....	56	58	56	
6	.980	.958	.982	59	66	63	59	66	61	62.0	....	55	57	58	
7	.970	.958	.960	58	65	60	57	68	58	61.0	....	55	58	54	
8	.952	.934	.942	58	65	58	60	66	56	60.7	....	55	56½	50	
9	.928	.939	.946	57	64	59	58	64	55	59.0	....	54	58	53	
10	.934	.936	.935	57	64	59	60	64	56	60.0	....	53	58½	52	
11	.912	.916	.920	57	64	62	59	65	60	61.3	....	54	59	57	Thunder, very faint and of short duration.
12	.907	.908	.910	59	64	60	59	61	56	58.7	....	55	57	53	
13	.937	.942	.943	59	64	60	58	64	57	59.7	....	56	60	56	
14	.964	.972	.978	59	65	61	59	64	58½	60.5	....	56	58	57	
15	.986	.992	.980	60	66	62	57	69	59	61.7	....	55	58	58	
16	.964	.970	.950	59	68	62	58	69	59	62.0	....	55½	54	....	
17	.953	.966	.959	58	67	60	60	70	58	62.7	....	50	58	52	
18	.970	.986	.973	59	65	59	58	66	57½	60.5	....	54	59	49	Thunder, very faint, at 3.45 p. m.
19	.980	.985	.958	57	66	59	59	72	55	62.0	....	51	62	47	
20	.961	.968	.944	58	66	59	58	66	55	59.7	....	53	59	48	
21	.942	.922	.924	57	65	60	57	68	56	60.3	....	51	60	54	
22	.932	.948	.954	57	66	57	60	67	55	60.7	....	55	61	44	
23	.954	.950	.959	57	64	59	59	68	58	61.7	....	56	61	51	
24	.942	.962	.970	58	65	61	60	65	57½	60.8	....	54½	60	56	
25	.946	.938	.942	59	65	61	59	65	57	60.3	....	56	59	55	
26	.938	.964	.966	59	67	62	59	67	59	61.7	....	56	56	54	
27	.980	.986	.990	60	67	63	60	66	61	62.3	....	56	59	55	
28	.992	.990	.994	62	64	62	62	63	59	61.3	....	59	59	57	
29	.992	.950	.942	60	63	60	57	60	57	58.0	....	57	58½	55	
30	.920	.920	.918	58	64	59	59	64	57	60.0	....	56	59	55	
Total...	1.580	1.692	1.733	....	....	....	1762	1972	1736.5	1823.6	....	1649	1760.5	1622	
Mean...	23.953	23.956	23.958	....	....	....	58.7	65.7	57.9	60.7	....	55.0	58.7	54.1	
		23.956						60.7					55.9		

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. April 1	8.55 p. m.	9.5 p. m.	9	S	2½	M	8	S	2½	H	10	......	......	......	......	......	......	......	......	......
								S	3	M										
2	1.15 p. m.	1.20 p. m.	2	E.SE	2	M	10	S.SE	2	M	2	......	......	......	......	......	......	......	SW	2
				E SE	2	L														
3	......	......	9	SE	2½	M	10	S	2	M	10	......	......	......	......	......	......	......	......	......
				E.SE	3	L														
4	......	......	10	S	2½	......	8	S	1	M	10	......	......	......	......	......	......	......	......	......
				E	2	L														
5	......	......	6	NE	1	M	9	SW	2	Above M.	3	......	......	......	......	......	......	......	SW	1
								S	2	M										
6	......	......	6	S	2	M., H.	8	S.SW	2½	M., H	3	......	......	......	......	......	......	......	......	......
								SE	2	M.										
7	......	......	7	SW	1	M., H.	9	S	1	M	1	......	......	......	......	......	......	......	......	......
8	......	......	2	......	......	......	9	E	1	M., H	1*	......	......	......	......	......	......	......	SW	2
9	......	......	5	W	2½	Cirr.	9	S	1	M., H	1	......	......	......	......	......	......	......	SW	2
10	......	......	3	W	2	Cirr.	10	W	1	M., H.	0	......	......	......	......	......	......	......	SW	2
								S. and E.	1	M										
11	......	......	2	W	2	Cirr	9	SE	1	M	7	......	......	......	......	......	......	......	......	......
12	......	......	4	SW	2	M., H	10	SW	1	M	1	......	......	......	......	......	......	......	SW	1
13	2.10 p. m.	2.20 p. m.	2	SW	1	M., H	10	S	2	M	4	......	......	......	......	......	......	......	SW	1
	3.20 p. m.	5.30 p. m.																		
14	......	......	5	SE	2	M	9	S.SW	2	M., H	9	......	......	......	......	......	......	......	......	......
								SE	1	M.										
15	......	......	7	SE	2	M., H.	6	SE	2½	M	3	......	......	......	......	......	......	......	......	......
16	......	......	5	W	1	Cirr.	2	ESE	2½	M	1	......	......	......	......	......	......	......	SW	1
				E.SE	2½	M.														
17	......	......	3	W	1	Cirr	6	W	1	H	3	......	......	......	......	......	......	......	......	......
								E.SE	2½	M										
18	......	......	7	E	2	M	7	E.NE	2	M	1†	......	......	......	......	......	......	......	NE	1
19	......	......	8	W	1	H	7	W	1	Cirr	3	......	......	......	......	......	......	......	SW	1
								SE. & N.	2	M										
20	......	......	5	......	......	......	10	NE	2	M	4	......	......	......	......	......	......	......	W	2
21	......	......	10	SE	2	M	9	SE	2	M	3	......	......	......	......	......	......	......	SW	1

22	...	...	1	...	...	...	8	S ...	2	M ...	0	...	...	...	...	...	...	...	W ...	1
23	...	...	9	...	...	...	10	SE ...	2	M ...	2	...	...	...	...	...	...	...	...	...
24	...	...	2	W ...	1	Cirr ...	10	SE ...	2	M ...	5	SE ...	2	M ...	...	...	...	...	SW ...	1
25	...	...	9	S ...	1	M., H	9	S ...	2	M ...	4	S ...	2	...	...	...	...	...	SW ...	2
26	...	...	2	...	...	...	7	S ...	2	M ...	1	S.SW ...	2	...	...	...	...	...	SW ...	1
27	...	...	3	W ...	2	H ...	9	S ...	2½	M ...	6	S.SW ...	2½	M., H	...	...	...	...	SW ...	1
28	4 p. m. ...	5.10 p. m. ..	8	W.SW ...	2½	M., H	9	S.SW ...	2½	M ...	10	...	...	...	...	...	...	...	S SW ..	1
	5.20 p. m. ..	5.40 p. m. ..	...	S ...	2	M ...														
29	1 p. m ...	1.35 p. m.	10	...	...	Fog ...	10	SE ...	2	M ...	5	...	...	...	...	...	...	...	W ...	2
	1.50 p. m. ..	4.20 p. m. ..																		
30	...	...	0	...	...	...	9	S ...	2	M ...	2	...	...	...	...	...	...	...	W.SW ..	2
Total ...	...	...	161	...	...	...	256	...	...	...	115	...	...	...	...	...	...	...	...	...
Mean ...	...	...	5.4	...	...	...	8.5	...	...	...	3.8	...	...	...	...	...	...	...	...	...

* Clouds at 6 p. m. W. 2 H.; S. 2 M.

† Clouds at 11 a. m. SW. 2 H. cirr., exquisitely fine and regularly distributed; middle strata NE. 2½.

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Barometer.						Thermometer in open air.				Psychrometer.				Remarks.
	Height.			Thermometer attached.							Dry bulb.	Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	2 A. M.	2 P. M.	9 P. M.	Mean.		7 A. M.	2 P. M.	9 P. M.	
1858.				°	°	°	°	°	°	°		°	°	°	
May 1	23.918	23.930	23.947	57	64	59	57	65	57	59.7	....	51	59	53	
2	.952	.960	.984	60	63	61	58	64	59	60.3	....	56½	60	58	
3	.980	.970	.996	60	62	61	61	60	58	59.7	....	59½	59	58	Thunder at 6.50 p. m.
4	.964	.948	.964	58	61	60	56	60	57	57.7	....	55	59	56	
5	.952	.962	.980	58	65	62	57	65	59	60.3	....	57	58	56	
6	.974	.970	.980	60	65	62	58	68	59	61.7	....	57	59	58	
7	.982	.970	.980	57	64	62	55	66	60	60.3	....	54	58	58	
8	.968	.972	.992	60	66	63	58	68	60	62.0	....	56	59	58	
9	.969	.965	.967	59	65	62	60	70	61	63.7	....	56	60	58	
10	.973	.972	.992	59	67	63	58	71	60	63.0	....	55	59	57	
11	.996	.994	.990	61	65	59	62	66	56	61.3	....	58	60	53	
12	.990	.992	.974	58	66	58	61	69	57	62.3	....	49	59	43½	
13	.970	.954	.936	61	63	57	61	62	53	58.7	....	56	57	48	
14	.938	.936	.952	60	63	60	61	64	59	61.3	....	56	58	57	
15	.948	.940	.955	60	63	62	58	63½	60	60.5	....	56½	59	59	
16	.972	.942	.978	61	63	62	58	62	59	59.7	....	57½	60	58	
17	.980	.976	.970	61	65	62	59	65	59	61.0	....	58	59	59	
18	.976	.964	.970	59	62	59	57	64	58	59.7	....	56	61	55	
19	.970	.976	.972	57	64	57	57	66	54	59.0	....	55	59	49	
20	.984	.978	.970	58	64	60	58	65	57	60.0	....	57	57	56	
21	.980	.974	.974	60	65	62	60	65	59	61.3	....	57	59	58	
22	24.008	.984	.992	58	64	60	57	63	59	59.7	....	56½	60	57	
23	24.006	.982	24.018	58	64	61	56	66	59	60.3	....	55	60	57½	
24	23.986	.976	23.976	57	64	61	58	69	57	61.3	....	56	59	55	
25	.960	.986	.976	57	65	57	57	65	54	58.7	....	53	57	45	
26	.974	.986	.994	59	65	62	57	68	59	61.3	....	55	56	57	
27	.994	.996	24.000	58	61	60	56	61	58	58.3	....	55	58	57	
28	.998	.986	24.002	58	64	60	55	66	58	59.7	....	55	59	57	
29	.998	.992	24.000	56	61	60	56	62	58	58.7	....	52	58	56	
30	.990	.984	23.986	59	64	61	59	67	59	61.7	....	56	60	58	
31	.980	.950	.974	59	64	60	57	68	59	61.3	....	56	62	57	
Total...	123.230	2.167	123.341	....	....	....	1798	2023.5	1801	1874.2	....	1722.5	1827	1722	
Mean...	23.972	23.970	23.979	....	....	....	58.0	65.3	58.1	60.5	....	55.6	58.9	55.5	
		23.974						60.5					56.7		

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858.																				
May 1	3.25 p. m.	3.35 p. m.	8	SW	1	M. h	10	E	2	M	2	......	......	......	......	......	......	......	SW	2
2	2.55 p. m.	3.40 p. m.	9	S	2	M	9	S	1	M	3	......	......	......	......	......	......	......	......	......
	4.10 p. m.	4.20 p. m.																		
3	9 p. m.	9.5 p. m.	8	S.SE	2	M	10	E	......	Fog	10	......	......	......	......	......	......	......	......	......
4	5.40 p. m.	9.50 p. m.	10	S	2½	......	10	E	2½	Fog	10	......	......	......	......	......	......	......	......	......
5	......	......	10	......	......	Fog	9	S	2	......	7	......	......	......	N.NE.	2	......	......	......	......
6	......	......	10	E	2	Fog	6	E.SE	2½	M. h.	9	......	......	......	......	......	......	......	......	......
7	9.20 p. m.	9.30 p. m.	10	SE	2½	Fog	5	SE	2½	M	9	......	......	......	......	......	......	......	......	......
8	......	......	6	E	2	L	6	NE	2	M. h	3	......	......	......	......	......	......	......	W	1
								S	2	Bel. m.										
9	......	......	3	W	2	M. h	6	NE	2	M. h	4	......	......	......	......	......	......	......	......	......
								SE	2	M										
10	......	......	3	S	2½	M	6	SE	2	M	3	......	......	......	......	......	......	......	SW	2
								E.SE	2½											
11	......	......	3	N	2	M	8	SE	2	M	3	......	......	......	......	......	......	......	W	2
								and E.SE.	2½											
12	......	......	3	......	......	......	9	SE	2	M	3	......	......	......	......	......	......	......	W; very dry.	2
								N	2											
13	......	......	9	SE	2	M	9	SE	1	......	0	......	......	......	......	......	......	......	W	2
14	......	......	5	SE	2½	M	8	S	2½	......	7	......	......	......	......	......	......	......	......	......
15	......	......	9	SE	2½	......	10	SE	2½	......	9	......	......	......	......	......	......	......	......	......
16	3 a. m.	4.30 a. m.	10	E.SE	2	......	10	SE	2	......	10	......	......	......	......	......	......	......	......	......
	11.30 a. m.	1.15 p. m.																		
17	5 p. m.	5.15 p. m.	8	......	......	......	9	SE	2	......	10	......	......	Fog	......	......	......	......	......	......
18	6.15 a. m.	7.40 a. m.	10	SE	2½	......	10	SE	2	......	2	......	......	......	......	......	......	......	......	......
19	......	......	5	SE	2½	......	5	SE	2½	......	3	......	......	......	......	......	......	......	W	2
20	......	......	9	SE	2½	......	7	SE	2	......	3	......	......	......	......	......	......	......	......	......
21	......	......	8	E SE	2	......	7	SE	2½	......	10	......	......	......	......	......	......	......	......	......
22	10.20 a. m.	10.40 a. m.	10	SE	2½	......	9	SE	2½	......	2	E.SE	3	......	......	......	......	......	S.SW	2
23	......	......	10	E.SE	2½	......	8	E	2	M	10	......	......	......	......	......	......	......	......	......
								S	2											
24	......	......	8	SE	2½	......	3	E.SE	2	......	5	E.SE	2	......	......	......	......	......	......	......
25	......	......	2	S	1	......	6	E.SE	2½	......	3	S.SW	2	......	......	......	......	......	......	......

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. May 26			9	SW SE	2½ 2½	M. h M.	9	E.SE	2		10									
27			10			Fog	10				9									
28	3.30 p. m. 6.40 p. m.	4.40 p. m. 8 p. m.	10			Fog	8	SE	3		10									
29			10				10	SE	2½		10	E	2	L						
30	6.35 p. m.	6.45 p. m.	3				9	SE	2½		10									
31	3.50 p. m.	4.20 p. m.	0				9	SE	2		10	E.SE	2½							
Total			237				250				199									
Mean			7.7				8.1				6.4									

No. 1.—*Register of Meteorological Observations*—Continued.

Day of the month.	Barometer.						Thermometer in open air.				Psychrometer.						Remarks.
	Height.			Thermometer attached.							Dry bulb.			Wet bulb.			
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	
1858.				°	°	°	°	°	°	°				°	°	°	
June 1	23.970	23.988	24.010	59	59	58	58	57	58	57.7				58	56	55	
2	24.008	.989	23.998	58	63	60	59	64	58	60.3				56	60	59	
3	23.974	.966	.964	57	64	60	59	64	59	60.7				56	60	64	
4	.960	.950	.958	56	65	60	57	68	55	60.0				47	60	52½	
5	.954	.952	.970	57	61	59	57	62	56	58.3				54	60	50	
6	Barometer broken																
Total										297.0							
Mean										59.4							

CARACAS.

Day of the month.	Height 7 A. M.	Height 2 P. M.	Height 9 P. M.	Therm. att. 7 A. M.	Therm. att. 2 P. M.	Therm. att. 9 P. M.	Open air 7 A. M.	Open air 2 P. M.	Open air 9 P. M.	Mean.	Dry bulb 7 A. M.	Dry bulb 2 P. M.	Dry bulb 9 P. M.	Wet bulb 7 A. M.	Wet bulb 2 P. M.	Wet bulb 9 P. M.	Remarks.
June 16							70	81	72	74.3				65	69	69	
17							70	79	73	74.0				67	69	69	
18							70	76	71	72.3				68	70	68	
19							70	79	72	73.7				66	70	68	
20							70	79	71	73.3				67	71	69	Thunder at 2.45 p. m.; very faint.
21							69	76	71	72.0				66	69	67	
22							69½	77	71	72.5				67	70	68	
23							69	79	72	73.3				65	66	69	
24							69	79	72	73.3				65	67	69	
25							69	76	72	72.3				66	69	69	
26							69	75	71	71.7				67	68	68	Thunder at 6.30 p. m.; faint.
27							70	73	69	70.7				67	69	67	
28							68	74	69	70.3				65	69	67	
29							68	78	70	72.0				66	66	67	
30							69	76	70	71.7				66	70	68	
Total							1039.5	1157	1066	1087.4				993	1032	1022	
Mean							69.3	77.1	71.1	72.5				66.2	68.8	68.1	
								72.5							67.7		

No. 1.—*Register of Meteorological Observations*—Continued.

Date.	Rain.		Clouds.												Winds (well defined.)					
			7 A. M.				2 P. M.				9 P. M.				7 A. M.		2 P. M.		9 P. M.	
	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
1858. June 1	11.15 a. m.	2.45 p. m.	10	S.SE	2½	Mid	10	E.SE	2½	Mid	9	...	...	...	...	...	...	...	SW	2
2	...	...	7	SE	2½	...	9	SE	2½	Mid	10	...	...	...	...	...	...	...	...	...
								E	2½	Bel. mid.										
3	3.55 p. m.	4.10 p. m.	1	...	...	...	9	SE	2	...	1	...	...	...	...	...	...	...	S	2
4	...	...	8	SW	1	High	8	SE	2½	Mid	2	...	...	...	...	...	...	...	S.SE	1
5	11.5 a. m.	11.20 a. m.	9	SE	2	Mid	9	NW	2½	} Mid	3	...	...	...	...	...	...	...	SW	3
	11.55 a. m.	1.10 p. m.	...	...	...	...	...	E.SE	2½											

CARACAS.

Date.	Time of beginning.	Time of ending.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Amount.	Course.	Velocity.	Kinds.	Direction.	Force.	Direction.	Force.	Direction.	Force.
16	3.45 p. m.	4.5 p. m.	5	S.SE	3	Mid	5	SE	2	...	4	...	...	...	...	...	...	...	...	...
	4.30 p. m.	4.45 p. m.	...	E	1	Low														
	5.20 p. m.	5.55 p. m.																		
17	...	...	5	E	2½	Mid	7	SE	2½	Mid	9	...	...	...	...	...	...	...	...	...
				E	2½	Low														
18	5.15 a. m.	5.30 a. m.	10	...	...	...	7	E	2	...	10	...	...	...	...	...	...	...	...	...
	1.5 p. m.	1.30 p. m.																		
	3.40 p. m.	4.10 p. m.																		
19	...	...	4	SE	2	...	5	...	...	...	5	...	...	...	...	...	...	...	...	...
				E	3	...	...	E	2	...	...	E	2							
20	8 a. m.	8.10 a. m.	9	...	...	...	8	SE	1	...	10	...	...	...	...	...	...	...	...	...
	10.5 a. m.	11.10 a. m.	...	E	2	...	...	E	2	...	...	E	2½							
	2.45 p. m.	4.5 p. m.																		
21	...	...	10	...	...	...	10	...	...	...	6	Station'y	...	High	...	...	...	...	...	...
				SE } E.SE }	2½	Low	...	E	2	...	...	E	2	Low	...	...	...	...	...	...
22	...	...	10	E	2	Low	9	E	2	...	6	E	2½	Low	...	...	...	...	...	...
23	...	...	0	...	...	...	8	SE	2½	...	9	E	2½	...	...	...	...	...	...	...
24	...	...	8	SE	2	...	5	S	2	...	9	SE	2	...	...	...	...	...	...	...

25	a. m.....	9.50 a. m., mist.	10	SE......	2	... .	10	E........	2	....	10	....	......	....	....	......	....	......	....	......
26	6.5 p. m...	6.10 p. m..	9	....	......	....	10	8........	2½	Mid......	10	....	......	....	....	......	....	......	....	......
	6.50 p. m..	7.20 p. m..	......	....	......	....	......	E........	2	Low										
27	9.10 a. m..	10.15 a.m., mist.	10	E........	2	....	10	E	2	....	10	....	......	....	....	......	....	......	....	......
	5.20 p. m..	9.30 p. m..																		
28	4.30 p. m..	4.50 p. m..	9	ESE	2½	....	10	E.SE....	2	....	5	....	......	....	....	......	....	......	....	......
	7.20 p. m..	7.45 p. m..	......	....	......															
29	....	....	7	E	2½	....	3	....	....	....	0	....	......	....	....	......	....	......	....	......
30	9.50 a. m..	10.15 a. m.	10	E	2½	....	10	....	......	....	9	....	......	....	....	......	....	......	....	......
	11.20 a. m.	11.45 a. m.																		
	9.15 p. m..	9,30 p. m..																		
Total......	....	....	116	....	......	....	117	....	......	....	112	....	......	....	....	......	....	......	....	......
Mean......	....	....	7.7	....	......	....	7.8	....	......	....	7.5	....	......	....	....	......	....	......	....	......

Half-hourly Barometrical Observations at Colonia Tovar, Venezuela.

The numbers marked thus * are the maxima and minima of the day.

Date.	9 A. M.	Ther.	9½ A. M.	Ther.	10 A. M.	Ther.	10½ A. M.	Ther.	11 A. M.	Ther.	3 P. M.	Ther.	3½ P. M.	Ther.	4 P. M.	Ther.	4½ P. M.	Ther.	5 P. M.	Ther.	5½ P. M.	Ther.	Amplitude.
1858. Feb. 3	24.032	58	24.046	59	24.054	61	*24.056	61	24.054	62	24.008	64	24.004	64	*24.002	61	*24.002	61	24.003	60	....	....	.054
4	.052	55	060	55	* .064	56	.064	57	.062	59	.012	61	.010	61	.009	61	* .008	60	.010	59	....	....	.056
5	.062	56	.070	57	* .072	57	.070	57	.070	57	.016	60	* .012	60	.014	60	* .012	60	.016	59	....	....	.060
6	.048	56	.054	59	* .060	59	.059	60	.050	61	.003	62	23.998	61	23.997	61	23.994	61	*23.992	60	23.994	59	.068
7	.022	59	.029	60	* .031	61	.031	62	.030	62	*23.972	61	* .972	61	.975	61	.974	60	.974	59	23.976	59	.059
8	.008	59	.018	62	.022	64	* .024	64	.020	64	.960	63	* .957	62	.958	62	.959	61	.960	60	....	....	.067
9	.020	61	.028	63	.030	64	* .031	64	.026	64	.980	64	* .972	64	.974	63	.974	62	.976	62	....	....	.059
Total ..	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.423
Mean...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.0604

METEOROLOGY.

THE CLIMATE OF SACRAMENTO, CALIFORNIA, BY THOMAS M. LOGAN, M. D.

Latitude 38° 34′ 41″ N. Longitude 121° 27′ 44″ W.

As supplementary to the abstract of meteorological observations for 1853, 1854, and 1855, published in the reports of the Smithsonian Institution, the accompanying tables for 1856–'57, together with the results of the aggregate five years, have been prepared.

It may not meet the exactions of a rigid science to deduce a positive view of the climate from a series of observations extending through only five years, still an approximation may now be arrived at that will be sufficiently near to afford a very just appreciation of some of the climatic features of this portion of the great valley of the Sacramento, due allowance being made for irregularities and disturbing causes. Owing chiefly to the difficulty of procuring reliable instruments and proper tables and instructions, the records, which were made in various forms and with differing calculations, required re-arrangement and tabulation to render them comparable with each other. These considerations will be a sufficient apology with those who have much experience in arranging statistical tables for a certain amount of inaccuracy which has crept into our former publications. In the present instance we have used every possible precaution while rectifying former errors,* which are herewith specified, that the advantages already received may be rendered more valuable hereafter.

BAROMETER.

The series of barometric observations have not been, in one respect, continuous. Had they been conducted with one and the same instrument doubtless some valuable deductions might have been gathered from their analysis; as it is we can only note some of the most obvious results. During 1853 the ordinary ship barometer, (the only one to be had then,) which was used, appears to have ranged entirely too low. The readings from this instrument, as well as those which were registered from a common open cistern, and a siphon of Gay Lussac,

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* *Errata in former publications.*—The latitude and longitude of Sacramento are correctly given above, and are erroneous in the previous reports.

1853.—*Bar.* Mean for January, for 29.65 read 29.75; annual mean, for 30.01 read 30.02 inches *Therm.* Mean maximum, for 80°.40 read 80°.04; mean minimum, for 49°.00 read 49°.08; mean for October, for 78°.00 read 73°.00. *Winds.* SE., total, for 101 read 111.

1854.—*Bar.* Mean of January, for 29.11 read 30.11; minimum of May, for 29.00 read 29.60; mean minimum, for 29.76 read 29.81; annual mean, for 29.98 read 30.07 inches. *Therm.* Mean maximum, for 79°.54 read 79°.29; mean minimum, for 42°.72 read 42.73 *Rainy days.* March, for 9 read 4. *Inches of rain*, for 8.25 read 3.25. Annual total of *clear days*, for 223 read 228. Total *rainy days*, for 60 read 55.

1855.—*Bar.* Maximum of July, for 29.85 read 30.15; mean maximum, for 30.09 read 30.14 inches. *Dew point.* Annual mean, for 47°.52 read 46°.69.

were never corrected for temperature. During 1856 and 1857 Green's Smithsonian barometer was employed, and its readings reduced to 32° Fahrenheit. No correction for altitude was ever made, as the cisterns of the various instruments employed were at so small an elevation above the level of the sea. Neither was the elastic force of vapor applied at the time of the record. This force has been calculated only during the past year, according to the rules established by Regnault for deriving every degree of it exhibited in the atmosphere from the readings of the wet and dry-bulb thermometers. It will be seen that it increases directly with the temperature, and amounted during 1857 to nearly half an inch during midsummer, or one sixty-seventh of the entire atmospheric weight.

The absence of either abrupt or great changes gives indication of the tropical feature which the climate possesses. As a general rule the atmospheric pressure varies but little, and that through slow and long continued movements, rather than in the sudden manner characteristic of the latitude on the Atlantic coast and elsewhere. Nevertheless, although the mercurial column rises and falls within very restricted limits, yet there are changes, represented it is true by small measurements, which occur with wonderful regularity and certainty, diurnal movements at fixed hours, as well as annual ones, having reference to the position of the sun in the ecliptic. The former, or horary oscillations, as revealed on the chart of diurnal barometrical curves, present, in a marked degree, the two diurnal maxima and minima observed within the tropics; the ante-meridian maximum, at about 9 to 10 a. m., being more constant than that at the same period post meridian. Without a single exception the pressure is always less at 3 p. m., and this has no reference to whether the column stands high, as in the cold, or low, as in the hot season.

The following table, calculated from the horary observations, taken once a month during 1857, gives the mean successive hourly range for the year. The signs + and — denote the range of each hour above or below the mean of the twenty-four hours.

Table of successive hourly ranges of barometer for 1857.

Hours.	January 22.	February 23.	March 22.	April 29.	May 22.	June 22.	July 22.	August 28.	September 23.	October 21.	November 27.	December 23.	Mean.
7 a. m.....	+ .044	+ .134	− .064	+ .098	− .008	+ .052	+ .028	− .024	+ .057	+ .080	+ .056	+ .117	....
8 a. m.....	.041	.125	.057	.098	.016	.042	.036	.024	.061	.095	.044	.117	....
9 a. m	.041	.114	.032	.103	.012	.038	.042	.032	.075	.092	.053	.122	....
10 a. m.....	.036	.081	.026	.101	.008	.048	.044	.014	.078	.084	.065	.127	....
11 a. m.....	.031	.058	.018	.083	.010	.048	.039	.002	.067	.079	.038	.107	....
12 m.	.028	.028	.043	.053	.040	.041	.037	.017	.052	.062	.025	.078	....
1 p. m.....	+ .015	.024	.049	+ .031	.037	.018	+ .020	.018	.031	.037	.014	.047	....
2 p. m.....	− .029	.018	.046	− .010	.040	+ .014	− .008	.038	+ .009	+ .008	.006	.029	....
3 p. m....	.033	+ .012	.046	.029	.052	− .007	.014	.038	− .007	.000	.004	+ .004	....
4 p. m.....	.053	− .005	.043	.047	.059	.019	.012	.046	.025	− .024	+ .006	− .002	....
5 p. m.....	.029	.005	.040	.135	.056	.031	.031	.050	.032	.030	− .003	.017	....
6 p. m.....	.031	.010	.008	.054	.035	.019	.046	.056	.032	.030	+ .013	.021	....
7 p. m.....	.028	.007	.040	.060	.026	.046	.038	.033	.053	.018	.016	.027	....
8 p. m.....	.026	.006	− .008	.048	− .024	.058	.017	.018	.035	.039	.002	− .036	....
9 p. m.....	.023	.022	+ .015	.040	+ .002	.037	.010	− .005	.024	.036	+ .004	+ .037	....
10 p. m.....	− .047	.022	.040	.019	.040	.027	.010	+ .030	.022	.045	− .005	− .039	....
11 p. m.....	+ .002	.042	.046	.011	.043	− .016	.007	.023	.019	.038	.005	.042	....
12 p. m.....	.002	.042	.052	.030	.045	+ .012	.009	.026	.021	.032	.009	.051	....
1 a. m.....	.005	.051	.057	.027	.048	.015	.012	.028	.016	.030	.019	.064	....
2 a. m.....	.005	.053	.064	.025	.051	+ .007	.013	.031	.013	.034	.032	.066	....
3 a. m.....	.010	.062	.067	.022	.053	− .005	.013	.030	.020	.040	.046	.074	....
4 a. m.....	.013	.083	.072	.019	.051	.012	.011	.065	.033	.035	.066	.074	....
5 a. m.....	.015	.087	.072	.019	.043	.024	.019	.086	.045	.052	.086	.091	....
6 a. m.....	+ .013	− .097	+ .073	− .022	+ .034	− .028	− .000	+ .108	− .026	− .046	− .086	− 106	....
Sums.......	600	1186	1078	1084	833	664	516	842	853	1066	703	1495	....
Means......	.025	.049	.045	.045	.035	.028	.022	.035	.036	.044	.029	.062	.038

The mean successive daily range frequently, in summer, does not amount to more than the ninety-four thousandth part of an inch. The following calculation from the readings of the Smithsonian barometer during the last two years substantiates this fact.

Barometer.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean, 1856..........	.130	.114	.116	.114	.056	.091	.066	.070	.078	.088	.103	.160	.099
Mean, 1857..........	.110	.126	.101	.071	.109	.062	.046	.059	.057	.075	.110	.143	.089
Mean for 2 years.....	.120	.120	.109	.093	.083	.097	.056	.065	.068	.082	.107	.152	.094

The mean difference of the successive months above or below the annual average of the five years, as can readily be calculated from the data furnished, does not amount to more than one-sixteenth of an inch. Between the highest mean mensual mean and the lowest a fraction over one-fifth of an inch is found. The extreme ranges observed during the month are also limited, as may be seen in the subjoined table for 1857, wherein is also revealed the annual tide shown in the chart of curves; gradually descending as the sun approaches the northern tropic, and ascending as he returns towards the southern.*

January......................	0.633	July..........................	0.349
February	0.713	August	0.401
March	0.571	September	0.411
April	0.427	October	0.526
May	0.433	November.....................	0.590
June	0.404	December.....................	0.641

The extreme annual ranges are also small. During 1853 the maximum height of the barometer occurred in November and December, and read 28.980, giving the difference as the extreme annual range of 1.460 inch. This, however, is the result of an extreme minimum, never before nor since observed. A more reliable and the next lowest minimum was 29.380 inches, observed with Gay Lussac's siphon barometer on the morning, 1st January, 1855, before daylight, during a strong gale from the SE. The greatest mensual range was also observed in the same month, the maximum for the year having reached 30.410 inches in the same month, and giving a difference of 1.030 inch for the month as well as for the year The lowest reading for the same year was 29.569 inches on the 19th September. The extreme annual range was therefore 1.050 inch. These instances of extreme range are very rare, and must be regarded as exceptional. The extreme range for 1854 was only 0.850, and that of 1857 but 0.783 inch. During the rainy season northerly winds always determine the greatest elevation, and southerly the greatest depression of the mercurial column. This rule is not so constant during the dry season.

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* The mean for July of the series is higher than that of June, in consequence of some peculiar disturbing causes in June, 1853, which year should be regarded as exceptional, and which may in part be attributable to a defective instrument.

The mean annual atmospheric pressure is put down at 30.006 nches. This has been obtained from the mensual means derived from he three daily readings. The diurnal mean calculated from the ourly observations presents the following differences, which, if ap-lied, would give the absolute mean for each month.

Date.	BAROMETER.		
	Daily mean.	Hourly mean.	Difference.
1857.			
January 22	30.233	30.237	+0.004
February 23	30.018	29.976	—0.042
March 23	30.139	30.172	+0.033
April 29	29.948	29.932	—0.016
May 22	30.007	30.031	+0.024
June 22	29.889	29.879	—0.010
July 22	29.856	29.855	—0.001
August 28	29.905	29.927	+0.022
September 23	29.922	29.908	—0.014
October 21	29.986	29.969	—0.017
November 27	30.225	30.203	—0.022
December 23	30.155	30.120	—0.035
Mean difference			0.020

It will be observed, on referring to the diurnal as well as annual curves, that while each curve varies there is still, due allowance being made for disturbing causes, a very apparent similarity, the evidence of some regular moving influence, going and coming, present at one season, absent at another, and returning again, and so on. These phenomena bear the closest analogy with those observed at Algiers, Oran, and other localities on the southern shores of the Mediterranean, as established by A. Mitchell, A. M., M. D.*

THERMOMETER.

Like the barometer the thermometer reveals also some features of a tropical rather than the temperate climate, to which latitudinally Sacramento appertains. The mean monthly and annual temperatures, as seen in the accompanying tables, are calculated, like those of the barometer, from the daily observations made at 7 a. m., 2 p. m., and 9 p. m. This arithmetical mean is found to differ occasionally from that obtained from the thermometrograph during the last two years. The minimum temperature, as seen from the curves projected in the chart of hourly observations, occurs between 4 and 5 a. m., and the maximum about 3 p. m. Consequently the mean deduced from the latter is generally minus that of the former. The following table gives the correction to be applied in order to obtain the absolute mean:

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* British and Foreign Medico-Chirurgical Review, No. XXXIII, 1856.

Date.	THERMOMETER.		
	Daily mean.	Hourly mean.	Difference.
1857.			
January 22	48.00	48.50	+0.50
February 23	54.00	53.75	—0.25
March 23	52.00	50.38	—1.62
April 29	62.66	61.88	—0.78
May 22	63.66	62.46	—1.20
June 22	70.66	69.83	—0.83
July 22	77.00	75.23	—1.77
August 28	66.33	65.21	—1.12
September 23	64.00	64.08	+0.08
October 21	59.00	58.50	—0.50
November 27	52.66	53.58	+0.92
December 23	43.33	43.50	+0.17
Sum			9.74
Mean			0.81

As this correction is deduced from the difference between the observations of a single isolated day in each month of the year, due caution and allowance for variation of seasons and other disturbing causes must be exercised. For this reason we have not applied the correction to our tables, but purpose prosecuting the series of hourly observations; and with a view to uniformity hereafter will adopt the *term days*, commencing at 10 p. m.*s* mean time, Gottingen, on the Friday preceding the last Saturdays of February, May, August, and November, and on the Wednesdays nearest the 21st of each of the other months. Another and most important object in this connexion will be the determination of the hours of mean temperature. As will be seen in the table subjoined, the measures of the critical interval are so from corresponding with the quantity obtained in all other localities, and which are generally so near as to amount almost to a constant, that the two times of the day at which the mean temperature occurs can only be regarded as approximative. January affords a solitary instance of the daily mean temperature occurring after midnight, viz: 12*h*. 30*m*. p. m.

Table of the Hours of Mean Temperature and the "critical interval" between those hours.

Date.	Daily mean.	Morning hour.		Evening hour.		Critical interval.	
1857.		*h.*	*m.*	*h.*	*m.*	*h.*	*m.*
January 22	48.50	11	30	12	30	13	00
February 23	53.75	10	45	10	15	11	30
March 22	50.38	8	41	9	19	12	38
April 29	61.88	9	53	9	7	11	14
May 22	62.46	7	30	8	16	12	46
June 22	69.83	7	33	8	6	12	33
July 22	75.63	8	54	8	41	11	47
August 28	65.21	7	36	8	47	13	11
September 23	64.08	8	42	9	55	13	13
October 21	58.50	9	38	9	15	11	37
November 27	53.58	10	47	12	35	13	48
December 23	43.50	10	45	9	30	10	45
Mean						12	20

One of the most striking features of the climate, seen on the accompanying chart of diurnal variations, is the greatest reduction of temperature after the hour of maximum elevation. Howsoever high the wave of temperature towers up under the influence of a vertical sun and cloudless sky, it sinks proportionately low during the night, rendering it cool and chilly. As an instance of the reliability and freedom from exaggeration of the curves of temperature in this respect, we would remark that the record of the thermometrograph for July, 1857, reveals a range of 41 degrees, and a mean daily range of 18.68 degrees, while the chart of diurnal observations describes a curve of only 24 degrees. The following table exhibits the successive hourly ranges during one day of each month in the year.

Table of successive Hourly Ranges of the Thermometer for 1857.

Hours.	January 22.	February 23.	March 22.	April 29.	May 22.	June 22.	July 22.	August 28.	September 23.	October 21.	November 27.	December 23.	Mean.
7 a. m.	— 4.50	— 4.75	— 2.38	— 6.88	— 1.46	— 2.83	— 6.23	— 1.21	— 4.08	— 3 50	— 5.58	— 5.50	....
8 a. m.	— 3.50	— 4.73	— 1.38	— 4.88	1.54	2.17	— 3.23	0.79	— 2.08	— 2.50	— 5.58	— 5.50	....
9 a. m.	— 2.50	— 3.75	0.62	— 0.88	3.54	6.17	0.77	2.79	0.92	— 2.50	— 3.58	— 3.50	....
10 a. m.	— 2.50	— 0.75	2.62	1.12	6.54	8.17	4.77	4.79	1.92	1.50	— 1.58	— 1.50	....
11 a. m.	— 0.50	0.25	3.62	2.12	7.54	8.17	7.77	5.79	2.92	1.50	0.42	0.50	....
12 m.	0.50	3.25	4.62	4.12	6.54	7.17	8.77	5.79	2.92	4.50	1.42	2.50	....
1 p. m.	1.50	4.25	5.62	5.12	5.54	6.17	9.77	4.79	2.92	5.50	2.42	4.50	....
2 p m.	2.50	5.25	5.62	9.12	6.54	6.17	11.77	4.79	2.92	4.50	2.42	4.50	....
3 p. m.	4 50	4.25	5.62	10.12	6.54	5.17	12.77	4.79	3.92	4.50	3.42	5.50	....
4 p. m.	4.50	4.25	5.62	10.12	5.54	4.17	9.77	4.79	4.92	4.50	2.42	4.50	....
5 p. m.	3.50	3.25	5.62	7.12	4.54	5.17	6.77	4.79	3.92	4.50	2.42	3 50	....
6 p m.	2.50	2.25	4.62	5.12	4.54	5.17	4.77	4 79	3.92	3.50	1.42	3.50	....
7 p. m.	2.50	1.25	3.62	4.12	1.54	3.17	4.77	2.79	3.92	2.50	1.42	2.50	....
8 p. m.	1.50	0.25	2.62	3.12	0.54	0.17	1.77	0.79	2 92	2.50	0.42	1.50	....
9 p. m.	1.50	0.25	1.62	0.12	— 1.46	— 1.83	— 0 23	— 0.21	0.92	0.50	0.42	0.50	....
10 p. m.	1.50	0.25	— 0.38	— 0.88	— 4.46	— 1.83	— 2.83	— 2.21	— 0.08	— 1.50	0.42	— 0.50	....
11 p. m.	1.50	— 0.75	— 2.38	— 3.88	— 5.46	— 3.83	— 4.23	— 3.21	— 1.08	— 2.50	0.42	— 2.50	....
12 p. m.	0.50	— 0.75	— 3.38	— 3.88	— 6.46	— 6.83	— 4.23	— 4.21	— 1.08	— 3.50	0.42	— 3.50	....
1 a. m.	— 0.50	— 0.75	— 4.38	— 4.88	— 7.46	— 7.83	— 6.23	— 5.21	— 3.08	— 3.50	— 0.58	— 2.50	....
2 a. m.	— 0.50	— 1.75	— 6.38	— 5.88	— 8.46	— 8.83	— 8.23	— 6.21	— 4.08	— 3.50	— 0.58	— 1.50	....
3 a. m.	— 2.50	— 1.75	— 7.38	— 6.88	— 9.46	— 8.83	— 10.23	— 7.21	— 5.08	— 3.50	— 0.58	— 1.50	....
4 a. m.	— 3.50	— 2.75	— 8.38	— 7.88	— 8.46	— 9.83	— 11.23	— 8.21	— 5.08	— 5.50	— 0.58	— 2.50	....
5 a. m.	— 4 50	— 2.75	— 8.38	— 7.88	— 5.46	— 9.83	— 8.23	— 8.21	— 6.08	— 4.50	— 0.58	— 1.50	....
6 a. m.	— 3.50	— 3.75	— 7.38	— 6.88	— 2.46	— 5.83	— 10.23	— 6.21	— 7.08	— 3.50	— 0.58	— 1.50	....
Sums.	57.00	58.00	104.24	123.00	122.08	135.34	159.00	104.60	77.84	80.00	39.68	67.00	....
Means.	2.38	2.42	4.34	5.13	5.09	5.64	6.63	4.36	3.24	3.33	1.65	2.79	3.92

The mean daily range for each month is exhibited in the subjoined table, which embodies the two last years' observations with the thermometrograph.

For 1856–'57.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Mean of all highest readings by day.	51.32	57.38	63.56	68.22	71.30	79.20	78.95	81.03	78.99	67.75	59.41	50.64	67.29
Mean of all lowest readings by night	39.81	43.72	47.91	50.01	53.35	58.88	58.88	64.69	55.45	49.86	43.64	37.80	50.33
Mean daily mensual range.........	11.51	13.66	15.65	18.21	17.95	20.32	22.07	16.34	23.54	17.89	15.77	12.84	16.96

Dividing the year into its meteorological seasons, the mean daily range will be as follows:

Spring, (February, March and April)..............................	15°.84
Summer, (May, June, July, August, and September)..........	19°.64
Autumn, (October and November)..................................	16°.83
Winter, (December and January)....................................	12°.18

Reverting to the table of monthly and annual means we find the respective mean temperature of the seasons to be as follows: For the spring months, mean 55°.31, the mean maximum being 71°.20, and the mean minimum 42°.13; for the summer, mean 70°.19, and the mean maxima and minima 92°.50 and 55°.11, respectively; for the autumn, mean 58°.47, and mean maxima and minima 78°.20 and 44.°00, respectively; in the two winter months the mean is 45°.94, the mean maxima 0°.90, and the mean minima 29°.70.

Thus it is demonstrated that there is a mean difference between winter and spring of 9°.35; between spring and summer of 14°.88; between summer and autumn of 11°.72; and between autumn and winter of 12°.53. The difference of the means of the hottest and coldest months between summer and winter is also shown to be 24°.25, and the extreme variation, or the difference between the mean maxima of the former and the mean minima of the latter, 41°.50.

It will be noticed that in our division of the seasons we have, in accordance with the phenomena observed, defined February as the first of the three spring months, and appropriated five months to summer, and only two to autumn, and two to winter. Indeed, the dormant season is of so short duration that the tropical division into the wet and dry seasons would perhaps be more appropriate. The whole period of sensible winter is far from being a complete season of suspension of vegetation. During the period we have assigned to it many forms of vegetable life are still active; particularly the roots of grasses and winter grains. The lowest mean daily temperature belonging to this period is seldom below 40°. Although the thermometer has been known to fall as low as 33° as late as the 10th of February, still the leafing process generally commences during the first week of February and is completed at a temperature not much exceeding that of the mean annual. Sometimes a greater degree of cold is experienced in March than in February, and at other times spring is as well advanced in March as at other seasons it is in May. In 1855 the mean temperature of May was 3° lower than that of April, 1857, notwithstanding, the distribution of heat for the three months of spring is marked by no great variability in successive years, nor great constant differences of the months. The measure of heat increases very gradually from month to month. Indeed, the same uniformity of temperature is found to obtain throughout all the meteorological seasons. In summer the greatest vicissitudes of temperature are found to occur, as is readily seen in the subjoined table for 1856 and 1857. The commencement of autumn is quite similar to the beginning of spring in its mean of daily temperature. The earth remaining warmer than the atmosphere under the decline of temperature, activity is partially renewed after the drought of summer by the influence of the light early showers of October. The first frosts occur about the middle of November, and the decline into winter is prolonged until the latter part of December. Ice is seldom formed before the beginning of January, and then rarely remains unthawed for 24 consecutive hours. As a physical constant it is a matter of some difficulty to place within 5° of different latitudes isothermal lines for the seasons. That of 60° for the spring, designed for the United States Army Meteorological Register, which connects Sacramento with Beaufort, North Carolina, on the Atlantic coast, and San Diego, on the Pacific, curves 5° 52′ latitude to the south on arriving at the latter point. A corresponding divergence to the north occurs during the winter. The isochimenal line of 45°, which is common to Beaufort, North Carolina, and Sacramento, describes a northerly curve of 8° 03′ latitude before reaching the Pacific at Port Orford, Oregon, latitude 42° 44′; the mean annual temperature of which place is only 53° 6′. The isotheral of 70°, starting from latitude 40° on the Atlantic side, comes out on the Pacific coast on the parallel of 30°. The great curvature to the south on the Pacific coast during spring and summer demonstrates one of the peculiarities of the distribution of heat in this region. For the mean of the three months of spring the sea temperature which predominates on the line of coast westward of the coast range of mountains is strikingly uniform, and shows but little, if any, advance on that of winter. Indeed, the same may be said of the summer months. For some hundreds of miles on the 40th parallel there is very little difference in the sea temperature for the entire year, and the cold of the Pacific in summer extends, according to the Army Register, from the 50th to the 30th parallel. Thus while the extremes of summer heat are common to the whole valley of the Sacramento and San Joaquin, the mean summer temperature of San Francisco is only 60°, and there is only one day recorded among the observations of Dr. Henry Gibbons when the temperature rose above 79° during the summer months.

Table of greatest Monthly Vicissitudes of Temperature, as obtained from two successive daily means, calculated for the meteorological seasons of 1856 *and* 1857.

1856.

SPRING.						SUMMER.						AUTUMN.						WINTER					
Date.	Daily mean.	Vicissitude.	Winds.			Date.	Daily mean.	Vicissitude.	Winds.			Date.	Daily mean.	Vicissitude.	Winds.			Date.	Daily mean.	Vicissitude.	Winds.		
			7.	2.	9.				7.	2.	9.				7.	2.	9.				7.	2.	9.
Feb. 26	53.67	5.34	NW	NW	W	May 3	57.67	10.66	NW	NW	S	Oct. 28	59.00	8.00	NW	N	N	Dec. 22	41.38	9.67	NE	SE	SE
27	48.33		NW	NW	NW	4	68.33		S	SW	SW	29	67.00		N	NW	NW	23	51.00		NE	SE	SW
Mar. 8	54.33	7.34	N	N	SW	June 13	79.00	8.67	E	S	S	Nov. 2	68.00	9.67	NW	NW	NW	Jan. 6	46.67	8.00	N	NW	N
9	61.67		NW	NW	NW	14	70.33		S	S	S	3	58.38		N	SE	SE	7	38.67		N	NW	N
April 3	56.67	5.00	W	SW	S	July 11	81.67	9.34	SE	S	S												
4	61.67		S	SW	SW	12	72.33		SW	S	S												
						Aug. 5	70.67	8.66	S	S	S												
						6	79.33		S	NW	SW												
						Sept. 22	67.00	10.67	SE	W	SE												
						23	77.67		N	N	NW												

1857.

Feb. 5	48.33	7.33	SE	W	S	May 23	68.33	8.34	N	NW	N	Oct. 16	68.00	6.00	N	N	SW	Dec. 6	49.00	5.33	SW	NW	NW
6	41.00		NW	NW	NW	24	76.67		S	NW	NW	17	62.00		SE	W	SW	7	43.67		N	NE	N
Mar. 19	57.67	5.67	SW	NW	NW	June 17	87.00	8.67	NW	NW	SW	Nov. 5	62.67	7.00	SE	SW	SW						
20	52.00		W	SW	S	18	78.33		SE	SE	SE	6	55.67		E	N	NW						
April 23	68.67	6.34	E	N	S	July 15	70.67	7.33	SE	S	SE												
24	62.33		S	SW	SW	16	78.00		N	N	SW												
						Aug. 7	78.67	6.33	SE	SW	SW												
						8	80.00		SE	NW	SW												
						Sept. 14	73.00	7.33	N	N	S												
						15	65.67		NE	N	SE												

Hygrometry, Wind, Hail, Snow, Electrical and other Phenomena.

An examination of the results of the psychrometer will reveal the peculiar state of the atmosphere during the summer months. So great is the apparent aridity at times that the lower ærial strata are frequently found to contain during the hottest part of the day not more than 15 to 20 per centage of their capacity for moisture. As an isolated and extreme case, on the 10th July, 1856, at 2 p. m., wind N. and light, and temperature 100°, the dew-point was found at 22°. This, we believe, is the greatest dryness that has yet been observed on the surface of the globe on low lands. Humboldt, in his Cosmos, states that the greatest dryness he has observed was in the steppe of Platowskaja, after a SW. wind had blown for a long time from the interior of the continent. With a temperature of 74°.07 he found the dew-point at 24°, the air containing $\frac{16}{100}$ths of aqueous vapor. The principal agent in this hygrometric peculiarity of the climate is to be found in the direct effect of northerly winds. In the winter and spring the north winds are the coldest and serve, as the land is then cooler than the sea, on account of the distance of the sun, to condense the moisture wafted with the atmospherical current from the southern hemisphere, and to precipitate it in the form of rain. During this season the southeast trades, charged to their utmost capacity with moisture, commence descending as their temperature decreases, and precipitate more and more rain as they become chilled by the north winds. During the summer, owing to the fact of these northerly winds passing over a highly heated and arid surface, their temperature is raised, thereby increasing their capacity for moisture, which not being able to obtain from the surface passed over, they appear as dry winds, reminding one of the reputed sirocco of Italy. Nevertheless, dry as these winds apparently are, on coming in contact with the westerly winds chilled by the oceanic polar current along the coast, and their temperature being again reduced, the vapor they contain is rapidly condensed; hence the heavy mists that are precipitated during the afternoon at San Francisco and at the gaps along the coast. In the valley, as a general rule, the direction of the wind is from north by west to southeast. It seldom blows from the east or northeast with any appreciable force. Doubtless the prevailing wind off the coast, where no causes of local deflection exist, is west, as established by Lieut. Maury. This wind, rushing into the heated valleys through the gap at San Francisco and Benicia, reaches us at Sacramento and the northern part of the valley as a southwest wind, while at Stockton and the San Joaquin valley it is a westerly and northwesterly wind. To this wind, together with that descending from the slopes of the sierras, may be attributed our cool summer nights.

The influence of the winds on the temperature, as we have just seen with respect to the hygrometric condition of the air, varies according to the season of the year. It is during the occurrence of northerly winds in the summer that we experience our hottest weather, which seldom lasts long, however, before the temperature becomes equalized by a change of wind to the southward. Upon an examination of our daily and hourly records we find it to be a common occurrence during the summer months for the wind to commence blowing from the north at or shortly after the morning observation, and to remain in this quarter until afternoon, when it would change round to the south, freighted with moisture and invigorating freshness. It is the prevalence of these cool winds which temper our summer climate so delightfully, the greater or less predominance of which renders the mean temperature plus or minus.

As regards the *force* of the wind, it is generally but slight. The observations in this respect having been registered for the two last years only it is impossible to make full deductions therefrom with any degree of completeness. The following enumeration of the frequency, course, and seasons of winds, during 1856 and 1857, stronger than (3) a fresh breeze, will afford some idea of this feature of the climate.

The whole number of times it blew with the force of four, (4,) or what is estimated a strong wind, from the north, was 29, viz: January, three times; February, five times; March, once; April, four times; June, once; September, three times; October, twice; November, eight times; and December, twice Eighteen times it blew from the south with the force of four, (4,) viz: January, once; August, twice; September, four times; October, three times; November, four times; and December, four times. It blew only eight times with the force of (5) a high wind, viz: three times from the north, once in February, once in April, and once in November; and again five times from the south, viz: once in January, once in October, once in November, and twice in December. But twice does it appear in the register to have blown a gale, (6,) and on both these occasions it was from the southeast, in the month of November. These results, as before stated, are derived from the record of the last two years. Prior to this no precise estimate was made of the force of the wind. The only time it was ever observed during the whole series of five years to blow with a force above six was on the last night of the year 1854, or rather on the morning of the 1st of January, 1855, when a strong gale from the southeast, attended with rain, was experienced. As a general rule, it very rarely rains with the wind from the northern half of the octant, which may be attributed to its coming to a warmer from a colder region. During the last five years there have occurred only fifteen exceptions to this rule, and the aggregate quantity that fell at these different periods does not amount to two inches. On one occasion, the 27th of December, 1855, the snow which fell at daylight, amounting, when melted, to 0.016 inches by the rain gauge, was added to the amount. This was the heaviest fall of snow ever experienced; indeed only three other instances of this phenomenon appear on our record, and in all three the fall was very light. Hail storms are more common. These, also, are of short duration, and are attended with more or less disturbance of the electrical equilibrium. The breaking up of the rainy season is the period of the most violent manifestations of these latter phenomena. With the exception of the spring of 1857, which was a season of drought, hail and thunder storms have invariably occurred during the months of April and May, but have never been very severe in this immediate locality. A hail storm which occurred at a point within eight miles of the city, in May, 1854, is represented to have been very violent. But we have experienced nothing in this locality like that, proceeding from a dense nimbus, which suddenly arose from the southwest on the 13th of May, 1855, and, while discharging its watery contents, rivalled, in the vivid shocks of its well-charged battery, the thunder gusts of more tropical regions.

The aurora borealis has been observed only once—on the night of the 16th of December, 1857; the sky being entirely clear at the time, the wind light, from the east—the thermometer reading 44°, and the barometer 30.321 inches, reduced for temperature. This phenomenon first appeared in a northeast direction, in the form of a diffused light defined by an arch below. From this arch, of about 15° radii above the horizon, the light extended in width apparently 10° above Alioth, in the constellation of the Great Bear, and gradually spread over the whole northern section of the heavens, the dominant hue being deep rose. Its aspect, however, was frequently changed by the successive appearance and shifting of streaks or columns of white light, which seemed to be more conspicuous at either extremity of the arch. With the exception of a somewhat similar phenomenon seen once at Sonora, Tuolumne county, during the winter of 1852–'53, we have heard of no other instance of the aurora being seen in California.

Before proceeding to a consideration of the rains we would, in this connexion, briefly refer to the transparency of the atmosphere for which California has been noted. The relative frequency of clear and cloudy days in summer and winter, as appears in the tables, although substantially correct, does not convey a just idea of the clearness of the sky. The results are calculated from three daily observations; and if it so happens that at either of these the least cloudiness is visible it is recorded as a cloudy day, without regard to quantity. Now, one of the peculiarities of the summer climate is, that if there be any cloudiness during the day, which is rarely the case, it is almost invariably clear at night. Indeed, on this account, perhaps there is no region better adapted to astronomical purposes; for, as Sir David Brewster expressed his wish, "no clouds disturb the serenity of the firmament, and no changes of temperature distract the emanations of the stars." As to the quantity of cloudiness, this not having been estimated previously to the last two years, of course the results in this respect cannot be regarded but as approximative to a constant, the number of cloudy days having been in excess during 1856 and 1857.

RIVER, RAINS, ETC.

The rise and fall of the river at Sacramento is graduated by the terms high and low-water mark, or zero. A solid column, surmounted with a wind-vane, was set up by the city near the river bank in September, 1856, when the river had attained the lowest stage ever known. The fig. 2 in the accompanying hydrographic scale agrees with the zero in our published observations up to that date. The mean depth of the channel of the river in this neighborhood is 16 feet below low-water mark, and the width of the river is about 300 yards. There is a tidal rise and fall of about one to two feet at Sacramento, according to the course and force of the wind and the stage of the river. If the wind blows strongly from the north this fall is still greater, especially during spring tides. The stage of the water is also affected by the temperature, as well as by the fall of rain. The months of November, December, January, February, March, and April constitute the "rainy season," although more or less rain generally falls during October and May. The first and generally the greatest rise in the river occurs about the 1st of January, after the early rains. The warmer these rains are the less snow falls in the mountains, and consequently the more sudden is the rise of the river. From the middle of January to the middle of February there is generally a marked abatement, and sometimes a complete suspension of rain, and the river declines correspondingly. From the middle of February to the last of April the latter or warmer rains set in, and cause a second or spring rise, which is kept up in accordance with the prevailing temperature. If the spring and early summer have been cold, the spring freshet soon passes off, and the river maintains a high level, as it did in 1857, in consequence of the gradual melting of the snow at its sources; and the converse obtaining if the hot weather sets in early. Recurring to the hydrographic scale, we would observe that the figures to the left indicate, when applied to the river, the number of feet from zero or extreme low-water mark at spring tide to the highest point the Sacramento has yet been known to rise, viz: nearly 22 feet, in January, 1852. The curves for all the years are not complete, our notes not being full and regular. The same scale of feet, if read for inches, when applied to the perpendicular lines, will denote at a glance, and which is most important in this connexion, the *monthly* quantity of rain that fell at Sacramento during the last five years—the rain for 1853–'54 being placed in the first column of each month, of 1855 in the second, and of 1856–'57 in the third. The scale to the right represents inches, and is intended to show the comparative annual fall of rain since the year 1852. As will readily be seen, the rains during 1856–'57 have been so much below the average that they should be regarded as exceptional. Averaging the rains of 1852–'53–'54–'55, we find an annual fall of 21,352 inches; whereas the average of the last five years gives only 17.113 inches. In the rain chart of the Army Meteorological Register, Sacramento is included with San Francisco in the area of 22 inches of rain; and Dr. Gibbons puts down the mean annual rain of the latter place at 21.17 inches. This corresponds with our estimate of the amount for Sacramento, and rather strengthens the opinion just expressed, that the years 1856–'57 should be regarded as exceptional. Although the river is, of course, but slightly affected by the amount of rain that falls in this immediate vicinity, nevertheless the connexion here preserved is of much interest, inasmuch as experience shows that the amount of rain that falls at Sacramento bears a quantitative proportion to that which is precipitated in the higher parts of the valley, as well as in the mountains. Certainly, the river never has attained a high stage when there has occurred a deficit of rain at Sacramento. To substantiate these assertions the following facts, condensed from our publications in the California State Medical

Journal, will suffice. As therein stated the winter and spring of 1849–'50 was a season of continual outpourings. The first settlers tell us that the rain came down in torrents, and that tubs and casks left out at night were found full and overflowing next morning. This must, of course, be taken *cum grano salis*. There were no ombrometers in those mythical days, when the rain appears to have been as abundant as the gold. Doubtless the rains were copious; certainly they set in earlier than they have ever done since. "The first rain of 1849 took place on the 23d of September. Through the month of October they became much more severe and cold, and, as no adequate preparation had been made for protection against this element, the sufferings of the immigrants were consequently aggravated." * * * "Through the latter part of December and beginning of January, 1850, the rains were so heavy that serious apprehensions began to be entertained, for the first time, of an inundation." * * * "By Christmas the water was over the lower portions of the city; on the 8th of January, 1850, it rose rapidly; and on the 10th, and for several days after, there was no dry land in town, except the knoll at the public square." * * * "In a few days the waters subsided, the sun broke from its cloudy confines and shone bright and beautiful again. This weather continued until the heavy rains of the following March." * * * "On the 7th of April the waters began again to run into the town, and on the 8th the council voted an appropriation of money for constructing a temporary levee, which was made, and the principal business portion of the city saved from an overflow."—(History of the City.) The opening half of the winter of 1850–'51, when commence our own observations, was rainless, and consequently the river remained at low-water mark until January, 1851, during which month about three-fourths of an inch of rain fell, and a corresponding rise in the river occurred. From this period the river remained very low until April 5, when it attained, although by no means a high level, still a greater elevation than at any prior date of the season, and navigation continued open to most of the upper trading points on the Sacramento, as well as to Marysville, until the summer. The rains that fell during this interval amounted to about 4 inches.

The rainy season of 1851–'52 commenced early, and the river rose correspondingly. By the 30th December it was up to within 4 feet of its natural banks, in consequence of the heavy rains which fell up to that date, amounting in the aggregate, during September, October, November, and December, to about 10 inches; thus compensating, in a measure, for the deficit of the previous season. The rain of the year 1852 was well distributed among all the months of the wet season, and amounted in the aggregate to about 27 inches. The heaviest rains occurred in March and December, and consequently the city was overflowed both these months, the levee not proving adequate. The first of these inundations occurred on the 7th March, owing to the washing away of the embankment at the flood-gate in the levee at Sutter lake, as well as to a crevasse on the American river; and for one week nearly the whole city remained submerged. The rains which followed after the great fire of November, 1852, were the heaviest known for that season of the year of which we have any positive record. About 12 inches fell in December. Accordingly the river rose 17 inches higher than in the flood of 1850. From the 25th December to the 24th January, 1853, when the waters began to retire, the city remained almost entirely submerged. During the following March the fall of rain amounted to 7 inches, and again a corresponding rise of the river occurred. On the 29th it rose 12 feet in twenty-four hours, and soon reached above the original banks; and, backing up from a break in the levee at Sutterville, the greater part of the city was again overflowed by the 2d April, and thus remained more or less deluged until the rains subsided towards the last of May. The amount of rain that fell during the latter month was nearly 1½ inch, and the aggregate for January, February, March, April, and May, and which kept up the river at so high a level, was about 17 inches.

From the period to which we have thus brought down our account of the freshets of the Sacramento river and the corresponding rains, up to the present time, (1st January, 1858,) there has been no extraordinary rise to record, as may readily be seen by a glance at the hydrographic scale. As may also be there seen, the rains during the same interval have been considerably below the average.

Abstract of Meteorological Observations made at Sacramento, California, during the year 1856, *latitude* 38° 34′ 41″ *N., longitude* 121° 27′ 44″ *W., (as determined by G. H. Goddard, C. E , late of the State Surveyor General's office,) with monthly remarks.—By Thomas M. Logan, M. D.*

1856.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Averages for four years.
BAROMETER.														
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Maximum	30.242	30.305	30.271	30.230	30.079	30.114	30.036	29.990	30.065	30.294	30.344	30.619	30.215	— .008
Minimum	29.629	29.692	29.665	29.599	29.614	29.626	29.694	29.657	29.569	29.721	29.750	29.707	29.660	— .030
Mean	29.992	30.009	29.982	29.981	29.890	29.845	29.849	29.833	29.843	30.024	30.061	30.218	29.961	— .024
THERMOMETER.														
	Degrees.	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*
Maximum	59.00	66.00	78.00	69.00	80.00	94.00	100.00	98.00	95.00	77.00	77.00	54.00	78.91	— 1.52
Minimum	32.00	42.00	39.00	46.00	49.00	61.00	63.00	58.00	57.00	41.00	36.00	32.00	46.33	+ 1.13
Mean	48.02	52.64	57.03	58.80	63.91	71.06	75.12	69.59	70.93	58.04	52.18	43.86	60.09	— 0.21
THERMOMETROGRAPH.														
Maximum	60.00	69.00	79.00	70.00	83.00	97.00	100.00	99.00	98.00	78.00	79.00	54.00	80.00	
Minimum	30.00	37.00	37.00	43.00	45.00	52.00	55.00	53.00	52.00	37.00	34.00	29.00	42.00	
Range	30.00	32.00	42.00	27.00	38.00	45.00	45.00	46.00	46.00	41.00	45.00	25.00	38.00	
DEW POINT.														
Maximum	53.00	52.00	64.00	59.00	60.00	65.00	66.00	66.00	59.00	56.00	55.00	48.00	58.70	+ 1.19
Minimum	29.00	22.00	31.00	35.00	45.00	29.00	22.00	24.00	24.00	29.00	31.00	28.00	29.08	— 4.48
Mean	42.49	41.82	45.64	46.06	52.03	53.90	53.87	53.45	49.56	44.84	41.40	37.25	46.85	— 0.88
RELATIVE HUMIDITY.														
Maximum	.946	.943	.939	.938	.886	.890	.811	.810	.876	.939	.939	.944	.905	
Minimum	.676	.364	.413	.412	.387	.175	.096	.119	.113	.268	.251	.520	.316	
Mean	.862	.758	.732	.749	.710	.626	.569	.651	.536	.695	.748	.821	.704	
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Totals.*	*Days.*
Number of clear days	10⅓	13⅓	16	13	13⅔	21⅓	28⅔	25⅓	22⅔	18⅓	14	9	205⅔	— 9⅓
Number of cloudy and foggy days	20⅔	15⅔	15	17	17⅓	8⅔	2⅓	5⅔	7⅓	12⅔	16	22	160⅓	+ 12¼
Number of rainy days	17	4	5	8	4	1	....	....	⅓	1⅔	6⅔	8	55⅔	— 2¼
Quantity of clouds	6.6	4.7	5.7	6.5	5.6	3.1	3.8	3.5	3.8	6.1	6.9	7.4	5.3	
Inches of rain	4.919	0.692	1.403	2.132	1.841	0.033	....	....	Sprinkle	0.195	0.651	2.396	14.262	— 3.901

Abstract of Meteorological Observations—Continued.

1856.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Mean.		Averages for four years.
																											Days.
1st days and 2d force of N. wind...	10	1.7	7⅔	1.6	4⅓	1.3	4⅔	1.6	1⅓	1.1	4	2.1	1⅔	2.1	⅔	1.0	4⅔	1.3	7⅓	1.8	8	2.1	6	1.8	60⅓	1.6	+ 27⅙
Do..........do....NW. wind.	7⅔	1.8	10	3.3	7	1.4	5⅓	1.7	2⅓	1.8	4⅔	1.9	2⅓	2.0	1⅔	1.8	4⅔	2.3	7⅔	2.0	7	2.6	8⅔	2.1	69	2.0	— 30 1-6
Do ....do....W. wind ..	1	0.8	1⅓	1.5	2⅔	0.7	3⅔	1.5	1⅔	2.1	2⅓	2.8	⅔	2.5	1⅓	1.6	2	1.7	1	1.6	1⅔	2.3	⅔	1.3	20	1.7	+ 5¾
Do..........do....SW. wind.	⅓	0.3	1⅓	1.5	4⅔	1.1	4⅔	1.7	7⅔	1.6	4⅓	2.0	9	2.4	4⅓	2.1	4	1.9	2⅓	2.0	2	1.5	2⅔	2.0	48⅓	1.6	— 18½
Do..........do....S. wind...	1	1.8	1⅔	1.0	1	0.6	5⅓	1.9	11⅔	1.7	11⅓	2.2	10⅔	2.2	11	2.1	6	2.2	5⅓	2.5	2	2.6	1⅓	1.6	67⅓	1.8	+ 16
Do..........do....SE. wind...	4⅓	2.2	4	1.3	6⅔	1.6	5⅔	2.1	6	1.5	2⅓	2.0	5⅔	2.5	10⅓	2.6	5	2.1	5⅔	2.4	5⅔	2.4	8	2.8	69⅓	2.1	— 7
Do..........do....E. wind ...	3⅔	1.7	2	1.0	2	1.0	⅓	1.0	....	.....	⅓	1.0	⅓	2.0	⅔	2.0	1⅓	1.2	1⅓	1.3	1⅔	1.3	....	.....	13⅔	1.1	+ 3⅓
Do..........do....NE. wind.	3	1.5	1	1.7	2⅔	1.0	⅓	1.0	⅓	1.0	⅔	2.5	⅔	1.5	1	2.0	2⅓	1.0	⅓	1.0	2	2.0	3⅔	1.7	18	1.4	+ 7 1-6

GENERAL REMARKS.

The foregoing table for 1856 is the result of three daily observations, made at 7 a. m., 2 p. m., and 9 p. m., with the instruments and instructions recommended by the Smithsonian Institution. The readings of the barometer have been reduced to the temperature of 32° Fahrenheit, but not to sea level. The height of the lower surface of the mercury is 41 feet above the mean level of the sea at San Francisco. The rainy days are included in the cloudy and foggy days, and are also put separately to show the number of these days on which rain fell every month. Professor Coffin's psychrometrical table for determining the elastic force of aqueous vapor and the relative humidity of the atmosphere will be used in our register hereafter, and the dew-point column omitted. The following corrections of errata are to be applied to our tables for 1853–'54, published in the Smithsonian Report for 1855: Barometer mean for September, 1853, 30.00, and mean mean 30.02 inches; mean of barometer for January, 1854, 30.11 inches.

MONTHLY REMARKS.

January.—The means of the barometer and thermometer were above the average of the three preceding years, the former by 0.254 inch, and the latter by 3.59 degrees. The rainy days exceeded the average to the number of seven. There were five days of more or less fog. The quantity of rain was plus the average 1.460 inch. A sprinkle of snow, just enough to be perceptible, occurred on the 8th at 9 a. m. On the 3d frost remained all day unthawed in the shade.

February.—There was little variation in the atmospheric pressure from that of previous years. The mean temperature was plus the average by 1.14 degree. Spring opened early. On the 7th the willow (*Salix*) flowered. On the 13th the buttercup, and on the 16th the wild violet were also in blossom. The rain fell short of the average by 1.460 inch.

March.—The temperature exceeded the average still more this month, being plus 3.12 degrees. Spring progressed rapidly. On the 1st the peach was in full blossom, and on the 10th was leafed out. Although the deficit of rain for the month amounted to 2.560 inches, frequent showers, accompanied on the 29th by lightning and thunder, tempered, in this locality, the effects of the drought which prevailed generally throughout the State.

April.—There was very little variation in the readings of the barometer and thermometer from that of previous years. Seasonable rains invigorated vegetation, and although nothing like the deficiency was made up, still the Sacramento river remained comparatively high for the season, in consequence of the warm rains melting the snow. Its temperature averaged about 54°, being four degrees lower than that of well water. The last frost of the season occurred on the 29th. The barn swallow made its first appearance on the 1st, and toward the latter part of the month wild geese were observed wending their way northwardly. At the last of the month salmon and sturgeon began to ascend the river in considerable numbers.

May.—The average readings of the barometer and thermometer did not vary much from those of the four preceding Mays. The prolongation of the wet season to the last of the month somewhat compensated for the deficiency of the semestral fall of rain, which was reduced down to 6.263 inches. On the evenings of the 6th, 8th, and 9th sheet lightning in the northern horizon revealed the time of occurrence of terrific hail storms at various points at these respective dates. That which occurred at Butte creek, Shasta county, was accompanied by a gale, the belt of which was not over half a mile in width, and the extent of ground on which the largest sized hail fell two miles. These hailstones were about the size of carbine balls, of a nucleus of ice surrounded by snow, apparently. On the 21st snow fell lower down on the foot hills than at any previous time during the winter. The temperature of the river still remained 4 degrees lower than that of well water, the current running at the rate of four miles an hour.

June.—Throughout the whole month the weather was very variable. Instead of the close, sultry atmosphere that usually obtains as the sun enters the calm belt of Cancer, strong, chilly winds, varying from SSW. to WNW., just at the period of the summer solstice, prevailed, freighted with moisture from the ocean. As the land, however, had already attained a high degree of temperature, of course it could not condense the vapors of water held by the air; consequently no rain fell after the 1st, when 0.033 inch are now chronicled as the last for this extraordinary season. The total amount, therefore, of rain for the season of 1855–'56, at Sacramento, was minus the average 4.264 inches The river continued to fall steadily. Its temperature on the 21st was 4 degrees higher than that of well water 12 feet below the surface, which fact showed that the great bulk of the melted snow from the mountains had passed off.

July.—Notwithstanding the cloudless sky which characterized nearly this whole month, the tempering of the atmosphere by fresh southerly breezes was more obvious to one's feelings than by the thermometer, the mean of which was only 0.60 minus the average of the three preceding Julys. During the few days that northwardly winds predominated the heat became intense. An important meteorological fact connected with this unpleasant wind is that all the moisture has been wrung out of it that a dew-point of zero in the cold latitudes could extract. It is, indeed, a return wind, which, after blowing over the surface fresh from the ocean, grows colder as it goes north, where the process of condensation commences, and when it comes back it is as parching and obnoxious to animal and vegetable life as the simoon of the eastern deserts. The river reached a very low stage this month, and its temperature at 12 feet below the surface read 75°, while well water at the same depth was 66°.

August.—This last of the summer months closed after a remarkably cool summer. The whole number of days of extreme heat, in which the thermometer reached 90° and upward, amounted to only 11 for the summer, viz: two in June, six in July, and three in August. On the 26th the temperature of the earth at 53 feet below the surface (the depth then obtained in an artesian well) was 60°, the thermometer having fallen about a degree and a half for every 10 feet from the depth of 15 feet, at the time of reaching which latter depth it read 66°.

September.—This month was characterized by variable weather. The barn swallow made its last appearance on the 5th. On the 10th, at $5\frac{1}{2}$ o'clock p. m., we were suddenly visited with a high wind from a heavy bank of clouds in the southwest horizon, which at one time presented indications of approaching rain, but was intercepted by the arid mountains and high lands of Santa Cruz, Alameda, and San Francisco, where the accompanying lightning and thunder are reported to have been extremely violent.

For several days previous to the equinox a regular declension of atmospheric pressure was experienced, attended with a stagnant, sultry condition of the air. This was succeeded by a sprinkle of rain (the first of the season in this locality) at daylight on the 20th, when the lowest reading of the barometer, as above, was recorded. As the sun entered Libra, however, the weather presented one of the most favorable specimens of our autumnal climate, a fresh circulation of air being kept up by southerly breezes.

The most remarkable feature of the month was the brilliant ærolite which appeared on the evening of the 11th, at about 8 o'clock. As it was seen simultaneously in an area of several hundred miles, bounded by Red Bluffs, Iowa Hill, Stockton, San Francisco, and Santa Cruz, the probabilities are that at the time of its brief appearance it was in the upper regions of our atmosphere, and that, judging from the interval that elapsed between its explosion and the reaching of the report here, which resembled distant thunder, its distance then was between thirty and thirty-five miles. After comparing all the different accounts that have reached us, it would seem that its course was on the southern side of the zenith, from SE. to NW., and that its relative position to the point of aspect here was at first about forty degrees above the horizon, and twenty when it vanished. When first seen it appeared but little larger than Venus, but as it approached the earth it increased in size as suddenly as it diminished again just before bursting into brilliant corruscations of light that reflected all the prismatic colors. The moon was near the close of its second quarter at the time, and the atmosphere clear and transparent.

The Sacramento river fell to a lower point than has ever been before observed, which will be the zero of the scale of a new river gauge about to be constructed by the city. Its present mean temperature twelve feet below the surface reads 70°, while that of well water at the same depth is 60°. The temperature in the artesian well at sixty-five feet below the surface is $59\frac{1}{2}$°.

October.—The mean temperature of this month was 5°.47 minus the average. On the 1st the flight of wild geese southwardly, which had been observed since the 8th September, prepared us to expect the rain that fell on five different days—the 7th, 15th, 17th, 19th, and 24th; and though not amounting to much in quantity, it was sufficient to indicate that the atmospherical changes which characterize the rainy season had set in. The first frost occurred on the 20th, and ice formed on the 22d, at daylight. The effect of the rains and snows was sensibly demonstrated in the Sacramento river, both quantitatively and thermometrically. On the 17th, it rose suddenly ten inches, and fell again immediately to low water mark ; its temperature declining 12° lower than that of the previous month. The temperature of well water fell to 57°. On the last day of the month the leaves of the willow began to fall.

November.—Although the readings of the barometer were not much below the average, more or less stormy weather prevailed over the greater part of the State. In the south, the setting in of the rains was attended by disasters of a somewhat novel character. A shower of sand swept over a portion of Los Angeles county, completely destroying the grass on the pasture lands About the same period, severe gales prevailed at Humboldt Bay. The mornings of the 27th and 30th were unusually cold for the season. The rains of the month did not make much impression on the river, further than a rise of about 9 inches ; its temperature was 46°, while that of well water was 59°. The temperature of the Artesian well, at 73 feet, where it was discontinued, stood at 58°.50. The fall of leaf of the fig, apple, pear, and cotton-wood tree occurred on the 1st, 5th, and 30th dates of the month respectively.

December.—The month was rendered remarkable for the unprecedented persistence of continuous cold weather and the number of cloudy days—much beyond the average of the three previous years. The barometer maintained an unusually high range in consequence of the prevalence of northerly winds. The readings of its extraordinary maxima were made on the evening of the 19th and morning of the 20th, while the wind was fresh from the N.NW., and the temperature ranged from 30° to 40°. Its diurnal mean fell only five times below 30 inches. The minimum was registered on the 29th at 9 p. m., preceding a SE. storm which was general throughout the State. On the same day it snowed at San Francisco, and about the same period the Coast range of mountains presented the unusual appearance of being covered with snow. The river was not much affected by the rains of the month ; its temperature read 41°.

Abstract of Meteorological Observations, by Thos. M. Logan, M.D., Sacramento, California.

1857.	January.	February.	March.	April.	May.	June.	July.	August.	Septemb'r.	October.	Novemb'r.	Decemb'r.	Means.
BAROMETER.													
Maxima	30.423	30.438	30.343	30.204	30,140	30,044	30.007	30.002	30.121	30.170	30.263	30.449	30 222
Minima	29.791	29.725	29.772	29.777	29,707	29,640	29,658	29.661	29.710	29.644	29.673	29.808	29.714
Means	30.215	30,081	30.083	29 971	29,940	29.850	29,822	29.845	29.916	29.942	30.062	30.165	29.991
THERMOMETER.	°	°	°	°	°	°	°	°	°	°	°	°	°
Maxima	61	59	66	79	87	98	90	92	84	79	65	57.00	76.72
Minima	31	34	44	55	53	61	62	60	58	49	38	37.00	45.17
Means	48.54	50.25	56.42	63.27	65.51	71.93	71.45	71.31	67.93	61.49	53.24	47.37	60.73
THERMOMETROGRAPH.													
Maxima	63	62	69	83	91	101	94	96	86	79	67	58	79.08
Minima	30	30	40	45	51	54	53	55	52	45	35	32	43 50
Range	33	32	29	38	40	47	41	41	34	34	32	26	35.58
DEW POINT.													
Maxima	53	54	54	64	63	72	59	60	58	56	58	49	58.33
Minima	26	26	35	30	37	36	36	38	36	29	26	30	32.08
Means	43.44	43.51	47.53	51.20	51.26	51.13	52.65	51.38	49.67	46.81	42.11	39.68	47.78
FORCE OF VAPOR.													
Maxima	.423	.423	.442	.635	.762	.873	.626	.572	.551	.483	.491	.343	.552
Minima	.136	.090	.204	.223	.282	.287	.336	.341	.308	.143	.095	.123	213
Means	.295	.297	.347	.421	.427	.500	.474	.454	.415	.352	.286	.253	.377
RELATIVE HUMIDITY.													
Maxima	100	100	94	100	88	85	83	84	82	94	100	93	91.92
Minima	61	28	45	32	34	24	32	26	27	33	29	30	33.42
Means	84.28	80.33	78.16	75.03	69.43	66.22	64.33	62.47	63.75	66.18	69.62	77.65	71.45
Number of clear days	5⅔	8⅔	9⅔	20⅔	17⅔	18⅔	26⅓	22⅔	19	16⅓	11⅔	10⅓	187⅓
Number of cloudy and foggy days	22	4	16	8⅓	12⅓	10⅓	3⅔	7⅓	11	12⅔	8⅓	12⅔	128⅔
Number of rainy days	3⅓	15⅓	5⅓	1	1	1	1	1	0	2	10	8	49
Quantity of clouds	8.2	8.6	6.1	4.3	2.0	1.4	0.2	1.0	1.9	2.1	3.8	4.6	3.7
Quantity of rain and fog	1.375	4.801	0.675	Sprinkle.	Sprinkle.	0.350	0.012	Sprinkle.	0.000	0.655	2.406	2.632	12.906

Abstract of Meteorological Observations—Continued.

1857.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Means.	
1st days and 2d force of N. wind....	9	1.6	5⅓	2.1	4⅓	1.4	6⅔	1.7	1⅔	1.7	1⅔	0.3	2⅔	1.3	2⅔	1.1	5	0.7	7⅔	0.7	5	2.2	7⅓	1.5	59	1.4
Do........do......NE wind...	⅔	1.0	0	0	⅔	1.0	⅓	0.7	⅓	0.6	0	0.0	0	0.0	⅔	0.5	⅔	0.3	2	0.7	1⅔	0.9	1⅔	1.0	8⅔	0.6
Do........do......E. wind	1⅔	0.6	1⅓	1.5	2⅓	0.6	1⅔	1.3	⅓	0.3	⅔	0.3	⅓	0.3	0	0.0	⅓	0.3	1	1.0	3⅔	1.2	3⅔	1.2	17	0.7
Do........do......SE. wind...	6⅓	1.3	9⅓	1.6	3⅔	1.5	3	2.4	9	2.2	7	1.7	7⅔	1.8	9⅔	1.1	7	1.1	5⅓	1.0	7	2.0	7	2.5	82	1.7
Do........do......S. wind.....	7	1.6	4⅔	1.5	5	1.5	6⅓	2.3	8	2.1	9	2.1	12⅔	1.9	8⅓	2.0	6⅔	2.0	3	1.7	2	3.1	⅔	1.3	73⅓	1.9
Do........do...... SW. wind ..	1	1.0	1⅔	1.6	7⅓	1.3	8⅓	2.1	6	2.0	6⅔	2.0	5⅔	1.9	7	1.6	5⅔	1.3	3	1.3	2⅓	1.8	1⅓	1.8	56	1.6
Do........do......W. wind ...	⅓	0.6	1	1.1	⅔	0.6	⅔	1.3	⅔	1.0	⅔	0.7	0	0.0	1	1.7	⅔	0.2	1⅓	1.0	⅔	1.7	0	0.0	7⅔	0.8
Do........do......NW. wind..	5	1.8	4⅔	1.9	7	1.5	3	1.7	5	1.8	4⅓	1.2	2	1.0	1⅔	0.5	4	1.6	7⅔	1.1	7⅔	2.3	9⅓	1.8	61⅓	1.5

Table of the results of Meteorological Observations for five years at Sacramento, California, by Thomas M. Logan, M.D.

1853–'54–'55–'56–'57.	MONTHLY MEANS.												ANNUAL MEANS.			
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	2 years	3 years.	4 years.	5 years.
BAROMETER.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*				*Inches.*
Maxima	30.351	30.353	30.309	30.291	30.174	30.136	30.105	30.036	30.067	30.241	30.341	30.408	....	....	...	30.234
Minima	29.620	29.663	29.765	29.735	29.690	29.547	29.748	29.702	29.736	29.789	29 715	29.749	....	....	....	29.705
Mean	30.054	30.070	30.037	30.050	30.000	29.869	29.958	29.900	29.894	30.049	30.085	30.107	....	....	....	30.005
THERMOMETER.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Maxima	61.40	65.00	72.60	76.00	82.40	95.80	96.70	96.00	91.60	85.40	71.00	60.40	... ...	....	.. ...	79.53
Minima	28.40	36.80	41.40	48.20	49.60	56.20	59.15	57.60	53.00	48.40	39.60	31.00	....	... ...	....	45.78
Mean	45.25	51.28	54.41	60.23	63.92	71.62	74.95	70.88	69.58	64.11	52.82	46.63	....	....	....	60.47
THERMOMETROGRAPH.																
Maxima	61.50	65.50	74.00	76.50	87.00	99.00	97.00	97.50	92.00	78.50	73.00	56.00	79.79	....	....	....
Minima	30.50	33.50	38.50	44.00	48.00	53.00	54.00	54.00	52.00	41.00	34.50	30.50	42.75	....	...	....
Range	31.50	32.00	35.50	32.50	39.00	46.00	43.00	43 50	40.00	37 50	38.50	25 50	37.04	....	....	....
DEW POINT.																
Maxima	50.17	52.50	59.00	60.00	61.00	68.67	63.25	63.62	57.14	56.00	54.62	49.50	....	58.56	57.36	....
Minima	28.33	22.00	32.67	33.83	38.00	35.67	37.88	37.75	35.38	31.00	30.75	24.63	....	31.75	33.40	....
Mean	41.34	42.23	46.10	47.75	50.13	54.70	54 73	52.64	48.75	47.14	42.10	38.71	... ...	47.04	47.35	....
RELATIVE HUMIDITY.																
Maxima	97.30	97.15	93.95	96.90	88.30	87.00	82.05	82.50	84.80	93.95	96.95	93.70	91.21	....	....	....
Minima	64.30	32.20	43.15	36.60	36.35	20.75	20.80	18.95	19.15	29.90	27.05	41.00	32.52	....	....	....
Mean	85.21	78.07	75.68	74.92	70.22	64.14	60.62	63.79	58.68	67.84	72 21	79.88	70.94	....	....	....
Number of clear days	10	13 6-15	13 14-15	13 5-15	17 13-15	22 9-15	25 12-15	24 3-15	33 5-15	17 14-15	14 2-15	13 13-15	....	....	....	210 6-15
Number of cloudy and foggy days	12 2-15	5 5-15	11	10 1-15	8 14-15	5 12-15	4 3-15	6 6-15	5 10-15	10 5-15	9 8-15	9 14-15	....	....	....	99 5-15
Number of rainy days	8 13-15	9 4-15	6 1-15	6 9-15	4 3-15	1 9-15	1	6-15	1	2 11-15	6 5-15	7 3-15	....	....	....	55 4-15
Quantity of clouds	7.4	6.7	5.9	5.4	3.8	2.3	2.0	2.3	2.9	4.1	5.4	6.0	4.5	....	....	....
Quantity of rain, in inches	3.043	3.891	3.306	2.290	0.930	0.141	0.003	Spkle.	0.001	0.373	1.191	1.944	....	....	....	17.113

Meteorological Observations—Continued.

1853-'54-'55-'56-'57.	MONTHLY MEANS.									
	January.		February.		March.		April.		May.	
1st days and 2d force of N. wind........	5 8-15	1.7	4 7-15	1.9	3 2-15	1.4	3 7-15	1.7	1 3-15	1.4
Do........do ....NE. wind.......	1 7-15	1.3	1 1-15	0.9	1 2-15	1.0	8-15	0.9	5-15	0.8
Do........do........E. wind........	1 8-15	1.2	1 8-15	1.3	1 2-15	0.8	12-15	1.2	8-15	0.2
Do........do........SE. wind.......	7	1.8	6 1-15	1.5	5 10-15	1.6	4 14-15	2.3	6 4-15	1.9
Do........do........S. wind.........	2 14-15	1.7	2 4-15	1.3	3 8-15	1.1	4 9-15	2.1	7 6-15	1.9
Do........do........SW. wind	1 13-15	0.7	2 6-15	1.6	6 6-15	1.2	7 4-15	1.9	8 9-15	1.8
Do........do........W. wind.......	8-15	0.7	10-15	1.3	1 4-15	0.7	1 7-15	1.4	13-15	1.6
Do........do........NW. wind......	10 2-15	1.8	9 11-15	2.1	8 11-15	1.5	6 14-15	1.7	5 12-15	1.8

1853-'54-'55-'56-'57.	MONTHLY MEANS.									
	June.		July.		August.		September.		October.	
1st days and 2d force of N. wind........	1 14-15	1.2	1 6-15	1.2	12-15	1.1	2 6-15	1.0	3 13-15	1.3
Do........do........NE. wind.......	5-15	1.3	3-15	0.8	7-15	1.2	1 1-15	0.7	10-15	0.9
Do........do........E. wind........	6-15	0.7	2-15	1.2	5-15	0.8	10-15	0.8	10-15	1.2
Do ....do........SE wind.......	5 3-15	1.9	9 2-15	2.2	12 1-15	1.6	7	1.6	5 5-15	1.7
Do........do........S. wind.........	8 3-15	2.2	8 1-15	2.1	7 10-15	2.1	5 2-15	2.1	2 12-15	2.1
Do........do........SW. wind......	6 6-15	2.0	6 11-15	2.2	7 6-15	2.1	6 8-15	1.6	5 5-15	1.7
Do........do........W. wind........	14-15	1.5	2 6-15	1.3	9-15	1.9	1 4-15	1.0	1	1.3
Do........do........NW. wind......	6 9-15	1.6	2 14-15	1.5	1 10-15	1.3	5 14-15	2.0	11 5-15	1.6

1853-'54'-55-'56-'57.	MONTHLY MEANS.				ANNUAL MEANS.			
	November.		December		2 years.	3 years.	4 years.	5 years.
1st days and 2d force of N. wind.........	5 5-15	2.2	4 8-15	1.7	1 5	....	....	38 1-15
Do........do........NE. wind.......	1 12-15	1.5	3 4-15	1.6	1.1	....	....	12 5-15
Do........do........E. wind.........	2 2-15	1.3	2	1.3	1.0	....	....	11 13-15
Do........do ....SE wind	5 3-15	2.2	3 5-15	2.3	1.9	....	....	77 3-15
Do........do........S. wind	2	2.9	1 4-15	1.5	1.9	....	....	55 13-15
Do........do........SW. wind......	3 3-15	1 7	4 9-15	2.3	1.7	....	....	66 8-15
Do........do ....W. wind	13-15	2.0	12-15	0.0	1.3	....	....	12 10-15
Do........do ....NW. wind......	9 7-15	2.5	11 3-15	1.8	1.8	....	....	90 7-15

REMARKS.—The mean mean of the barometer for July is apparently higher than that of June, in consequence of some peculiar disturbing causes in June, 1853; which month should have been regarded as exceptional. 1856 being leap-year, of course a fractional part must enter into the average of the clear and cloudy days for February, as well as of the number of the days of the wind.

ON THE BEST HOURS OF DAILY OBSERVATION TO FIND THE MEAN TEMPERATURE OF THE YEAR.

BY PROF. CHESTER DEWEY.

The mean temperature of a day is to be obtained, originally, from observations of the thermometer, taken twenty-four times daily, or double that number. The mean of daily and hourly observations of this kind must give a close approximation to the actual mean temperature. From a series of such hourly observations the *two*, or *three*, or *four* hours may be selected, which will give nearly an equivalent result.

The large Meteorological Society of Manheim, in Germany, selected the hours of 7 a. m. and 2 and 9 p. m., but I could find no reason for this selection in any accessible work, when I began observations in meteorology in 1815. In 1816 and 1817 I made twenty-four hourly observations of five days each in the different seasons; the first of the kind on record, so far as I know, being made for thirty days. The mean of the 24 observations is 41°.50; of 10 a. m. and 10 p. m, 41°.45; and of 7, 2 and 9 about one degree higher. Coming so near the mean I adopted those hours of the Manheim Society, for the ease of comparison with the results obtained by them.

The mean of observations at 6 a. m., 2 and 10 p. m., gave a close approximation to the mean of 24 observations; but the morning hour would be too early for half the year in view of many observers.

The results of this series of observed temperature I communicated to Secretary Calhoun, as he was about to organize the system of meteorological observations, so successfully made by the surgeons at the military posts of the United States since 1819. These hours were adopted for all the posts.

The fitness of these hours, 7 a. m., 2 p. m., and 9 p. m, for observations, is sustained by the following facts:

1. By the hourly observations for a year at Leith Fort, Scotland. These give the mean of 24 daily observations, 41°.50; of 10 a. m. and 10 p. m. very nearly the same; and of 7, 2 and 9 about *one-fourth* of a degree above the mean of the 24 observations.

2. By the hourly observations at Amherst College, Massachusetts, through 1839, under the direction of Prof. Snell. The mean of the 24 observations is 47°.23; of 10 a. m. and 10 p. m., is 47°.16; and of 7, 2 and 9, is 47°.88. This last, then, is *two-thirds of a degree* above the 24 mean. Prof. Snell shows the mean at 6 a. m.; 2 and 10 p. m. is nearly the same as the mean of the 24 observations.

3. By the "Girard Observations," under the direction of Prof. Bache, an extensive series of several years, bi-hourly and hourly.

The mean of 7, 2 and 9 is only three-tenths of a degree above that of 24 observations, and from this last, that of 10 and 10, differs only one-tenth of a degree.

4. Brooklyn Heights' Observations, hourly, for 1856, by E. Meriam, esq. I have summed only the first seven days in each month. The mean of 24 observations is 47°.72, and of 10 and 10 is very near the

same; while that of 7, 2 and 9 is 48°.28, or greater than the 24 mean by *one-half* a degree nearly.

5. At Sacramento, Cal., lat. 38 N. The 24 mean is 64°.41, and the mean of 7, 2 and 9 is 64°.11.

NOTE.—By the last three it is evident that the mean of 7, 2 and 9 approaches nearer to that of the 24 mean, as the places have a lower latitude, and an examination of the 24 hours observation in the Arctic regions shows quite a departure of the mean of 7, 2 and 9 from the mean of 24 observations.

The 24 hourly observations give the mean of the year—

At Halle	48°.00
At Gottingen	52 82
At Padua	56 74

On calculating the mean of 7, 2 and 9, I find that—

At Halle	48 89
At Gottingen	53 45
At Padua	57 47

Observations on the temperature of Salem, Massachusetts, were made with much care by Dr. Holyoke for thirty-three years preceding 1819. The hours of observation were *four*, viz: 8 a. m., noon, sunset, and 10 p. m. By interpolating for sunset, in my series of 24 daily observations, I found that the mean from these four hours is only a little greater than that of the three hours, 7 a. m., 2 and 9 p. m. Dr. Holyoke's mean temperature of Salem is 48.68 degrees. The mean heat at Leith, by the 24 daily observations, is 48.24, and by the hours, 7, 2 and 9, is 48.50.

This approximation from these four hours, and one of them variable, is another unexpected result.

Between 1842 and 1855 the observations at the military posts were directed to be made at four periods of the day, viz: a *little before* sunrise as the *coldest* generally; at 3 p. m. as the *hottest*, and at 9 a. m. and 9 p. m. as approximating the mean temperature of the day, but half the sum of the observations at sunrise, S. R., and 3 p. m. was to be taken as the mean heat of the day. In the preparation of the "Army Meteorological Register," published in 1856, the fourth part of the sum of those four observations was taken as the mean of the day, because Dr. Coolidge and his associate became satisfied from extensive comparison of the twenty-four daily observations, that the mean of the four observations was nearer the twenty-four mean, than those at sunrise and 3 p. m. would give. Dr. Coolidge states also, that the evidence was clear from the comparison of numerous twenty-four hourly observations at the posts that the mean of 7, 2, and 9, was for all the posts, the nearest approximation of any hours selected to the mean of the twenty-four daily observations. In 1855, therefore, the Surgeon General, Dr. Lawson, issued his circular requiring a return to the original hours of observation, viz: 7 a. m., 2 p. m., and 9 p. m.

In ascertaining the relative correctness of the results in the "Consolidated Tables" of the Army Meteorological Register, taken for twenty-three years from the three daily observations, and for twelve years from the four hours' record, it was important to make some tests. These are as follows:

1. Prof. Snell performed the labor of interpolating for sunrise in his hourly observations for the year 1839, and sent to me the following result: While the mean of the twenty-four hourly observations is 47°.23, the mean of the four hours, S. R., 9 a. m., 3 and 9 p. m., is 47°.13, making a difference of only one-tenth of a degree.

This was an unexpected result, but of high interest. My own observations interpolated in the same way gave only a little greater difference.

2. The Consolidated Tables in the Army Meteorological Register yield the following proofs:

a.—For Fort Columbus, N. Y., p. 600, latitude 40°.42,

The mean of 33 years is	51°.69
The mean of 7, 2, and 9, 21 years, is	51°.42
The mean of the four hours, 12 years, is	51°.83

Either hours give a close approximation.

b.—For Alleghany Arsenal, Penn., p. 605, latitude 40°.32,

The mean for 21 years is	50°.86
The mean of 7, 2, and 9, for 9 years is	50°.43
The mean of four hours, 12 years is	50°.75

This is another close approximation.

c.—For Fort McHenry, Md., p. 607, latitude 39°.17,

The mean of 21 years is	54°.86
The mean of 7, 2, and 9, of 12 years is	53°.97
The mean of four hours, 9 years is	54°.86

d.—For Fort Monroe, Va., p. 608, latitude 37°.00,

The mean of 30 years is	59°.22
The mean of 3 hours, 18 years is	59°.29
The mean of 4 hours, 12 years is	59°.04

e.—For Fort Gibson, Indian Territory, p. 624, latitude 34°.47,

The mean of 27 years is	60°.81
The mean of 3 hours, 15 years is	61°.53
The mean of 4 hours, 12 years is	60°.19

f.—For Fort Gratiot, Mich., p. 627, latitude 43°,

The mean of 14 years is	46°.29
The mean of 3 hours, 9 years is	46°.62
The mean of 4 hours, 5 years is	45°.30

g.—For Fort Brady, Mich., p. 629, latitude 46½°,

The mean of 26 years is	40°.37
The mean of 3 hours, 18 years is	40°.56
The mean of 4 hours, — years is	39°.53

h.—For Fort Snelling, Minn. Ter., p. 632, latitude 45°,

The mean for 34 years is	44°.54
The mean for 3 hours, 22 years is	45°.17
The mean for 4 hours, 12 years is	44°.06

i.—For Fort Leavenworth, Kan. Ter., p. 633, latitude 39⅓°,

The mean of 23 years is	52°.78
The mean of 3 hours, 12 years is	52°.35
The mean of 4 hours, 11 years is	52°.65

k.—For Jefferson Barracks, Mo., p. 625, latitude 38½°,

The mean of 22 years is	55°.46
The mean of 3 hours, 11 years is	56°.42
The mean of 4 hours, 11 years is	55°.77

In all these only whole years are introduced, while in the annual means of the Consolidated Tables, parts of years are sometimes introduced, which will account for a slight discrepancy to be noticed in some of the results.

The conclusion from the above results is that the observations at the three hours, and at the four, give close approximations.

To all this add the assertion of Dr. Coolidge, previously mentioned, which led to a return to the hours of 7 a. m., 2 and 9 p. m., at the Military Posts. At these three hours also, the observations under the direction of the Smithsonian Institution are made over the country.

These are convenient hours for recording observations over our extensive country, and the results need only slight correction, according to the publications in the Toronto Observations, and still less according to the data already detailed.

From the observations of 1839 at Amherst College, and the results communicated by Prof. Snell, I have deduced the following table of corrections. Their object is to give the monthly mean, and hence the annual mean of twenty-four daily observations, by applying the numbers in the table, to the monthly mean at any hour, according to their signs:

Difference of the monthly means of each hour from the monthly mean of the twenty-four hours, being the correction to be applied to the monthly mean of each hour to obtain the means of the twenty-four hours. Thermometer. Fahrenheit.

	January.	February.	March.	April.	May.	June.	July.	August.	Septem'r.	October.	Novemb'r.	December.	Mean for year.
1 a. m.	3.90	2.78	4.53	6.23	5.51	6.64	6.39	5.14	5.36	4.87	2.34	1.63	4.63
2 a. m.	4.24	3.03	4.81	6.69	6.48	7.28	6.83	5.66	6.12	5.65	2.99	2.20	5.16
3 a. m.	4.13	3.20	5.36	7.42	7.41	7.92	7.28	6.03	6.92	6.46	3.49	2.55	5.68
4 a. m.	4.50	3.94	5.69	7.85	7.88	8.04	7.42	6.29	6.56	7.09	3.72	2.70	6.06
5 a. m.	4.72	4.20	6.04	8.12	8.18	7.80	7.54	6.66	7.88	7.72	4.03	3.32	6.35
6 a. m	4.68	4.78	6.12	7.77	6.77	6.96	6.02	5.81	7.44	7.65	4.34	3.78	5.93
7 a. m.	4.75	4.78	4.62	5.97	4.22	4.20	3.80	4.48	5.32	6.87	4.38	3.97	4.77
8 a. m.	3.83	3.78	2.08	3.04	1.62	1.40	1.09	1.96	2.52	4.31	2.68	4.13	2.70
9 a. m.	1.46	1.45	—0.46	— 0.08	—0.60	—0.88	—0.87	—0.93	—0.56	+0.83	+0.34	+2.40	0.19
10 a. m.	—1.26	—0.85	—2.57	— 2.69	—1.12	—3.12	—3.80	—3.04	—3.38	—2.24	—1.43	—0.55	—2.34
11 a. m.	—4.10	—2.72	—4.77	— 5.65	—5.12	—5.68	—6.43	—5.45	—6.04	—5.02	—3.01	—2.76	—4.73
12 m.	—6.32	—4.26	—6.38	— 7.92	—6.75	—8.08	—8.50	—6.86	—8.16	—7.06	—5.01	—4.30	—6.63
1 p. m.	—7.46	—5.35	—7.65	— 9.46	—8.15	—9.36	—8.83	—8.23	—9.12	—8.24	—6.12	—6.14	—7.84
2 p. m.	—7.80	—6.06	—8.34	—10.42	—8.75	—9.00	—9.50	—7.86	—9.80	—9.28	—5.97	—6.30	—8.26
3 p. m.	—7.32	—5.80	—8.11	— 9.81	—8.27	—8.60	—7.50	—7.67	—9.20	—9.24	—5.28	—5.60	—7.70
4 p. m.	—5.84	—4.89	—7.23	— 8.61	—7.86	—7.84	—7.17	—6.23	—8.40	—8.24	—3.85	—3.76	—6.66
5 p. m.	—3.32	—3.10	—5.65	— 7.04	—5.97	—6.00	—5.83	—5.26	—6.44	—5.65	—2.28	—2.03	—4.88
6 p. m.	—2.06	—1.18	—3.46	— 4.50	—4.08	—4.20	—4.17	—2.82	—3.52	—3.50	—0.85	—0.68	—2.92
7 p. m.	0.24	—1.05	0.17	— 1.69	—2.38	—1.92	—1.54	—1.44	—1.47	—1.24	—0.64	—0.31	—1.11
8 p. m.	0.64	—0.43	0.93	0.27	—0.19	—0.04	0.98	0.33	0.11	0.13	0.08	0.20	0.26
9 p. m.	1.50	0.28	1.89	1.77	1.36	1.96	3.05	1.59	1.99	1.16	0.80	0.69	1.53
10 p. m.	2.01	0.57	3.29	3.31	2.73	3.20	3.79	3.02	3.53	1.90	1.16	1.20	2.48
11 p. m.	2.42	1.19	4.29	4.23	3.99	4.20	4.24	3.79	4.61	3.24	1.96	1.58	3.31
12 mid.	2.50	1.70	4.85	4.92	4.75	5.48	5.31	4.52	5.34	4.09	2.40	1.98	3.99
3 and 9 a. m. and 3 and 9 p. m.*	—0.05	—0.22	—0.08	— 0.13	0.05	0.10	0.49	0.26	—0.21	—0.20	—0.16	—0.01	—0.01
7, 2, 2, (9)	—0.01	—0.18	0.01	— 0.23	—0.05	—0.22	0.10	—0.05	—0.12	—0.02	—0.02	—0.24	—0.11
9 and 9	1.48	0.87	0.72	0.93	0.53	0.54	1.09	0.33	0.72	1.00	0.57	1.55	0.80
10 and 10	0.38	—0.14	0.36	0.31	0.81	0.04	0.60	—0.51	0.11	—0.17	—0.13	0.33	0.12
7, 2, and 9	—0.48	—0.33	—0.61	— 0.89	—0.96	—0.95	—0.88	—0.60	—0.83	—0.42	—0.29	—0.55	—0.65
6, 2, and 10	—0.37	—0.24	0.36	— 0.24	0.25	0.05	0.10	0.32	0.39	0.09	—0.16	—0.44	0.01
7, 2, and 10	—0.35	—0.04	—0.14	— 0.38	—0.60	—0.53	—0.64	—0.12	—0.32	—0.17	—0.18	—0.38	—0.32
7, 2, and 11	—0.21	—0.03	0.19	— 0.07	—0.18	—0.20	—0.49	0.14	0.04	0.28	0.09	—0.25	—0.07
6, 8, 2, 4, 10, and 12	—0.09	0.02	0.13	0.00	—0.12	—0.13	—0.08	0.20	0.11	0.07	0.13	0.17	0.03

* This line is for the four hours used by the Royal Society.

NOTE.—The numbers after the sign — to be subtracted, and the others to be added.

To use the table, let the mean of observations at 7 a. m., for the month of April be 42°.57; apply the correction for that month and hour in the table, 5.97, and you have this sum, 48.54, which is the mean of the 24 hour observations for that month.

For the two hours, 7 and 7, in April, you would have—

$\frac{42.57 + 50.23}{2} + \frac{5.97 - 1.69 = 48.54}{2}$, the same mean.

For the three hours, 7, 2, and 9, in March, take out the three means—

$\frac{30.19 + 43.15 + 32.92}{3} = 35.42$, and corrections from the tables are

$\frac{4.62 - 8.34 + 1.89}{3} = -0.61.$

The sum 34.81 is the mean of the 24 observations for the month of March.

NOTE.—At the foot of the preceding table are given the corrections for observations, made at various different hours of the days, to show the nearer or more remote approximations to the mean of the 24 daily results.

The first of these is for the hours 3 and 9 a. m., and 3 and 9 p. m., the hours adopted by the Royal Society for obtaining the approximate mean temperature. These hours are convenient, except that of 3 a. m.

The next corrections are derived from one-fourth of the observations at 7 a. m., 2 p. m., and 2 (9) p. m., the last being twice the temperature of 9 p. m. A very near approximation is easily obtained in this way: Thus, the mean of the year, in Amherst observations—

At - - -	7 a. m., is		42°.46
At - - -	2 p. m., is		55°.29
Twice - -	9 p. m., is		91°.40
Sum - - - - - - -		=	189°.15
Divide by 4 - - - -		=	47°.29
Add the correction -		=	— .11 from the table.
Approx. mean - -		=	47°.18
Mean of the 24, hourly		=	47°.23
Difference - - - - -		=	0°.05, only $\frac{1}{500}$th of a degree.

Using the same formula for the Leith observations, the approximate mean differs from that of the 24 observations only $\frac{1}{900}$th degree.

And for Toronto......	$\frac{1}{400}$	"
Franklin arsenal, Pennsylvania.........	$\frac{11}{100}$	"
Halle, about..........	$\frac{1}{2}$	"
Padua, less than..........	$\frac{1}{2}$	"
Gottingen......	$\frac{7}{100}$	"
Girard observations, not..........	$\frac{1}{500}$	"
Brooklyn heights about the same.		

The advantages of using the fourth part of the observation at 7 a. m., at 2 p. m., and twice that at 9 p. m., are obvious. The preceding cases are ample illustration.

This table of corrections will have a special value in our country from the locality in the heart of New England, where the observations were made. No similar table has before been derived from them. While it presents the analogies of other similar tables, it will be better adapted to a large district of our country where meteorological observations are being made systematically. Some gratification will result to Professor Snell in such an application of his laborious and scientific efforts, in this particular, in 1839.

Such tables, it is evident, avail nothing where one or more times of observation, as sunrise or sunset, have a constant change, even though they may give an approximate mean. In different latitudes sunrise has different hours, as well as sunset, and the corrections must require a far greater series of observations and far more labor. Though the four hours used at the military posts for several years give an approximate mean, no correction for the sunrise observation is yet obtained.

So great is the labor of making the observations, and of discussing them for practical purposes, that the fewest practicable hours, not exceeding three, should be adopted for the observations of meteorologists generally. Only a few observers, who are favorably situated also, can afford to make hourly observations for a year or for years; and when such have been made, as enable observers to make the corrections from prepared tables, the great object will be attained by using only three hours of observation. The last line of corrections in the preceding table is derived from six hours of observation, used for some time at the Toronto Observatory, viz: *six* and *eight* a. m., *two* and *four* and *ten* p. m., and *twelve*, or midnight. Though the corrections are very small for these six hours, they are too numerous for ordinary object or advantage. The same objection lies against the use of any four hours separated by six hours, as *one* and *seven*, both a. m. and p. m.; which, however, give very nearly the mean of 24 observations a day. Some of these hours will be very inconvenient and troublesome. Take even the hours adopted by the Royal Society, 3 and 9 a. m., and 3 and 9 p. m.; 3 a. m. is a very inconvenient hour, though the four give very nearly the mean of the daily 24 observations, as shown in the first line of particular hours.

In a series of observations of twelve years, like those in the "Army Meteorological Register" of 1856, these four hours, or any four hours, would require a million more observations than the three hours, besides increasing the labor of the reductions one-third more than is necessary to attain the same approximation to accuracy.

It is hoped that adequate evidence of the value of observations at the hours 7, 2 and 9, has been presented, and that a near approximation to the true mean is attainable. The results may be corrected, if need be, by the prepared tables.

Rochester University, *March* 31, 1858.

METEOROLOGICAL OBSERVATIONS AND RESULTS.

BY J. WIESSNER.

1st. The *daily* results of mean temperature of the air in shade, as bserved on a farm in the District of Columbia.

2d. The *monthly* results.

3d. A trial adjustment, assuming that the mean motion of temerature may be represented by the motion of an elastic ball jumping ip and down.

4th. A comparison of the Washington summer with the summers t Naples, Rome, Constantinople, Petersburg, and Savannah.

The probable error for the Washington series being very small, hows that the observations were made carefully and in large numer; also, that the last summer was a very regular one.

The figures in the former table for adjusting the daily observations ave the probable error ± 0°.3, so that ten years' further observaions will make them correct to the last figure.

Next, a table containing p for each day of observation. By sing the three tables and the simple formula $t_0 = t_m + p\,w$, all he observations now at the end of 1857, 4,500 in number, may be recomputed and compared with the individual records, which will give an average probable error of a single observation and reduction, = ± 1°.4.

Mean temperature of the air in the shade of the District of Columbia.

Date.	October. 1855.	November 1855.	December, 1855.	January, 1856.	February, 1856.	March, 1856.	Remarks.	December, 1856.†
	° F.	°	°	°	°	°		°
1	....	57.4	39.4	21.4	28.8	31.8	Mean for this period 36°.1, or after adjustment, 35°.8. Let μ be the number of weeks before or after the week, (Feb. 2—8,) + after, — before; then the adjustment gave the mean temperature for any week μ by the formula: tm. = 25°.3 + 0.130 μ^2 with the probable error, ± 4°.5. The probable error of the weekly means as found from observations, was ± 1°.8.	....
3	....	59.0	38.0	29.5	23.0	34.2		....
2	....	58.3	42.1	30.4	10.2	33.3		....
4	....	55.0	45.5	15.8	7.5	42.1		....
5	....	48.6	36.7	18.5	14.0	30.7		....
6	62.8	50.2	39.2	26.4	16.9	34.2		....
7	46.4	54.3	40.3	28 2	33.8	28.8		....
8	45.5	55.2	35.6	16.7	33 1	35.6		....
9	52.6	48.9	55.2	5.0	29.0	19.6		....
10	58.8	44.2	35.8	2.5	29.2	15.1		....
11	60.6	52.2	28.6	11.0	33.3	27.9		....
12	45.9	56.0	26.0	22.6	24.1	34.0		....
13	41.4	59.0	34.7	30.9	8.6	29.7		....
14	48.9	49.3	32.0	30.0	10.6	36.1		....
15	58.3	49.6	39.6	27.5	26.9	36.3		....
16	53.8	63.5	55.6	27.9	34.7	31.6		28.7
17	46 2	47.0	45.3	27.1	19.2	35.4		27.0
18	53.6	46 8	36.5	25.5	21.2	39.2		19 8
19	55 4	41.4	27.9	27.9	19.4	34.7		23.0
20	58.6	35.0	30.0	16.0	31.6	42.3		35.2
21	60.6	40.1	35 6	17.1	31.6	41.9		21.7
22	52.2	38.5	43.0	18.9	35.6	39.4		18.5
23	42.1	35.6	50.2	17.4	38.0	40.3		13.4
24	38.7	46.4	40.6	17.8	33.1	41.4		22.2
25	38.7	38.5	33.4	17.6	34.7	39.9		25.8
26	42.1	51.3	24.3	11.8	33.1	38.3		31.9
27	49.1	42.8	19.2	23.2	30.6	36.5		33.4
28	58.6	39.9	30.7	29.8	31.8	*		41.8
29	51.8	35.3	23.7	23.4	33.5	....		39.2
30	60.3	36.3	26.0	17.4	....	....		32.8
31	55.8	....	26.0	15.8	....	....		30.2
Mean...	51.5	47.8	36.0	20.7	26.1	34.5		27.8

* Thermometer broke.

† New station and thermometer, east corner District of Columbia.

A table, [w], of use for the reduction of observations for temperature of the air in the shade, made at different hours of the day by th formula

$$t_o = t_m + p\,w$$

t_o. The observed temperature.

t_m. The mean of the 24*h*.

p. A factor depending on the disposition of the atmosphere for sola heat, the mean factor of the month being unit.

$p\,w$. The correction to the mean temperature of the day to get ou the observed one.

t_m and p are to be found for each day by the method of least squares or by a good approximation to it, by a calculation shown on the next page.

Example.

Reduction of observation for temperature by the formula

$$t_0 = t_m + p\, w$$

East corner of the District of Columbia, September 1, 1857.

		Observed.	Equations of condition.	Comp'd Δ.	
	h. m.	°		°	
A.M.	5 30	$55.0 = t_m - 8.2\ p$	$-18.4 = -10.8\,p$	56.9	-1.9
	6 00	$57.8 = t_m - 7.6\ p$	$-15.6 = -10.2\,p$	57.8	0.0
	7 00	$63.8 = t_m - 4.2\ p$	$-9.6 = -6.8\,p$	63.0	$+0.8$
	8 00	$67.8 = t_m + 0.3\ p$	$-5.6 = -2.3\,p$	69.8	-2.0
	9 00	$73.8 = t_m + 2.5\ p$	$+0.4 = -0.1\,p$	73.2	$+0.6$
	10 00	$77.0 = t_m + 5.4\ p$	$+3.6 = +2.8\,p$	77.7	-0.7
	11 00	$80.8 = t_m + 7.3\ p$	$+7.4 = +4.7\,p$	80.6	$+0.2$
P.M.	12 15	$83.0 = t_m + 9.0\ p$	$+9.6 = +6.4\,p$	83.2	-0.2
	1 15	$83.8 = t_m + 9.4\ p$	$+10.4 = +6.8\,p$	83.8	0.0
	2 00	$83.8 = t_m + 9.3\ p$	$+10.4 = +6.7\,p$	83.7	$+0.1$
	3 00	$83.0 = t_m + 9.0\ p$	$+9.6 = +6.4\,p$	83.2	-0.2
	4 00	$81.8 = t_m + 8.0\ p$	$+8.4 = +5.4\,p$	81.7	$+0.1$
	5 00	$79.8 = t_m + 6.4\ p$	$+6.4 = +3.8\,p$	79.2	$+0.6$
	7 15	$70.5 = t_m + 0.1\ p$	$-2.9 = -2.5\,p$	69.6	$+0.9$
	8 15	$67.5 = t_m - 1.9\ p$	$-5.9 = -4.5\,p$	66.5	$+1.0$
	9 00	$66.0 = t_m - 2.8\ p$	$-7.4 = -5.4\,p$	65.7	$+0.3$
		$73.4 = t_m + 2.6\ p$	$131.2 = 85.5\,p$	$*\Sigma\,\Delta = 9.6$	

$$* \Sigma\,\Delta = 9.6 : 15.5 = 0.62$$

$$0.09$$

Normal eq., $\pm\ 0.53$

No. of observations, 16.

Result, $p = 1.53$

$t_m = 69°.4 \pm 0.13$

$\varepsilon_0 = \pm\ 0.5$

Table of w. *for the reduction of temperature observations to the mean of the day by the formula* $t_o = t_{m.} + pw.$, *obtained from* 4,400 *observations, made between* 1855 *and* 1857, *by M. Wiessner, and reduced by J. Wiessner, east corner of the District of Columbia, latitude* 38° 53′. 8, *longitude* 76° 52′. 0, *height* 120 *ft.*

Mean time, Washington.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean time, Washington.	Year.
h.	*F.* °													*F.* °
a. 1	−2.5	−4.5	−5.0	− 6.9	− 9.1	− 8.2	−7.2	− 6.9	−6.6	− 5.4	−3.9	−2.1	*a.* 1	−5.7
2	−3.1	−4.8	−5.5	− 7.9	−10.1	− 9.1	−7.7	− 8.2	−6.8	− 5.6	−4.2	−2.2	2	−6.3
3	−3.3	−5.0	−5.8	− 9.4	−11.0	− 9.8	−8.3	− 9.0	−7.3	− 6.2	−4.5	−2 8	3	−6.9
4	−3.4	−5.1	−6.1	−10.7	−11.7	−11.1	−8.7	−10.0	−7.4	− 6.7	−4.6	−3.2	4	−7.4
5	−4.1	−5.5	−6.4	−11.0	−10.2	− 8.2	−7.1	− 9.8	−7.8	− 7.0	−4.8	−3.5	5	−7.1
6	−4.3	−5.9	−8.4	− 9.0	− 6.8	− 3.6	−4.5	− 6.5	−8.8	− 8.1	−7.2	−5.5	6	−6.6
7	−6.0	−7.4	−5.8	− 4.5	− 2.7	− 0.8	−2.0	− 2.7	−5.6	− 6.5	−6.7	−5.1	7	−4.7
8	−4.1	−5.0	−2.5	− 0.3	+ 1.1	+ 1.3	+0.6	+ 0.6	−1.2	− 3.4	−4.2	−4.0	8	−1.8
9	−1.2	−2.0	+1.0	+ 2.7	+ 3.8	+ 3.5	+3.0	+ 3.3	+1.8	+ 1.0	−0.4	−1.3	9	+1.3
10	+2.0	+3.7	+3.4	+ 5.5	+ 6.0	+ 5.7	+5.0	+ 5.7	+5.1	+ 4.9	+2.7	+1.4	10	+4.3
11	+4.4	+4.3	+4.8	+ 7.1	+ 8.0	+ 7.2	+6.5	+ 7.0	+7.7	+ 7.0	+5.4	+4.1	11	+6.1
12	+5.9	+6.7	+6.2	+ 8.4	+ 9.7	+ 8.0	+7.5	+ 8.4	+9.4	+ 9.1	+7.6	+6.6	12	+7.8
1	+6.7	+8.0	+7.5	+ 9.2	+10.2	+ 8.5	+8.0	+ 9.3	+9.6	+10.1	+8.3	+7.7	*p.* 1	+8 6
2	+7.1	+8.8	+8.1	+ 9.6	+10.4	+ 9.0	+8.4	+ 9.1	+9.5	+10.6	+8.4	+7.4	2	+8.9
3	+5.4	+8.1	+8.5	+ 9.6	+10.5	+ 9.1	+8.0	+ 8.5	+9.4	+10.2	+7.5	+6.1	3	+8 4
4	+4.3	+7.2	+8.1	+ 8.9	+ 9.7	+ 8.0	+7.3	+ 7.5	+8.6	+ 8.4	+5.7	+3.4	4	+7.3
5	+2.8	+5.3	+6.2	+ 7.5	+ 7.9	+ 6.4	+6.2	+ 6.0	+6.8	+ 5.0	+3.4	+1.8	5	+5.4
6	+2.4	+3.2	+2.9	+ 4.7	+ 4.6	+ 4.1	+3.8	+ 3.8	+2.8	+ 1.8	+1.8	+0.3	6	+3.0
7	+1.2	+0.9	+0.9	+ 1.4	+ 0.9	+ 1.1	+1.1	+ 1.2	+0.2	− 0.3	+0.5	−0.2	7	+0.7
8	−0.3	0.0	−0.1	− 0.6	− 1.3	− 1.3	−1.1	− 1.3	−1.9	− 1.8	−0.5	−1.1	8	−0.9
9	−1.5	−1.1	−1.7	− 1.8	− 2.3	− 2.4	−2.9	− 2.5	−3.2	− 3.0	−0.8	−1.5	9	−2.1
10	−2.2	−2.2	−2.7	− 3.0	− 4.4	− 4.5	−4.2	− 2.8	−4.1	− 4.0	−2.2	−1.9	10	−3.2
11	−2.9	−3.0	−3.4	− 4.4	− 5.8	− 5.9	−5.4	− 4.2	−5.0	− 4 5	−3.3	−2.1	11	−4.2
12	−3 2	−3.7	−3.9	− 5.9	− 7.5	− 7.1	−6.3	− 5.8	−5.8	− 5.2	−3.8	−2.3	12	−5.0

Mean temperature of the air, in the shade, of the District of Columbia.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
857	*F.*											
1	30.3	35.7	40.0	48 3	51.1	72.9	*	74.9	69.5	54.7	46.0	44.6
2	32.7	23.7	22.6	30.7	60.0	70.1	*	74.6	71.4	61.8	50.0	37.8
3	32.4	19.0	21.9	34.7	62.8	68.3	*	74.5	69.5	63.2	43.3	44.3
4	29.0	42.0	32.7	49.6	61.1	68.5	*	72.5	74.5	56.5	42.6	37.4
5	31.5	46.2	34.6	60.7	63.4	53.8	*	72.8	75.4	56 6	53.3	43.0
6	23.5	54.0	36.7	48.0	61.1	61.3	*	73.7	72 5	54.4	64.9	43.6
7	21.0	49.8	26.4	33.7	56.9	68.8	*	71.8	58.8	54.7	66.7	44.7
8	11.6	52 5	23 9	44.1	61.0	70.9	*	73.1	58.0	53.7	71.9	55.7
9	20.4	27.2	29.4	50 5	62.0	68.0	74.7	77.0	63.1	55.9	71.5	64.5
0	28.1	25 1	27.0	46.6	68.7	65.6	75.9	74.9	69.0	58.4	43.4	45.8
1	30.0	17.5	33.5	50.0	51.3	68.8	74.3	75.0	71.1	59.6	39.5	37.3
2	17.4	26.0	29.0	43.9	51.9	70.7	75.6	76.5	72.6	64.0	42.8	29.5
3	21.9	38.6	26.7	37.0	57.4	75.0	79.0	81.3	72.0	65.2	50.5	30.0
4	23.0	40.6	38.4	42.3	63.5	75.3	77.6	84.4	73.3	67.0	37.6	40.6
5	23.2	52.1	40.2	43.3	58.4	75.2	77.7	82 5	71.6	63 2	30.0	41.8
6	11.9	59.8	43.1	40.3	57.5	79.7	76.1	73.6	65.3	53.6	41.6	40.4
7	31.9	60.0	45.1	38.7	59.2	75.8	75.2	76.8	78.2	50.8	45.3	45.0
8	4.7	56.0	53.1	39.2	50.0	75.8	75.7	75.3	76.3	53.7	46.5	52.2
9	14.0	62.3	41.9	41.5	43.6	67 9	81.5	71.8	61.8	61.6	41.8	43.6
20	17.1	39.0	44.1	35.1	44.5	75.2	80.8	69.3	64.7	43.2	26.4	35.2
21	33.1	47.7	48.4	40.5	50.8	74.6	78.0	66.8	61.0	40.6	31.0	34.8
22	6.7	38.6	48.9	39.5	60.6	†	75.0	67.1	65.4	43.5	42.0	42.0
23	4.1	44.4	48.6	45.9	64.9	†	71.9	70.0	58.8	49 5	47.8	38.7
24	7.4	52.0	60.0	47.2	67.7	†	73.9	66.4	57.8	53.2	30.7	36.5
25	11.0	61.9	52.0	51.2	71.7	†	76.7	64.7	59.2	54.8	22.0	30.3
26	10.0	41.8	41.0	52.3	72.5	†	79.8	70.6	65.4	49.2	22.0	32.7
27	37.7	38.7	41.2	56.3	69.7	†	79.2	69.4	67.5	48.0	29.8	30.4
28	32.7	42.8	44.0	53.8	67.4	†	79.0	76.5	66.5	41.9	32.5	37.3
29	33.9	……..	40.4	50.4	64.8	†	77 7	68.7	54.5	45.7	41.0	40.4
30	27.1	……..	46 4	51.4	65.8	†	74.2	65.2	49.7	45.2	41.7	38.5
31	36.4	……..	45.8	……..	71.1	†	75.2	63.7	……..	42.6	……..	38.9
Mean	22.4	42.7	38.9	44.9	60.4	70.6	76.7	72.9	66.5	53.7	43.2	40.6

52°.8

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* New thermometer from the Smithsonian Institution.
† Thermometer broke during the hailstorm of June 21.

Adjustment of temperature for Washington, Summer 1857.

m.	Arg. m.	Obs. °	Assumed eq. of condition.			
-3	April -3	$44.9 = x - 3y + 9z$	$-18.8 = -3y + 5z$	-18.8	$+18.8$	-6
-2	May -2	$60.4 = x - 2y + 4z$	$-3.3 = -2y$	-6.9	$+3.3$	-10
						-16
-1	June -1	$70.6 = x - 1y + 1z$	$+6.9 = -1y - 3z$	-13.0	$+9.2$	$+34$
0	July 0	$76.7 = x$	$+13.0 = -4z$	-9.2	$+2.8$	
$+1$	Aug. $+1$	$72.9 = x + 1y + 1z$	$+9.2 = +1y - 3z$	-10.0		$+17.$
$+2$	Sept. $+2$	$66.5 = x + 2y + 4z$	$+2.8 = +2y$	-57.9		
$+3$	Oct. $+3$	$53.7 = x + 3y + 9z$	$-10.0 = +3y + 5z$			
	Mean........	$63.7 = x + 4z$				
		$+11.6$				
		75.3				

Normal Eq.

$-57.9 = 20z$

$+17.2 = 12y$

Solution.

$z = -2.90$

$y = +1.4$

$x = 75.3$

Washington, Summer, 75°.3 *F.* $+ 1.4\, m - 2.90\, m^2 \pm 0°.5$.

April.	May.	June.	July.	Aug.	Sept.	Oct.	Sum of Resid.
+ 75 3	+ 75.3	+ 75.3	....	+ 75.3	+ 75.3	+ 75.3	+ 1.7
− 4.2	− 2.8	− 1.4	....	+ 1.4	+ 2.8	+ 4.2	− 1.9
− 26.1	− 11.6	− 2.9	....	− 2.9	− 11.6	− 26.1	
+ 45.0	+ 60.9	+ 71.0	+ 75.3	+ 73.8	+ 66.5	+ 53.4	3.3 : 6 = 0.5
Resid'ls—							0.0
− 0.1	− 0.5	− 0.4	+ 1.4	− 0.9	0.0	+ 0.3	± 0.4

Mean.

1.4 : 5.8 = 0.24

24 30

7.2

15.5

23th

Maximum temp. July 23, 75°.4

75.3

+ 0.3

− 0.2

75.4

For comparison—

The summer of		Lat.		
	Naples........	40°.9.............	75°.0 + 1.3 m − 1.75 m^2 ± 0.7	
	Rome.........	41.9.............	73.9 + 1 3 m − 1.69 m^2 ± 0.7	
	Constantinople	....	77.7 + 1.3 m − 2.05 m^2 ± 1.5	
	Petersburg....	59.8.............	61.7 + 0.9 m − 2.70 m^2 ± 0.8	
	Savannah.....	32.1.............	80.2 + 0.6 m − 1.28 m^2 ± 0.7	

OBSERVATIONS ON NATURAL PHENOMENA.

BY STILLMAN MASTERMAN, ESQ.

WELD, MAINE, *February* 26, 1857.

DEAR SIR: Pursuant to my promise, I present to you the registry of certain miscellaneous natural phenomena observed by myself during a few past years, belonging principally to the departments of meteorology and astronomy. Fragmentary and unsystematic as the observations are, they can be of comparatively little value; however, as every phenomenon of nature, even the most trifling, is worthy of a place in the great study of the universe, and as you are desirous of collecting all registries of natural phenomena, I deem it proper to place them at your disposal. The accompanying observations were made with no idea of placing them before the public, but under the conviction that perhaps they might be of some use in my future scientific investigations. Moreover, they were conducted during fragments of time which happened not to be taken up by what I considered to be more important duties, therefore in many cases they are separated by long intervals of time, not from the want of phenomena to observe, but from an inability to make trustworthy observations. So few observations afford very insufficient data for generalizations; however, the coincidence of certain results with those derived from more extensive series are frequently very apparent. The following are some of the well known principles which the annexed observations tend to confirm:

1. That shooting stars have been more numerous, at least for a few past years, on or about the 10th of August, and for a number of days both before and after that date, than at other times of the year.
2. That these meteors frequently leave long bright trains behind them in the sky.
3. That during an exhibition they commonly have one general direction of motion.
4. That exhibitions of the aurora borealis commonly commence at an early hour of the evening.
5. That auroral exhibitions generally have their maximum before midnight.
6. That in our latitudes auroras have been seen in all parts of the sky.
7. That the zodiacal light may be seen, in the absence of the moon, on clear evenings during the months of January, February, and March.
8. That this cone of light lies nearly in the plane of the ecliptic.
9. That the zodiacal light at times may be traced above 90° from the sun.

Yours, truly,

STILLMAN MASTERMAN.

Professor JOSEPH HENRY,
Secretary of the Smithsonian Institution.

A.

OBSERVATIONS OF SHOOTING STARS.

WELD, FRANKLIN COUNTY, MAINE.

1847—*December* 11.—At 8*h*. 30*m*. p. m. I saw a very brilliant shooting star, which fell in the northwest. I should judge that when it was in sight I could have read the smallest print without difficulty in its light. It left a bright streak or tail of phosphorescent matter, 60° or 70° in length, which remained motionless for about 30 seconds, when it gradually vanished. The nucleus of light was apparently of three-fourths the diameter of the lunar orb, and it was about 2 seconds in passing over 70° of the celestial sphere, disappearing very near the horizon.

1849—*September* 15.—Saw three large shooting stars.

September 19.—Observed three shooting stars.

September 20.—At 8*h*. p. m. I observed a brilliant shooting star, enveloped in a nebulous mist, and having a cylindrical cometic tail, 4° in length. It shot out brilliant jets or tufts of rays from its nucleus on its foremost side, which were bent back into the tail, presenting, in miniature, the phenomena of Halley's comet, so conspicuous to astronomers, during its last return in 1835. It passed between *α Andromedæ* and *β Pegasi*, towards *Fomalhaut*, describing 60° of the heavens in about 2 seconds' time. I also observed two other shooting stars on the same evening.

October 3, evening.—Saw two shooting stars.

November 14.—In the evening I saw four shooting stars.

1850—*August* 4.—At 8*h*. 30*m*. p. m. I observed a large meteoric star. Its path was marked by a trail of light nearly 15′ in width, which disappeared in about 4 seconds' time. Its path lay from *α Cygni* to near *ε Sagittarii*.

August 5.—At 9*h*. p. m. saw two shooting stars. The first appeared to be as bright and to subtend nearly the same angle as the planet *Jupiter*. It passed from *Unuk al Hay* in the *Serpent* to *Arcturus* in about three-fourths of a second. The other appeared like a mere line of light described by a brilliant point, and vanished in an instant.

August 7.—At 9*h*. 30*m*. p. m. saw a meteoric star, apparently to pass from near *δ Draconis* by *β* of that constellation to the foot of *Hercules*. It appeared to be a streak or trail of light about 8° in length, and, if my measurement of time can be trusted, it described an arc of 30° in less than a half second.

August 9.—In the evening saw four shooting stars.

August 10.—Between 8*h*. 30*m*. and 9*h*. 20*m*. p. m. I saw thirty-four shooting stars, some of which were very brilliant. All excepting four small ones appeared to pass down the *Via Lacte*, or near to and parallel with it, from the northeast to the southwest, some as follows: 8*h*. 30*m*., one passed from near *ε Cygni*, between *α* and *β Aquilæ*, to the *Milk Dipper* in *Sagittarius;* 8*h*. 35.*m*, two passed from *Eculeus* to the head of *Capricornus;* 8*h*. 40*m*., one passed from *η Ophiuchi* to

Scorpio; 8*h.* 48*m.*, one passed from *Scutum Sobieski* to γ *Sagittarii;* 8*h.* 58*m.*, observed two at the same instant, having their paths nearly parallel with each other, and about 8° apart. One passed to the east and the other to the west of the *Milk Dipper.* All of the foregoing seven meteors were accompanied by trails of light.

August 11 —Between 1*h.* and 2*h.* a. m., saw twenty-one shooting stars during ten minutes' observation. They passed down the *Milky Way* from *Cygnus* to *Scutum Sobieski.* A greater part of them were attended by trails of light.

September 1.—At about 9*h.* 10*m.* p. m., there was a brilliant meteor in the west, which approached the horizon rather slowly, describing in appearance a serpentine line. Its light was almost equal to that of the full moon, and its apparent diameter nearly 20′.

September 4.—Between 1*h.* and 4*h.* a. m., observed eight shooting stars. Some of them left brilliant trails.

September 22.—In the evening, saw two shooting stars fall in the SE.

September 30.—Between 8*h.* 5*m.* and 8*h.* 10*m.* p. m., saw two shooting stars fall to the southwest. Between 9*h.* 45*m.* and 10*h.* of the same evening, I saw three shooting stars pass near to the Milky Way and parallel with it.

October 7.—In the evening, saw three shooting stars.

October 9.—In the evening, saw four shooting stars.

October 30.—In the morning, saw a brilliant shooting star. Evening of same day, saw two shooting stars. One appeared to rise upwards from the earth. It was in the vicinity of the constellation Perseus.

November 1.—About 4*h.* a. m., observed two meteoric stars.

November 10.—8*h.* 30*m.* p. m., saw a meteoric star.

November 12.—6½*h.* p. m., saw a brilliant shooting star pass from near δ *Capricornus* to β *Draconis.* It left a conical trail of light, which remained visible but a little more than one second. Between 7*h.* and 8*h.*, saw a shooting star.

November 13 —At 6*h.* 30*m.* p. m., saw a meteoric star.

November 20.—In the evening, I saw a swiftly moving shooting star. I judged that it moved 20° of the sphere in ¼ second.

November 24.—7*h.* p. m., I saw a meteoric star.

December 1.—In the evening, saw two shooting stars.

December 30.—6*h.* 38*m.* p. m., saw a brilliant meteoric star.

1851—*January* 11.—Evening, saw a small shooting star.

January 24.—Evening, observed two shooting stars.

March 31.—I saw two shooting stars.

STILLWATER, MINNESOTA TERRITORY.

1851—*July* 19.—In evening, saw four shooting stars.

August 5.—In the evening, observed two shooting stars.

August 9.—In the evening, saw three shooting stars during fifteen minutes' observation.

August 10.—In the evening, saw nine shooting stars during one hour's observation.

August 20.—In the evening, saw four shooting stars during thirty minutes' observation.

August 21.—In the evening, saw three shooting stars during forty-five minutes' observation.

August 22.—In the evening, saw two shooting stars during fifteen minutes' observation. In the same evening I saw a shooting star apparently rise upwards. It was about three seconds in moving 45°, and made an angle with the horizon of about 30°.

August 26.—In the evening, saw five shooting stars during forty-five minutes' observation.

August 27.—In the evening, saw three shooting stars during thirty minutes' observation.

August 28.—In the evening, saw two shooting stars during sixty minutes' observation.

September 18.—In the evening, saw three shooting stars. One appeared to rise upwards more than 30° of the vertical.

September 23 —Saw a very brilliant shooting star.

September 24.—In the evening, saw two meteoric stars.

September 25.—In the evening, saw three shooting stars.

September 26.—In the evening, saw three shooting stars.

September 28.—In the evening, saw a meteoric star.

September 29.—In the evening, observed a brilliant shooting star.

SUMMARY RECAPITULATION.

Whole number of shooting stars recorded as observed previously to the beginning of the year 1852	173
Observed previous to the year 1850	16
Observed during the year 1850	100
Observed during the year 1851	57

During the last five months of 1850, I usually passed an hour or two in the open air on every clear evening, and noted down all of the shooting stars that I saw, the number in each month being as follows:

August	63
September	16
October	10
November	8
December	3
Total	100

During 1851, I not only passed much less time in making such observations, but likewise recorded only a part of the observations made. The following is the number recorded as seen in each of the months of that year:

January	3
February	0
March	2
April	0
May	0

June	0
July	4
August	34
September	14
October	0
November	0
December	0
Total	57

B.

AURORA BOREALIS AND OTHER METEORS.

WELD, FRANKLIN COUNTY, MAINE.

Remarkable Meteor.

1850—*September* 30.—At 9*h*. 30*m*. p. m. I saw a remarkably strange meteor in the southern sky. Its shape was that of an elliptical zone or ring, and when first seen its centre was about 5° east and the same distance north of *Fomalhaut*, or in R. A. 23*h*. 9*m*., and declination 25° 23′. Its longer axis lay in nearly an east and west direction. The length of its transverse axis was about 10°, and of its conjugate diameter 5°. Width of the bright belt or annular surface on the upper part of the ellipse 2°, on its lower part 1°. The northern part was very brilliant, but its southern part was dimmer. It moved slowly to the westward, and also had a *rotary* motion. At 9*h*. 45*m*. its centre was 4° north of *Fomalhaut* and on the same declination circle; being less brilliant than when first observed, but of the first noticed figure.

At 10*h*. its centre was in about R. A. 22*h*. 25*m*., and declination 27° 23′. Its length was then nearly 15°, and width 3°. It was scarcely perceptible. It disappeared at 10*h*. 10*m*.

STILLWATER, MINNESOTA TERRITORY.

First Class Aurora.

1851—*September* 29.—In the evening there was a remarkable exhibition of the *Aurora Borealis*. Soon after dark I observed a small and brilliantly white *arch*, having its point of culmination, which was about 10° above the horizon, very nearly, if not precisely, in the magnetic meridian, in the north. (The magnetic needle has a variation at this place of about 9¼° east, epoch 1850.) Soon after this, deep red *streamers* were shot upward from the arch, 10 or 15 degrees apart, along its whole length, which converged to a focus, as it were, in the south magnetic pole of the dipping needle. One of these, which stretched like a broad band along the magnetic meridian, was of a deep crimson or almost blood color. After a short pause the northern arch began to rise slowly towards the zenith, where it was apparently dispersed. On the disappearance of the first arch in the zenith a second arch began to form, and was soon completed, in the south, just as if it was the reuniting of the first arch after passing the zenith; also concentric with the magnetic meridian, and having an altitude of 30° above the southern horizon. The extremities of this southern arch reached nearly 40° on each side of the magnetic meridian. Beneath this arch, which was about 5° in breadth, was an intensely black arch concentric with the white one. Just as the southern arch was formed, two deeply red belts, springing from the horizon at the points formerly occupied by the extremities of the northern arch, stretched themselves through the zenith, crossing each other at that point, and ran down nearly to the southern arch. These soon vanished, when a black segment of a circle was formed in the magnetic north, having its edge fringed with a silvery white. During this the southern arch had remained nearly unchangeable. Presently, alternately red and white streamers darted up from the horizon, or near to it, all around the concave, varying in width from 1° to 3° or 4° and converging towards the zenith, the southern arch still remaining as before. On the ceasing of this phenomenon the southern arch became serpentine in its course.

About two hours after this, that is about 11 o'clock, the aurora, arriving at its maximum, presented a most beautiful spectacle. The whole northern sky, from the east to the west, became thickly beset with a multitude of stud like streamers, in the north coming to within only about 15° of the horizon, but at the east and west meeting the horizon along an azimuth of nearly 30°, which all converged into a beautiful *corona* about the pole of the dipping needle. These streamers seemed all to have a sort of tremulous or wave-like motion from one side to the other in rapid succession. Shortly afterwards the corona sent out streamers down the southern sky, thus completing the auroral illumination of the whole visible concave. Just at this time there was another arch formed, in the north, that is to say in the magnetic north, stretching about 60° along the horizon, with an altitude at the culminating point of 40°, and composed of brilliant white columns diverging from the north point of the compass, shaded with black beneath. In a few minutes this arch mingled itself with the columns, converging to the pole of the dipping needle; then there followed a succession of auroral waves, passing over the whole sky, not unlike the electric flashes sometimes observed in thunder clouds. The southern arch maintained its position nearly three hours, disappearing, however, during the occurrence of the last named phenomenon. During the above auroral display the sky was clear from clouds; for as brilliant as the auroras were the brighter stars could be plainly seen through them, even where they were intensely black. The aurora continued more or less brilliant during the remainder of the night. This auroral display was characterized by all the more conspicuous phenomena of the higher classes, such as arches, streamers, a corona, and auroral waves, the corona and waves being remarkably developed. The southern arch, however, was perhaps the most remarkable phenomenon of the exhibition.

Second Class Aurora Borealis.

December 23.—In the evening there was an auroral exhibition. A dark arch was formed in the north, having an altitude at its culminating point of 15°, and its centre of curvature lying in the magnetic meridian. Numberless streamers shot upward from the arch to an elevation of 45°. The aurora was visible about one hour. The brilliancy of the streamers would place this exhibition in the *second* class aurora.

Lunar Halo.

December 27.—In the evening I saw a beautiful halo around the moon. The interior diameter of the ring was about 3°, and its exterior diameter was fully 7°. The inner edge of the ring was of a deep crimson color, and its exterior a brilliant blue; while it had an intermediate annulus of yellow, bordering on an orange color. The width of the red ring was $\frac{3}{4}$°, that of the blue $\frac{3}{4}$°, and that of the yellow $\frac{1}{2}$°. The phenomenon was seen only about three or four minutes.

Auroras of the Third and Fourth Classes.

1852—*January* 23.—In the evening saw a fourth class aurora borealis.

January 24.—In the evening I observed the aurora borealis, but the exhibition was of little importance, being of the lowest class.

February 7.—In the evening saw aurora borealis.

February 18.—In the evening there occurred quite a brilliant exhibition of the aurora borealis, with finely developed streamers. I saw a very curious auroral meteor in the constellation *Virgo*. Its shape was that of the head of a huge spear. Its foremost point was in the vicinity of *Spica*, and the two anterior points were situated, the one near γ, and the other near η of that constellation. It remained visible only a few minutes.

February 19.—In the evening observed a slight auroral corruscation.

Parhelia.

February 26.—In the morning I observed two brilliant parhelia, one on each side of the sun. The sun's altitude at the time was nearly 15°, and the mock suns were distant about 30° on each side of the real sun. On their inner, or sides next the sun, their light was of dazzling brightness, and their outer sides were tinged with the prismatic hues.

Minor auroras.

March 9.—In the evening the sky was clear and serene. I saw an auroral arch in the north, having its centre coinciding with the magnetic meridian.

March 12.—In the evening, saw the aurora borealis.

March 17.—In the evening, saw a fourth class aurora borealis.

Parhelia.

March 17.—Soon after sunrise I observed two parhelia, one on each side of the sun, which remained visible at least two hours.

March 19.—After sunrise I saw a parhelion.

WELD, FRANKLIN COUNTY, MAINE.

Aurora borealis.

November 10.—In the evening I saw an auroral display, consisting of a number of short streamers beset around the magnetic north. While gazing on these I beheld a meteor resembling an electric spark, which suddenly emerged from a brilliant streamer that lay in the magnetic meridian, and vanished in a moment. It appeared to have a lateral and downward movement of about 2°. Color of streamers yellowish white.

November 11.—In the evening I observed an auroral exhibition, which was much more brilliant than that of the 10th instant. The streamers reached a height of 45°, being intensely bright, and of a yellowish white color.

Solar halo.

1853—*May* 27.—When the sun had descended about a semi-diameter of its lower limb, below the horizon in the west, I saw the following semi-circle of a solar halo. The interior diameter of the circular halo was about 8°, and its exterior diameter 18°. Its interior was crimson colored, and the several prismatic hues were depicted outward in succession. It was very brilliant, and a beautiful object for contemplation.

Aurora borealis.

June 2.—In the evening, saw an auroral exhibition. The streamers were quite brilliant, long, and slender.

June 27.—At a little past 9*h.* in the evening I saw a fine aurora. It was in the form of a great arch, about 140° in length, and from 2° to 3° in breadth. The arch on the east approached within 3° of *Altair;* on or near the meridian it passed through *Corona Borealis;* and its western extremity was near ζ *Leonis.* It was very brilliant; and I observed a number of oscillations or waves pass along its meridian portion longitudinally. These waves were slow in progress, and somewhat gyratory in appearance. Only a faint illumination was observed in the north.

Rainbow.

July 12.—When the sun had been hidden nearly fifteen minutes by the western hills, and was just on the point of passing below the plane of the horizon, I saw a beautiful rainbow. The bow was entire, and of splendid prismatic hues. Fragments of a secondary bow were seen. The bow in a few minutes showed a great preponderance of red rays, and did not disappear until the moment of sunset.

Aurora borealis.

September 2.—In the evening, observed an auroral exhibition. At first, a dark segment of a circle appeared in the magnetic north, about 10° in altitude at its culminating point. This was soon beset around its exterior with brilliant rays of a yellowish white. These rays extending out laterally shortly formed a serpentine arch, still with the black beneath. Then a few streamers shot upwards towards the zenith. Shortly afterwards these phenomena died away, and the northern sky remained quite luminous, with here and there patches of *cirrus* in filmentous wisps. I saw several small stars through the dark auroral vapor first observed.

1854—*March* 26.—In the evening observed brilliant aurora borealis. Saw a fine auroral arch, having an altitude from the northern horizon of above 45°, and reaching from the eastern to the western horizon. Width of arch about 10°. I saw many minor exhibitions of the aurora borealis during the winter of 1853–'54.

March 29.—In the evening I observed a beautiful auroral meteor. It resembled the tail of a huge comet, proceeding from a nucleus about 10° north of *Spica Virginis.* It lay along below *Leo Major*, branching out into two bright streams, with a fainter dawn between, the northern branch reaching *α Canis Minoris*, and the southern terminating a few degrees north of *Canis Major.* The above was its appearance at 8*h.* 15*m.* It was very brilliant, and remained visible for sometime.

May 16.—In the evening saw a fine auroral arch, having an altitude of 70° in the north. It was composed of a great number of short transverse streamers 2° or 3° apart.

Rapid oscillations in refraction.

September 4.—In the evening I observed rapid vertical oscillations in the lunar orb, when crossed horizontally by thin *cirrus* bands; the latter projected in perspective on the lunar disk, reminding one of the belts of Jupiter. She appeared to rise and fall rapidly in the vertical through about $\frac{1}{4}°$ arc: corresponding fluctuations being observed in the shadows of objects in her light. A number of other persons observed the phenomenon, which lasted about ten minutes.

The altitude of the moon was about 15° ; and the *cirrus* bands crossing her disk remained apparently unchangeable and motionless. A storm of rain followed before the next morning.

C.

THE ZODIACAL LIGHT.

WELD, FRANKLIN COUNTY, MAINE.

1853—*January* 31.—On this, as well as several preceding evenings, I have observed a pyramidal column of whitish light, after the ceasing of twilight, extending along the ecliptic from the western horizon to an altitude of 40° or more, which must be the conical body of the *zodiacal light.*

1854—*February* 21.—Between 8*h.* and 9*h.* in the evening I observed the zodiacal light. Its base at the horizon was above 18° in width, and the altitude of its vertex about 35°.

1855—*January* 14.—After the ceasing of twilight I saw the cone of zodiacal light. It was very brilliant, as much so as that part of the *milky way* visible at that season. Its vertex was above 90° from the sun; in fact, a faint illumination seemed to extend almost to the eastern horizon. Its width at its base was more than 20°. It was observed on several other evenings of the winter.

1856—*February* 2.—In the evening observed the zodiacal light; it having been seen on several evenings during the preceding month. It uniformly reaches about 90° from the sun, having an apparent width at the horizon of 40°. Sometimes a faint reflection is observed in the east.

1856—*February* 8.—After the ceasing of twilight in the evening observed the zodiacal light. Apparent width at the horizon 40°, length 10° from the sun.

1856—*March.*—I saw the pyramidal column of zodiacal light on every evening, in absence of the moon, during this month. It appears at the horizon of a width varying from 10° to 40°, and an apparent length of from 30° to 90°, and even upwards.

1857—*January.*—During this month I have frequently observed the zodiacal light. Its vertex is generally not less than 90° from the sun. On some very clear evenings a faint illumination may be traced to the distance of 170° or 180° from the sun, being visible a greater part of the night. Its width at the horizon sometimes reaches 40°. Its axis appears to lie a little above the ecliptic, or to have a small north latitude; the amount of which is difficult of determination.

REPORT

OF

RECENT PROGRESS IN PHYSICS.

BY DR. JOH. MULLER,
PROFESSOR OF PHYSICS AND TECHNOLOGY IN THE UNIVERSITY OF FREIBURG.

[Translated from the German for the Smithsonian Institution.]

In revising this translation, originally made by different persons, it has been the constant aim to give as nearly and as literally as possible the exact language of the author. But one exception has been made to this rule. In the case of the citation of English philosophers reference has been made to the original memoirs, and their own language adopted, instead of that of the report, wherever it was evident that the intention had been to give the equivalent German to their English. It is due to the author, however, to state that this change has been at most but a verbal one, not material to the sense. The notice is, however, deemed necessary, because this is the only departure, save in one or two unimportant cases, from the strict rendering of the language of the text.

GEORGE C. SCHAEFFER.

SECTION THIRD.

THE LEYDEN JAR AND EFFECTS OF THE DISCHARGE.

[Continued from page 456, of the Report of 1856.]

THE SECONDARY CURRENT.

§ 56. *Nature of the secondary current.*—When a battery is discharged by a long metallic wire the current in the conducting circuit wire induces a current in an adjoining closed wire conductor.

The wire which forms the conducting circuit of the battery is known as the *main wire.*

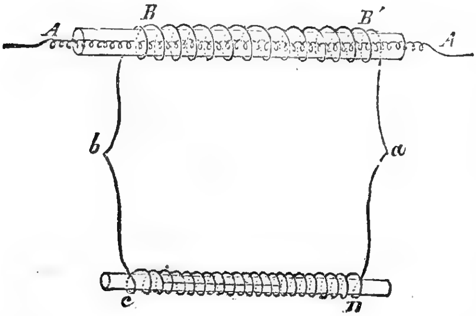
The wire in which a current is induced by the action of the current in the main wire is termed the *secondary wire.*

[The existence of the secondary current was demonstrated in a series of experiments by Professor Joseph Henry in 1838, published in the ,Transactions of the American Philosophical Society," vol. 6, p. 40, in 1839, a publication apparently unknown to our author.

The experiments of Riess and of Henry were therefore nearly simultaneous, as were the subsequent announcements. The article mentioned anticipates, however, much that is discussed in the following sections of this report, founded on later publications of Riess and others. Thus experiments upon screening effects, upon secondary conductors at different distances, and upon the difference in magnetism, were recited. The latter of these, in connexion with the matter in § 70, throw additional light upon the apparently abnormal development of magnetism. But the whole set of experiments, and the deductions from them, were given as a sequel to similar investigations upon secondary currents with galvanic electricity; severed from this connexion much of their value would be lost, and to reproduce the whole, together with later researches in the same line, would take up more space than can be spared in the present volume G. C. S.]

Riess proved the existence of the secondary current in the following manner; (Pog. Ann., XLVII, 55.)

Fig. 59.



Let A A, in fig. 59, be a copper wire wound spirally about a glass tube and introduced into the conducting circuit of a battery; A A consequently is the main wire. A wider glass tube is passed over the main wire, and upon it the secondary wire B B is wound, leaving its ends hanging free. The ends of a third spiral C D, also wound upon a glass tube, are to be fastened at *a* and *b*.

The connection at *b* being severed, and the ends of the wire separated a little, a spark is seen to pass at *b* when the battery, with a sufficiently strong charge, is discharged through the main wire.

This spark is a proof of the existence of the secondary current. A passage of electricity from the main to the secondary wire cannot take place if the secondary spiral be kept at a sufficient distance from the ends of the glass tube on which it is wound.

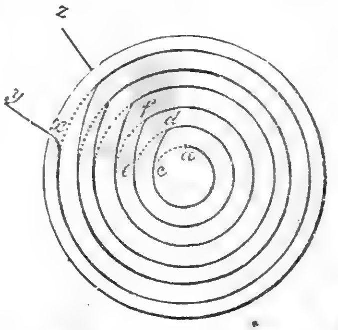
A steel sewing needle placed in the glass tube of the spiral C D, which we will call the *magnetizing spiral*, will be magnetized by the secondary current.

An electrical air thermometer inserted in the secondary circuit indicates heat produced by the secondary current.

Figure 59 represents the form in which Riess first arranged his experiments. Afterwards (Pogg. Ann., L, 9) he gave the spiral a more convenient form.

In a disk of wood, consisting of three pieces glued together, the diameter of which depends upon the size of the spiral to be formed, concentric grooves are to be cut and made into a spiral, by joining each circle with the following one by a curved groove; the innermost circle is joined to the second by the groove *c d*, (figure 60,) the second to the third by *e f*, &c. In these grooves a copper wire about half a line thick is so laid as to make a spiral. One end of the wire passes through the disk at *a*, and along the under side to *z*. From *a* the wire coils out to *c*, from *c* to *d*, from *d* to *e*, *f*, &c.; *x y* is the other end of the wire thus wound in a flat spiral.

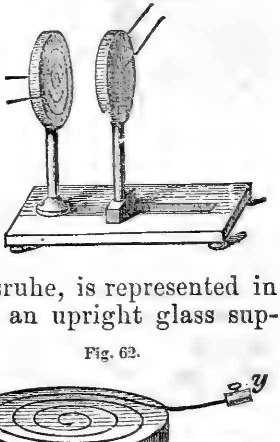
Fig. 60.



The disk is covered with a thin coat of pitch before placing the wire upon it.

The wire being fastened by the superposition of a hot metallic plate, the spaces between the rings of wire will be filled up with the pitch; a heavy heated plate laid on the disk will make the spiral perfectly level. This spiral is now blacked with coal and pressed upon another wooden disk to get the marks for a second spiral, which must correspond with the first as nearly as possible

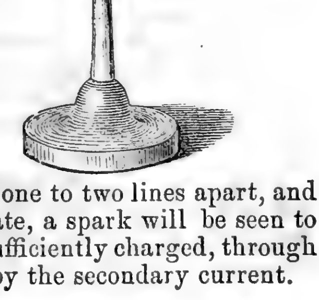
Fig. 61.



The disks are now fastened to glass supports, their planes being vertical. They are arranged upon the same stand opposite each other, and so that they can be approached and separated at pleasure. This arrangement is represented in figure 61.

Another arrangement of the flat spiral, much more convenient for many purposes, shown to me by Professor Eisenlohr, of Carlsruhe, is represented in figure 62. One of the spirals is fastened on an upright glass support in a horizontal position. The second spiral is fastened in the same manner on a glass rod, which has no foot; it is placed over the other, like the upper, over the lower condenser plate.

Fig. 62.



The distance between the spirals can be changed by placing glass plates of different thicknesses between them. For greater distances pieces of varnished wood having any desired thickness are interposed.

The ends of the wires are provided with screw clamps *z* and *y*, by means of which the spiral can be connected as may be desired.

Placing *y* and *z* of the lower spiral from one to two lines apart, and separating the two spirals by a glass plate, a spark will be seen to pass between *y* and *z* on discharging a jar, sufficiently charged, through the upper spiral. The spark is produced by the secondary current.

§ 57. *Magnetizing by the main current.*—To avoid false conclusions in regard to magnetizing by the secondary current, magnetizing by the main current should first be properly investigated.

Such an investigation was first made by Savary. Riess repeated Savary's experiments and obtained similar results. The following are Riess' results.—(Pog. Ann. XLVII, 55.)

In the conducting circuit of the battery, consisting of 25 jars with 1½ square foot coating each, a spiral of platinum wire was placed; 26 inches of this spiral were wound in 42 coils on a glass tube 3 inches long. The ends of the wire not wound up were, together, 34 inches long.

In each experiment a new non-magnetic English sewing needle, 13.9 lines long and 0.19 lines thick in the middle, was laid in the spiral. After the discharge stroke had passed through the spiral the needle was magnetized. To test the strength of the magnetism it was brought to a certain distance from a compass needle two inches long, (in what manner this was done cannot be easily understood from Riess' description,) and the deflection produced in the latter observed.

By increasing the charge of the battery, not only the strength but the polarity of the magnetism of the needle changed, as the following table shows:

Quantity,	5	10	15	20	25	27	29	30	32	35
Deflection,	9°	14.5	15	10.3	6.5	—2.5	—7.5	—8.5	2.3	11.5

It is seen that a stronger charge of the battery was not necessarily followed by a stronger magnetism; also, that the magnetism thus caused was not always such as might have been expected, according to Ampère's rule, (namely, that if we suppose the figure of a man to be introduced into the circuit, the positive current entering at the feet and passing out at the head, the figure, when it faces the needle, will have the north pole on its left hand,) for an abnormal magnetizing of the needle took place in all the deflections marked with the — sign.

In this series the strength of the magnetism of the needle at first increased with the magnitude of the charge, then decreased until the direction of the magnetism was reversed, and it was only after still more powerful charges that the normal magnetism appeared again.

These experiments are a proof that the direction of the discharge current cannot be deduced from the polarity of the needle.

With weaker charges the needle was normally magnetized; abnormal magnetism appeared with increased charges in fine needles only; coarse needles are always magnetized normally, although constantly increased charges produce in them an alternate decrease and increase of strength of the magnetism.

§ 58. *Magnetizing by the secondary current.*—This peculiarity in the magnetism of steel needles occurs in like manner in the secondary current. Magnetism produced by a secondary current will change in strength and direction:

1. By increasing the charge.
2. By increasing the surface of the battery, the charge remaining the same. The greater the surface, the stronger Riess found the magnetism of the needle; the same quantity of electricity being distributed

over a greater surface, it has a less density, and consequently a slower discharge, which is favorable to the production of magnetism.

3. The order of the periods of decrease and increase, as well as that of the reversal of the magnetism, will be changed by an alteration in the secondary circuit, such as introducing wires of constantly increasing length.

If the secondary circuit remains metallic as before, but interrupted at one place, so that the current has to pass with a spark, a very remarkable influence is observed on the magnetic effect; often the magnetism is in this way increased very greatly, sometimes it is weakened, and again it is changed in direction. The strongest magnetization by the secondary current, amounting nearly to saturation of the needle, has been obtained in this manner.

4. A continued change in the strength, as well as a change in the direction of the magnetism produced by the secondary spiral, takes place when, *cæteris paribus*, the length of the conducting circuit of the main spiral is continually increased.

The apparatus shown in figure 62 may be very conveniently used in these experiments. The lower spiral may be taken for the secondary circuit, and the magnetizing coil may be introduced between *x* and *y* by screwing its ends in the clamps.

§ 59. *Production of heat by the secondary current.*—It has already been mentioned that the secondary current produces thermal phenomena; Riess has also investigated thoroughly the laws of the development of heat by the lateral current.—(Pog. Ann., XLVII, 65.)

In the conducting circuit of the secondary spiral, a magnetic spiral and an electrical air thermometer were introduced. The following table contains the thermal and magnetic effects which the secondary current produces when the surface and charge of the battery are changed. *S* and *q* have the same signification as before.

S.	*Q.*	Heating.		Magnetism.
		Observed.	Computed.	
5	15	3.8	3.4	
	20	6.2	6.0	
	25	9.0	9.4	
	30	12.0	13.5	○
10	20	3.4	3.0	0.5
	30	7.0	6.8	1.5
15	30	4.	4.5	1.5
20	30	3.5	3.4	4.0
25	30	2.5	2.7	2.3
	40	4.4	4.8	—0.6
5	20*	6.2		8.8
	25*	8.3		2.0
	30*	9.8		—3.6

In the last column the deflections of the compass needle produced by the magnetized needle are indicated as explained above. Where no deviation is indicated the magnetism was not perceptible.

As far as the last three observations, indicated by *, the observed temperatures harmonize very well with the formula

$$h = a\frac{q^2}{s}.$$

From all the observations (the tables given by Riess contain a few more) the mean result for a was 0.075; the temperatures computed with this co-efficient in the above formula accord perfectly well with the observed values. Hence the formula holds good for the temperatures produced by the secondary current.

In the observations indicated by * the secondary circuit was interrupted, so that the current had to pass with a spark. This has a very important influence (above mentioned) upon the magnetization. It is shown here, while the heating power is scarcely affected—it being a little diminished.

When a German silver wire, 78 lines long and half a line thick, was inserted in the main circuit the heating was less; the co-efficient a, which was found above equal to 0.075, was now 0.028.

As may be readily conceived, the quantity of electricity in the secondary current is greater in proportion as the portion of the main spiral acting upon the lateral spiral is greater, other circumstances being equal. In order to determine the amount of increase of the secondary current thus produced, the secondary coil B B, (fig. 59,) closed by the platinum wire of the thermometer, was slipped over the straight prolongation of A A, and the temperature noted which was produced in the secondary wire by the discharge of $q = 20$ in $s = 5$. Then, in successive experiments, a different number of coils of the main spiral was brought under the secondary spiral, and the same quantity of electricity discharged in the same manner. These experiments gave the following results:

Length of straight wire.	No. of coils.	Heating in the lateral wire.
Lines.		
134	0	1.85
102	24	4.9
63.4	53	7.6
24.8	82	11.5
0	101	14.0

The numbers of the last column are the mean of two series of experiments, giving nearly the same results.

Since we know what elevation of temperature (1.85) is produced in the secondary wire by the action of a straight piece of the main wire 134 lines long, we can compute the heat produced by the action of a straight piece of the main wire 102, 634, &c., lines long, and thus we are able to determine how much heat is produced by the action of 24, 53, 82, 101 coils of the main wire. This gives—

With 24 coils	3.5
53 "	6.7
82 "	11.2
101 "	14.0

Thus the heat produced is very nearly proportional to the number of acting coils of the main wire; hence it follows that *the quantity of electricity generated by the conducting circuit of the battery in a secondary wire is proportional to the length of the acting part of the circuit wire, other circumstances being equal.*

If over the same main spiral A A the same lateral spiral be wound, first with its coils parallel to those of the main spiral, and then with more open coils, so that the main spiral acts always in the direction of its entire length, but at first upon a long part of the lateral wire running parallel with it, and then on a shorter and more open part; in the latter case the action evidently is as much less as the direction of the coils in the spirals differs, or the closer the lateral spiral is in comparison with the main spiral.

All the coils used for these experiments were wound to the right. It is not a matter of indifference, as far as regards the strength of the secondary current, whether the lateral spiral is wound in the same or the opposite direction to that of the main spiral. Upon a main spiral wound to the right, eight inches of copper wire were wound first to the right, then to the left, with the result:

	Heat.
Secondary spiral to the right	15.4
" " to the left	2.7

§ 60. *Action of the main wire on different secondary wires.*—A piece, (*a b*,) 26 inches long, of the same wire which formed the main wire was stretched out straight; parallel with it a piece (*c d*) of the lateral wire was stretched. The whole secondary circuit, in which the electrical thermometer was inserted, consisted of copper and iron wire. The piece *c d* of the secondary circuit, lying opposite *a b*, being a part of the iron or of the copper wire which forms the lateral circuit, with equal charges of the battery the temperature of the thermometer is the same, provided the iron and copper wire have the same diameter and the space between *a b* and *c d* is the same.

Therefore, if the resistance to conduction of the whole secondary circuit remains unchanged, it is perfectly indifferent for the strength of the secondary current whether a better or worse conducting piece of wire is exposed to the action of the main wire.

It is impossible for me to understand clearly the arrangement of the experiments relating to this matter from the description given.—(Pog. Ann., L, 3.)

§ 61. *Decrease of the secondary current in proportion to the distance from the main wire.*—To find how the action on the secondary wire decreases with the distance from the main wire, the piece running parallel must have a great length, because otherwise, at tolerably great distances, the heating of the lateral wire will be too little to be observed.

Riess stretched two copper wires 10 feet 6 inches long parallel to each other, (Pog. Ann., L, 7.) One of them was connected by means of copper wires 6 feet long with the circuit of the battery; the ends of the other were connected by similar wires with the platinum wire of the thermometer. By changing the distance between the axes of the parallel wires the thermometer showed *that the current generated by the straight part of the conducting circuit of the battery in the parallel wire decreases in the proportion in which the distance of the axis of the wires increases*, provided the distance of the wires at the start is not too small; for if the wires approach within a certain limit the heat produced increases in a less proportion than the distances decrease.

To obtain somewhat elevated temperatures by the secondary current, wires of great length must be used, and the management of these is very troublesome when they have to be stretched straight. Hence, when only the generation of an intense secondary current is desired, it is greatly preferable to wind the wires in a flat spiral, as already described, (144.)

The current which is excited by the main spiral in the secondary, is weaker the further the spirals are apart; but it is easily seen that between the strength of the current and the distance between the spirals there cannot be a simple proportion, for any one part of the circuit of the main spiral excites a current, not only in the curved part lying nearest to it and on the same side, but also in the more remote part of the curve, on the opposite side; the latter is indeed weaker, but it acts against the former and diminishes its effect. But the proportion of the two opposite currents evidently changes when the distance of the spirals is changed. If the starting point is from very small distances of the two spirals the strength of the secondary current at first increases more slowly, but at a greater distance far more rapidly than the increase of the distance of the spirals.

§ 62. *Action of adjoining closed conductors on the generation of the secondary current.*—Riess extended on the floor of a room three copper wires, 0.55 line thick and 10 ft. 6 in. long, parallel to each other, (Pog Ann., L, 12,) these wires being denoted respectively by A, B, and C. The axial distance between A and B was 4.45 lines, that of B and C 2.35 lines.

The wire A was inserted in the conducting circuit of a battery; from the ends of the wire C copper wires six feet long led to the thermometer, and consequently the secondary wire C included the thermometer in its circuit. When B was removed the unit of charge gave a temperature indication of 0.135; B being restored to its place nearly the same temperature was indicated; but when the ends of B were joined by a copper wire 14 feet long only 0.094 was the temperature indicated. Hence it follows that—

The current generated in a secondary wire by the conducting wire of a battery remains unchanged when a wire with free ends lies between the two wires; but the current is diminished if the intermediate wire is closed upon itself.

It is not essential that the wire B should lie between A and C in rder to weaken the current in C, which is generated by the discharge urrent traversing A. B may lie beyond C or beyond A; the lateral urrent excited in C by the main current of A will be always weaker when B is closed, or when a secondary current exists in B, than when his is not the case. Hence, *the main wire of a battery having generated lectrical currents in two secondary wires near each other, each of the two econdary currents is weaker than it would have been were the other not present.*

Two flat spirals, six inches in diameter, each formed of copper wire 13 feet long and 0.55 lines thick, were placed 10 lines apart. The hermometer of the secondary spiral indicated a considerable heat (42 division of the scale) when the quantity of electricity (20) accumulated n four jars was discharged through the main spiral. But when, under otherwise equal circumstances, the same quantity of electricity was discharged, while a copper disk 6 inches 10 lines in diameter and 0.33 lines thick was interposed between the spirals, the thermometer of the secondary spiral showed no sensible heat.

This remarkable effect of the copper plate evidently depends upon he good conduction which it offers to the current.

The interposed plate should be a poor conductor to allow a sensible heat to be developed in the secondary spiral. In proportion as the capacity for conduction in the interposed plate decreases the current in the secondary spiral increases.

Interposing plates were used successively as follows: 1. A sheet of in foil 0.01 line thick. 2. One of 0.0168 line thick. 3. Both together. 4. A sheet of imitation silver paper. These sheets were clamped between glass plates and placed one line distant from the main spiral. When the two spirals were two and a half lines apart the following temperatures were obtained in the secondary spiral for the unit of charge:

Without interposed plate	0.56
Interposed plate of imitation silver paper	0.57
" " thin tin foil	0.087
" " thick "	0.056
" " both sheets tin foil	0.034

Comparing the last three indications with the corresponding thicknesses of the interposed sheets of tin foil, we find that *the strength of the current in the secondary wire is inversely proportional to the thickness of the interposed metallic plate.*

The same result was obtained by repeating the experiments in the same manner but at greater distances.

§ 63. *Action of interposed insulating plates upon the formation of the secondary current.*—Faraday has ascribed a specific inductive capacity to the different insulators in relation to statical electricity, so that through a glass or shellac plate induction should be much stronger than through air.

The origin of the secondary current can only be satisfactorily explained by the generation of electricity by induction; and, in his view, we should expect currents of different strengths, if plates of different insulating substances were interposed between the main and secondary spirals.

If solid insulators possess a greater specific inductive capacity than air a well marked distinction should be made by means of the secondary current between solid conductors and insulators of electricity. Thus, while conductors, used as interposed plates, diminish the secondary current obtained through the medium of the air, insulators, applied as interposed plates, should increase the current.

In spite of careful investigation Riess was unable to find such an increase of the secondary current by the interposition of insulating plates, such as glass, shellac, &c. The use of these plates changes in no respect the force of the secondary current, which was found just as great as though air only had been between the spirals.—(Pog. Ann., L, 18.)

§ 64. *Action of the conducting wire of a battery upon itself.*—We have seen that no electrical current can be generated by induction in a wire with free ends. The conducting wire of an electrical battery is such a wire, but since its free ends pass into broad metallic surfaces, allowing the accumulation of opposite electricities, it is necessary to examine experimentally whether one part of the wire may not have an inductive action on another part.

Riess sought to solve this question in the following manner: (Pog. Ann., L, 19.)

The two spirals, one of which had served hitherto as the main, the other as the secondary spiral, were placed at a short distance apart, and joined so as to form a single conducting wire, so that, on being introduced into the circuit of the battery, the discharge current had to pass through both.

In one case the outer end of one of the spirals was united with the central end of the other in such a way that when the discharge current in the one spiral passed from the middle to the outside, it had to pass from the middle to the outside in the other also; and, consequently, the discharge traversed the two spirals in the same direction.

The outer end of one spiral was then joined to the outer end of the other, so that the current which traversed the one from the middle to the outside went from the outside to the middle in the other; the discharge thus traversing the two spirals in opposite directions.

Now, if one part of the conducting circuit can act upon another, each spiral in the first case must cause in the other a current in the same direction as the main current, but in the last mode of connecting the spirals a current opposed to the main current; and hence, in the last case the force of the current, *cœteris paribus*, should be weaker than in the first.

The thermometer being introduced into the circuit along with the combined spirals, it indicated, under like circumstances, perfectly equal temperature, in whichever manner the spirals were united; hence it follows, *that in the discharge of a battery no part of the conducting wire acts inductively upon another part.*

§ 65. *Retardation of the electrical discharge by conductors near the conducting wire of a battery.*—Riess introduced into the conducting circuit of a battery (Pog. Ann., XLIX, 393) a copper wire 13 feet long and 0.55 line thick, which was coiled in a flat spiral on a wooden disk six inches in diameter, covered with pitch and supported by a glass leg, as represented by fig. 61. A series of experiments, made with the circuit thus arranged, gave—

$$h = 0.43 \frac{q^2}{s}.$$

A copper plate 6 inches 10 lines in diameter and 0.33 line thick was placed parallel to the main spiral, at a distance of $2\frac{1}{2}$ lines. It gave—

$$h = 0.41 \frac{q^2}{s}.$$

Then a secondary spiral exactly like the main spiral was placed parallel to it, the ends being in perfect metallic contact. This arrangement gave—

$$h = 0.42 \frac{q^2}{s}.$$

Hence, neither the copper disk nor the secondary spiral had a sensible influence on the temperature of the conducting circuit. Instead of the perfect metallic closure, a less perfect closure of the secondary spiral was made; that is, the ends of the copper wire were connected by a platinum wire 138 lines long and 0.023 in. radius. The secondary spiral thus closed being placed 5 lines distant from the main spiral the result was—

$$h = 0.32 \frac{q^2}{s};$$

when placed at the distance of only $2\frac{1}{2}$ lines from the main spiral the result was—

$$h = 0.27 \frac{q^2}{s}.$$

The secondary spiral, closed by a German silver wire 460 lines long and one-twelfth line diameter, and placed $2\frac{1}{2}$ lines from the main spiral, gave—

$$h = 0.17 \frac{q^2}{s}.$$

The secondary spiral, closed by a glass tube filled with water 9 inches long, gave—

$$h = 0.39 \frac{q^2}{s}.$$

We will now subject these results to a somewhat closer examination. The current in the conducting circuit, as seen above, generates a current both in the copper plate and in the secondary spiral, but the current in the secondary spiral cannot induce a current in the main spiral, because the latter is not closed by metal, the two coatings of the jars being separated by glass. The only possible influence of the current in the secondary spiral upon that in the main spiral is some retardation of the discharge.

Now, if the closure of the secondary spiral is more perfect than that of the main spiral, the current of the former will pass more rapidly than that of the latter, and on that account no reaction of the secondary spiral can take place upon the main spiral; hence, with a more perfect closure of the secondary spiral, the temperature in the conducting circuit is found very little less than when no secondary spiral is present.

With an imperfect metallic closure of the secondary spiral the secondary current has a longer duration, and then the discharge current in the main wire finds, during its whole course, the secondary wire traversed by a current passing in the same direction, and we must assume that this is the cause of the retardation of the main current, which is indicated by the diminished temperature; by imperfect closure of the secondary spiral the temperature in the main current was reduced in the proportion of 0.43 to 0.17.

By inserting a tube of water into the secondary spiral the temperature again increases almost as much as though no secondary spiral had been present, which is well explained by the fact that, with very imperfect closure of the spiral, no sensible secondary current is generated.

The circumstance that, with quite perfect as well as with very imperfect closure of the secondary spiral, the influence on the main wire is less than for a moderately good closure, leads us to expect that, when the secondary spiral is closed by constantly increasing lengths of thin wire, at first the temperature of the main circuit will decrease, that, with a given length of the introduced wire, the influence of the secondary spiral will become a maximum, and then decrease again, and that, therefore, the elevation of temperature of the conducting circuit of the main spiral will again increase when the wire by which the secondary spiral is closed is lengthened.

This was verified by experiments which Riess made.—(Pog. Ann., LI, 177.)

Representing by 100 the temperature observed in the thermometre introduced in the conducting circuit of the main spiral, the secondary spiral being closed by a short thick copper wire, the results given by the insertion of a German silver wire 0.1517 line diameter and of different lengths, are as follows:

Length of wire.	Temperature.
4.8 feet.	70
9.8 "	55
19.7 "	52
29.6 "	48
39.4 "	52
88.7 "	61
138. "	66
286. "	76
582. "	87
Open.	100

It is seen from this table how very rapidly at first the temperature of the circuit of the main spiral decreases with increasing length of German silver wire inserted in the circuit of the secondary spiral, and that a minimum is reached when the length of the introduced wire is 29.6 Paris feet, in which case the heating effect is only 48 per cent. of that which is observed with perfect closure of the secondary spiral. When the length of the wire exceeds 29.6 feet the temperature gradually increases again; and by lengthening the wire to 582 feet the temperature rises to 87 per cent. of that originally obtained.

A metallic closed circuit near the conducting wire of an electrical battery acts retardingly on the discharge of the battery in proportion to he length of its closing wire. The circuit of the secondary wire being progressively prolonged its action successively increases, attains a maximum, and then decreases.

The changes which the temperature in the main wire undergoes by engthening the secondary wire, obey the law indicated by the last able, whether the charge of the battery be stronger or weaker; with stronger charges, as well as with weaker, the retarding effect of the secondary wire attains a maximum when the secondary spiral is closed by 29.6 feet of the above-mentioned German silver wire; and then the temperature in the main wire is 48 per cent. of that which would have been observed with an equal charge if the secondary spiral had a perfect metallic closure; but as soon as the conducting circuit of the main wire is lengthened by the introduction of a thin wire the course of the retarding effect of the lateral wire changes.

In the main conductor a platinum wire 7 inches 5 lines long and 0.023 line radius was introduced, and the results in the following able were obtained; the lateral spiral being closed by German silver wire of different lengths:

Length of German silver wire.	Temperature of main wire.
.0 feet	100
29.6 "	82
49.3 "	78
69. "	78
237. "	91
572. "	99

We see here that, on prolonging the main conductor, the maximum effect of the secondary wire is not reached until a greater length of wire has been introduced into the secondary spiral, and moreover that the retarding effect of the secondary wire is now much less. During the previous experiments the temperature of the main wire was reduced by the maximum effect of the secondary spiral to 48 per cent.; now, the maximum effect of the secondary spiral produces only a reduction to 78 per cent. of the temperature, which would have been observed either without the secondary spiral or by one perfectly closed.

This is easy to explain. The secondary current is stronger in proportion as the part of the main wire acting on the secondary wire is greater, and to the stronger secondary current we must also attribute a greater reaction upon the discharge. The length of the main wire was the same in both series of experiments, namely, 13 feet of copper wire, which acted upon the same length of the secondary wire. In the first series these 13 feet made by far the greatest part of the circuit of the battery; in the second a platinum wire was introduced, whose retarding power was equal to a copper wire 568 feet long and 0.55 line thick; consequently, in the last case, only about one-forty-fourth part of the virtual length of the main wire acted upon the secondary spiral.

Riess caused two other spiral disks to be made, each containing 53½ feet of copper wire two-thirds of a line in diameter. The large and small spirals were introduced into the main circuit.

The small main spiral being now placed opposite the small secondary spiral at a distance of 2 lines, the maximum retarding action of the secondary spiral took place when it was closed with 29.6 feet of German silver wire. With this maximum effect the temperature of the main circuit was 76 per cent. of that which was observed without the lateral spiral, or when it was perfectly closed.

When the large secondary spiral was opposed to the large main spiral at a distance of 2 lines, the maximum retarding action of the secondary wire occurred when the latter was closed by 79 feet of German silver wire, and in this case the temperature in the main wire was reduced by the retarding action of the secondary spiral to 25 per cent.

Finally, the two secondary spirals, properly connected, being placed opposite the two main spirals, then 138 feet of German silver wire had to be introduced into the secondary circuit to obtain the maximum retarding effect, and the temperature in the main wire was thereby reduced to 20 per cent. of that which would have been observed without a lateral spiral. From these experiments it follows that—

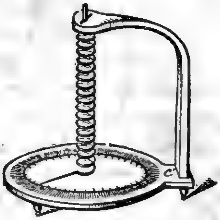
The maximum effect of a secondary wire upon the electrical discharge attained by lengthening the secondary circuit is as much greater as the length of the main wire acting on the secondary wire is greater. But, at the same time, to attain this maximum, a proportionately longer circuit is required for the secondary wire.

The length of the platinum wire in the air thermometer in these experiments was 143.5 lines. This wire, which is very long in proportion to the whole circuit, can never act inductively on the secondary wire; to make the longest possible part of the main wire act on the secondary spiral, the wire in the thermometer must be shortened, by which means the action of the main wire is, indeed, increased, but on the other hand the sensibility of the thermometer is diminished.

Riess, in order to shorten the platinum wire which closed the main spiral, used Berguet's metallic thermometer instead of the air thermometer.

A straight platinum wire 61.5 lines long and 0.04 line radius was fastened immovably in the axis of a sensitive thermometric spiral, similar to that represented in fig. 63, and introduced into the circuit in a suitable manner. The instrument was of course placed under a bell-glass. The platinum wire in the axis, on being heated by a discharge of the battery, communicated its heat to the spiral; the index then traversed a number of degrees, but soon returned to its first position, in consequence of the rapid cooling caused by the large volume of air in the bell-glass.

Fig. 63.



The experiments with the metallic thermometer teach nothing new, on which account no further mention need be made of them, though I could not leave this method of observing unnoticed.

§ 66. *Direction of the secondary current.*—To investigate whether the direction of the lateral current changes with the distance of the secondary wire from the main wire, Riess used the following method. (Pog. Ann., LXXI, 351.)

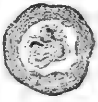
An insulator, which cannot be pierced by electricity, being placed between the free ends of the secondary spiral, no secondary current occurs. Nevertheless the electrical equilibrium of the secondary wire is destroyed by the act which would have produced the current, as the following experiment shows:

Fig 64.

If we place between the free ends of the secondary spiral a thin cake of resin, so that the two ends of the wire are opposed to each other, after the discharge of the battery by the main line, the two surfaces of the cake of resin may be distinguished from each other in the most decided manner. Peculiar electrical figures are produced, which, in most cases, are brought out by slightly breathing upon them. If it be desired to fix the figures, it is done, as shown by Lichtenberg, by strewing the surfaces with a mixture of flowers of sulphur and minium. On one of the surfaces of the resin treated in this way there appears a red disk, with a red border, and beyond it a dark (unpowdered) ring, surrounded by yellow rays. On the other surface yellow and red segments of circles are visible, embraced by a wide red ring.

Fig. 65.

Fig. 66.

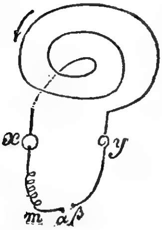


The rays and the ring increase with the strength of the electrical excitation; with very feeble excitation the rays of the first figure are wanting, and a simple red disk remains, which, however, is sufficiently distinct from the second figure, in which the red ring may always be recognized.

Each of these figures is composed of the two elementary forms which Lichtenberg has distinguished as positive and negative, and for this reason the direction of the secondary current cannot be deduced from these figures.

In the following experiments the ends of the secondary spiral were lengthened by copper wires, and a part of one formed a short, close coil, wound to the right. In fig. 67 let x and y indicate the ends of the secondary spiral to which the above-mentioned wires are attached. To magnetize a steel needle the ends α and β were put in contact, and the needle was placed in the coil, with its point toward m. To obtain the figures on the resin it was introduced between α and β. The results contained in the following table were obtained with the small main and secondary spirals, consisting of 13 feet of copper wire, already mentioned.

Fig. 67.



In the main spiral the discharge current passed in the direction indicated by the arrow. The following table shows the polarity indicated by the needle when it lay in the coil pointing towards m.

A glass plate was interposed between the two spirals.

Distance of spirals.	Main wire.	Quantity of electricity.	Polarity at *m*.
Line.			
1		5	N.
1		10	N.
1	Lengthened	10	S.
1		30	N.
1	Lengthened	30	S.
25		30	N.
25	Lengthened	30	S.
39.5		30	S.

It is seen that for the same direction of the main current the magnetism of the needle varies with the other circumstances, whence a difference in the directions of the secondary current might be deduced; but the resin plate being interposed between α and β, and the battery discharged through the main spiral under all the circumstances given in the table, fig. 65 was constantly formed on the side of the resin plate turned toward the end of the wire β—a proof that the direction of the secondary current remained the same, though the magnetism of the needle was reversed.

Riess used for producing the figure a small glass or copper plate, both sides having been covered with a thin coating of pitch or resin.

A surface of resin once used must be heated over the flame of a spirit lamp to melting before it can be employed again.

The direction of the secondary current, which, as already remarked, could not be directly determined from the figures of the resin plate, was ascertained in the following way: Two three-inch condensers were separated by a thin plate of mica; the lower one touched the nd of the wire α; the upper was so near the end β that, in disharging the battery, a small bluish spark passed. After discharging hrough the main spiral the upper plate was removed and tested by he electrometer. For a positive charge of the battery the condenser late, which touched the end β, was found electro-negative. The ayed figure (fig. 65) is, therefore, always produced by the end charged ith negative electricity; and, consequently, *the secondary current has lways the same direction as the main current.*

The experiment made by Riess for ascertaing the direction of the ateral current by the decomposition of iodide of potassium failed, as e did not succeed in producing the decomposition by the secondary urrent.—(Pog. Ann., XLVII, 74.)

§ 67. *Deflection of the magnetic needle by frictional electricity.*—The oils of a multiplier, used for producing a deflection of the magnetic eedle by a current of frictional electricity, must be very well insulated. iess has constructed such a multiplier (Pog. Ann., XL, 348) of a opper wire 105 feet long and one-sixth line in diameter, which, overed with three coats of silk and in 260 coils, formed 5 layers on eing wound upon a suitable frame. Before winding a length of the ire it was twice covered with shellac varnish, and the wrapping ut on before the varnish was perfectly dry. Each layer was again arnished after wrapping.

The cylindrical astatic needles belonging to this coil were 22.5 lines ong, 0.4 line in diameter, and 5 lines apart. The combined needles ade one oscillation in 6.6 seconds.

One of the wire ends of such a multiplier being placed in conducting onnexion with the conductor, the other with the cushion of the elecrical machine, a deflection of 10 to 20 degrees could be maintained y turning.

When it is desired to deflect the needle by the discharge current of he electrical battery the discharge of course must be retarded by the nsertion of bad conductors, such as moist strings, glass tubes filled ith water, &c.

The latest experiments made by Riess on this point (Pog. Ann., LVII, 535) gave results showing that the deflection of a magnetic eedle by the wire which slowly discharges an electrical battery *is ndependent of the surface of the battery*, provided a perfect discharge f the bat-tery takes place. It is therefore immaterial to the deflecion of the needle whether the same quantity of electricity is distriuted over one or over several jars.

Faraday had attempted (*Experimental Researches*, 363, Pog. Ann., 9) to compare the discharge current of the electrical battery with hat of a voltaic current. After obtaining a given deflection of the agnetic needle by discharging a battery he constructed a voltaic air, which, acting $3\frac{1}{5}$ seconds, produced the same deflection as the disharge of the battery; and he concluded that the quantity of electricity ielded by the pair was equal to that accumulated in the battery.

Riess justly remarks, that this conclusion is not well founded, beause the instantaneous action of the discharge current of the battery n the needle is essentially different from that of a galvanic current.

I have reported Riess' researches without interrupting the course of the narration by speaking of what has been done by others on the same subject. Let us now turn to these labors.

§ 68. *Knochenhauer's researches on the current.*—In a second article, with the title "*Experiments on Latent Electricity,*" (*Versuche über die gebundene, Elektricität*, Pog. Ann., LVIII, 391,) Knochenhauer presents the law according to which the force of the secondary current decreases when the distance from the main wire increases.

Riess has shown, as already mentioned, § 61, that the force of the secondary current decreases in the same proportion in which the axial distance of the secondary wire from that of the main wire increases.

Knochenhauer thinks this law is "evidently insufficient."

Starting, apparently, from the idea that the lateral current is a phenomenon of induction, Knochenhauer attempts to apply here *his* law.*

That a law stating the relation between action and distance, adapted to the case of spherical bodies only, in which all action can be considered as starting from a single point, cannot hold good for wires running parallel to each other does not stop Herr Knochenhauer. His law has such an astonishing elasticity that, by barely changing the coefficient, it serves for the secondary current. In his opinion there subsists between the force of the secondary current (measured by the air thermometer) and the distance of the wire the relation

$$\theta = \mathrm{A} a \sqrt{n}$$

in which θ denotes the temperature of the thermometer in the secondary wire, and n the distance of the secondary from the main wire.

This n, however, is not the axial distance, but the distance of the wire in the clear, in which he assumes three lines as unity; hence the magnitude of n has first to be computed from the axial distance a given by Riess.

He first compares his formula with the results found by Riess. A series of these observations he arranged in the following table, with the values computed by his formula:

d.	θ observed.	θ computed.	Difference.
Lines.			
2.71	0.216	0.219	+ 0.003
6.78	0.145	0.143	— 0.002
11.24	0.119	0.104	— 0.015
16.01	0.081	0.079	— 0.002
19.61	0.066	0.066	0.000
23.87	0.054	0.055	+ 0.001

In fact the values observed and those computed by the above formula correspond sufficiently well by making $\mathrm{A} = 0.401$, $a = 0.489$. Indeed, the formula answers for very short distances, for which the law of Riess, on evident grounds, is no longer applicable.

But does this accordance of Knochenhauer's formula with the observa-

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*See Report of 1856.

ions prove its correctness? Certainly not. When there are two onstants at our disposal it is easy to invent a whole mass of formulas hich would serve just as well; that is, they will accord with the few umbers observed within narrow limits, quite as closely as the limits re narrow. As a proof I propose

$$\theta = \mathrm{A} + b \log. \mathrm{D};$$

he first best arbitrary formula that occurs to me. In this formula let denote the temperature of the secondary wire, D the axial distance f the wires. Making $\mathrm{A} = 0.276$, and $b = 0.16$, this formula will gree with Riess' observations as well as that of Knochenhauer; as the ollowing table shows, in which the third vertical column contains he values computed by the above formula:

d.	θ observed.	θ computed.	Difference.
Lines.			
2.71	0.216	0.207	— 0.003
6.78	0.145	0.143	— 0.002
11.24	0.119	0.107	— 0.012
16.01	0.081	0.084	+ 0.003
19.61	0.066	0.069	+ 0.003
23.87	0.054	0.056	— 0.002

In spite of this harmony between observation and computation, this ormula expresses just as little as Knochenhauer's, the law according o which the force of the secondary current decreases with the distance rom the main wire.

Knochenhauer has himself made a series of experiments to confirm is formula, and by which he would show that the magnitude of *a* epends upon the conducting capacity of the main circuit, of the secndary circuit, &c. The description of the modus operandi of the xperiments, how the wires were extended, &c., is exceedingly obscure, nd since, I think, I have proved the inaccuracy of his formula, a further account of these experiments is unnecessary.

This memoir forms the introduction to further researches, which relate to the secondary current and currents in branched circuits. The following are the titles of the memoir on these subjects:

On the lateral current in divided conducting wires of the battery.—(Pog. Ann,. LX—LXX, 235.)

On the electrical current in divided conducting wires of the battery. (Pog. Ann., LXI, 55.)

On the diminution of the main current with divided conducting wires of the battery.—(Pog. Ann., LXII, 353.)

On the relation of the formulas which determine the development of heat by the electrical and the galvanic current.—(Pog. Ann., LXII, 207.)

Experiments on the electrical secondary current.—(Pog. Ann., LXIV, 64, and Pog. Ann., LXVI, 235.)

Determination of the compensating length of wire without the air thermometer.—(Pog. Ann., LXVII, 327.)

Solution of the problems recently proposed on branched galvani currents, for the discharge current of the electrical battery.—(Pog Ann., LXVIII, 136.)

On the ratio of tension in the discharge current of the electrica battery.—(Pog. Ann., LXIX, 77.)

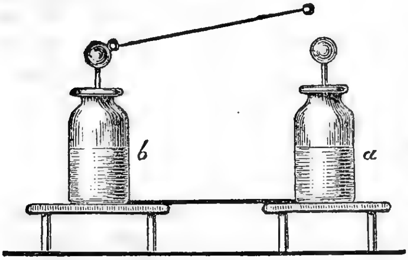
On the comparison of the electrical formula with the galvanic.—(Pog. Ann., LXIX, 421.)

The experiments mentioned in these memoirs are very badly described; the discussions inflated, confused, and full of difficult formulas which do not lead to simple, clear, and well founded results.

Since the design of this report is to present to the reader the progress of physics, and not to weary him with criticisms on fruitless labors, I need say no more of Knochenhauer's memoir on the lateral current and kindred subjects. The criticism on the abovementioned paper suffices to justify me in this respect.

§ 69. *Charging current of the electrical battery.*—In Fig. 68 let *a* and *b* denote two electrical batteries, both of which are insulated The exterior coatings of both batteries being in metallic connexion, suppose *a* to be charged and *b* to remain uncharged.

Fig. 68.



Now, if any suitable discharger, fitted to the knob of the jar *b*, approaches the knob of the charged jar, a spark passes, the jar *a* becomes partially discharged, a part of the (e. g.) positive electricity, which was accumulated on the inner coating of *a*, passes with a spark to the inner coating of *b*, while a corresponding quantity of negative electricity passes without a spark, by the conducting connexion of the outer coatings, from *a* to *b*.

In this manner *a* is partly discharged and *b* charged; the charge of *b* is not gradual, as in ordinary charging of jars, but very rapid. Dove terms the current which, passing from the outer coating of *a* to that of *b*, charges the latter battery, the *charging current*, (*Ladungsstrom*,) and he has compared the action of this current with the action of the discharge current already amply investigated. He found the following results, (Pog. Ann., LXIV, 81:)

1. *Induction.* In the outer connecting wire a cylindrical induction spiral was introduced, surrounded by an exterior secondary spiral. The effects were the same as in the discharge stroke.

2. *Sparks.* The outer connecting wire having been interrupted, a brilliant white spark, with a loud report, appeared at the place of external interruption the instant the spark at the inner conducting wire passed. A moist thread being introduced into the inner conducting wire, the spark assumes a redish yellow color and has a feeble report; the same change is also indicated in the place of interruption of the outer connecting wire, in which there is no moist thread.

Dove found further that the "charging current" produced in the same manner as the discharge current.

3. Galvanic effects.
4. Magnetization of steel.
5. Physiological effects.
6. Penetration of bad conductors, and
7. Evolution of heat.

The needle of a galvanometer inserted in the connecting wire of he outer coatings is not affected when the inner coatings are brought nto metallic contact with a white and loudly sounding spark, without he interposition of a moist thread; but it is sensibly affected when a noist thread is introduced there. The magnetizing of a steel needle placed in a spiral was produced with great effect in the first case, (without interposition,) but feebly in the second case, (with interposition.)

The contents of one of Dove's papers in Poggendorf's *Annalen*, (LIV, 305,) bearing the title, "On the current induced in magnetizng iron by means of frictional electricity," will have to be presented ater, because this subject is closely related to the corresponding effects of the galvanic current.

§ 70. *Hankel's researches on magnetizing steel needles by the discharge park of the electrical battery.*—Hankel has published two large memoirs on this subject, (Pog. Ann., LXV, 537, LXIX, 321.) In the irst he speaks of Savary's observations, and then proceeds to the lescription of his own experiments, the results of which are as follows:

1. When the discharge stroke passes through a spiral in which a teel needle is placed, a certain minimum of charge is generally necessary to magnetize the needle. Calling the polarity which it receives by the discharge stroke of this minimum, normal, the needle will become abnormally magnetic by gradually increasing discharges, and again normal by still stronger charges, &c. The abnormal magnetsm appears with strong charges of the battery, as the pieces of wire ntroduced into the circuit of the battery are longer in proportion as he charge is stronger.

When in addition to the spiral and the pieces of the conducting ircuit remaining constant in all the experiments, an iron wire 34 eet long and 0.1 line in diameter was introduced, abnormal magnetsm was obtained with a charge 70 (measured by sparks of the measurng jar); on inserting 82 feet of the same wire a charge of 120 was equired, and a wire of 154 feet required a charge of 160.

2. When a battery of more, and then one of fewer jars was used vith the same conducting circuit, the battery of the less number of ars produced the abnormal period with a less charge.

An iron wire of 202 feet having been introduced, a charge of 20 vith two jars produced abnormal magnetization, while by using 5 ars it was only obtained with a charge of 70, and with 9 jars, even he quantity of electricity 230, did not produce abnormal magnetizaion.

If with gradually increasing charges, the change from normal to bnormal magnetization is not always obtained, these periods are nevertheless not wholly wanting; for an increase and decrease of the trength of the normal magnetism is observed, and the minima of the normal magnetization correspond in this case to the abnormal periods.

Hankel applied himself to the explanation of this phenomenon, and he lays down the following as the fundamental idea:

"It is known from Faraday's researches, that a current at its commencement generates an opposite current in a neighboring conductor; at its cessation, on the other hand, a second current which passes in the same direction with the original one. The electrical sparks must act in both ways, upon a steel needle placed near the wires, as the needle is perpendicular to the direction of the current, the planes of the currents produced in the needle are likewise perpendicular to the length of the needle, and the magnetism of the needle will be in opposite directions according as we consider it to be excited by the action of the beginning or by the cessation of the spark. But the two instants of beginning and end of electrical sparks follow each other so rapidly, that their separate effects cannot be measured; hence magnetization is the result of both of these influences."

This is essentially the fundamental idea to which Wrede (*Berzelius' Jahresbericht, deutsch von Wöhler, 20ster Jahrgang*, S. 119,) sought to reduce the alternate normal and abnormal magnetism of steel needles by the discharge stroke in main as well as in secondary wires.

As already intimated by Riess, (*Dove's Repertorium*, VI, 218,) this mode of explanation belongs yet to the domain of conjecture. It is possible that this is the natural process in magnetizing steel needles by the discharge stroke, but it is by no means proved.

On the whole this explanation seems very plausible; but the deduction of the particulars of the phenomenon is not at all convincing, although Hankel expresses himself quite at length upon the subject. We will do well to consider this as still an open question.

Riess remarks, in the place above cited in Dove's Repertorium, that it is better, and more for the furtherance of science, openly to confess the deficiencies of our knowledge, than to attempt to aid it with half explanation and to cover up its defects; and in this connexion he quotes a passage from Franklin's letters, which should be taken to heart by every scientific man:

"I find a frank acknowledgment of one's ignorance is not only the easiest way to get rid of a difficulty, but the likeliest way to obtain information; I think it an honest policy."

In the second memoir Hankel treats of the following points:

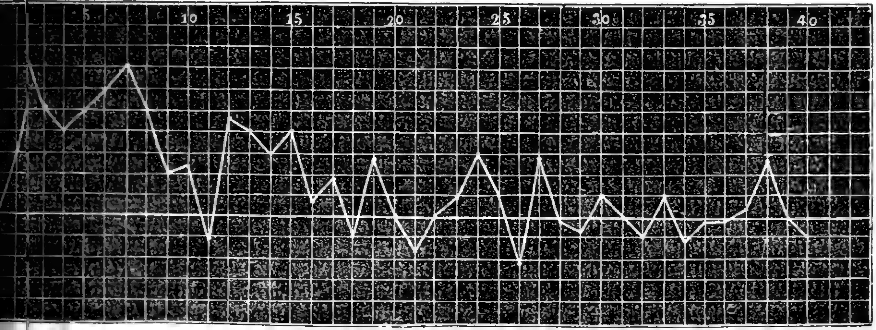
1. The number and magnitude of the magnetizing periods, mentioned in the first memoir.
2. The action of different spirals.
3. The action of the conducting wire upon itself.
4. The influence of the thickness of the needles.
5. The influence of the surface of the battery.
6. The changes of the alternations by obstacles interposed.
7. Special influence of particular metals, totally distinct from their conducting capacity.

We will consider these points in succession:

1. As a magnetizing spiral, a spiral of silver wire was employed with coils so close that the introduced needle covered 31 of them

he charge of the battery was regularly increased by 1 spark of the easuring jar, and at each discharge a new needle was magnetized; e strength of the magnetism communicated was then determined by e time which the needle required to make a given number of vibra- ons. A copper wire 2.63 metres long and 1.2966 millimetre diam- er was used in the circuit together with the spiral.

In this manner Hankel made a series of experiments whose results e represented graphically in fig. 69. The abscissas are proportional



the strengths of the battery charges, the ordinates to the strengths the corresponding magnetization. The ordinates above the hori- ntal 0 correspond to normal, those below to abnormal magnetism.

This curve does not produce the impression of regularity; it seems ther to mask some sort of a law by irregularities which cannot be rrected by computation. But in such cases the law may be repre- nted by averages obtained from numerous experiments.

Hankel says he repeated these experiments with the shortest circuits, determine the position of the abnormal, or equally significant weak rmal periods; from all his experiments with the same kind of needle, ing the same battery of nine jars, he found these periods to occur in e following charges: 3, 6, 9, 11, 14, 16, 18, 21, 23, 26, 29, 32, 5, 40.

Hankel says, “we see that the change in the polarity returns regu- rly;” but I can find in this series of numbers nothing very clearly pressed, and least of all regularity. He says, moreover, that this regu- rity might have been more clearly represented by the introduction fractions, but he purposely avoided them, as he had not measured em exactly, but only estimated them.

Now, what does this mean? Does not the above series of numbers present the means of numerous experiments made under the same ndition? If this is the case, why hesitate to introduce fractions? ean values are generally computed, not observed.

To render it possible for the reader to judge of the value of his re- lts, Hankel should have told how he arrived at the series 3, 6, 9, 1, &c.; and he should have communicated the separate series of periments in order that one might ascertain how far the separate ries differed from the mean on account of accidental disturbances.

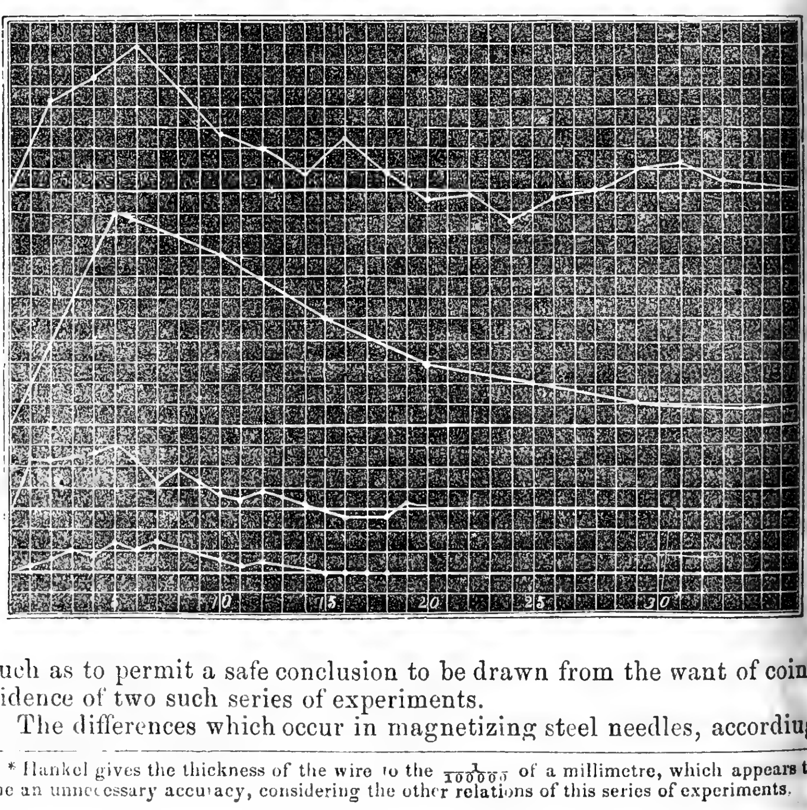
2. The series of experiments represented by fig. 69, were compared with two others in which the spirals were so moved in the directio n o their length that the needle covered only 28 coils in the second, andf only 11½ in the third series. The *general* result was, that the periods were longer in proportion as the needles covered fewer coils.

3. As mentioned above, Riess announced the proposition that, in discharging a battery, no part of the circuit acts inductively upon itself. Hankel contests this proposition. He comes to the opposite conclusion from the following experiments:

A copper spiral of tolerably large diameter was surrounded by a similar spiral, the two being so arranged that the discharge could at pleasure be made to pass through the two, either in the same or in opposite directions.* A magnetizing spiral was also introduced into the circuit The march of the magnetizing periods for both arrangements being then compared they did not harmonize, and hence Hankel inferred that there was necessarily an interference of effects.

Even if it be conceded that Reiss' experiments are not sufficient to establish his proposition, those of Hankel are still less fitted to overthrow it; for, in the phenomena of magnetism by the discharge stroke, our knowledge of what is regular or what may be accidental is not such as to permit a safe conclusion to be drawn from the want of coincidence of two such series of experiments.

Fig. 70.



The differences which occur in magnetizing steel needles, accordiug

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* Hankel gives the thickness of the wire to the $\frac{1}{100000}$ of a millimetre, which appears to me an unnecessary accuracy, considering the other relations of this series of experiments.

as a long wire introduced into the circuit is extended in a straight ine or wound into a spiral, will be considered below under No 6.

4. It appears in general, as Hankel infers from his experiments, hat with coarse needles the phenomena do not change ; the anomalous eriods occur only with stronger charges, and also appear to have lost n strength.

5. New experiments on the influence of the surface of the battery, orresponding to the previous ones, indicated that a diminution of the urface brought about the anomalous periods with decreasing charges, ut so shortened them .that, with a certain size of the battery, they eased to appear as abnormal magnetization ; weak and strong normal eriods only were then observed.

6. Besides the short insertion, with which the results in fig. 69 were btained, Hankel made experiments with inserted copper wires extended n a straight line 0.23 millimetre diameter, and varying between 0.375 nd 96.4 metres in length. The curves 1 and 2, fig. 70, represent he results which he obtained with the wires 12 and then 96.4 metres ong. These curves seem to indicate that with longer insertions the eparate small periods disappear, until at last only a large normal pe-iod is observed with stronger magnetism, after which follows a very road negative period, (from 30 to 100,) in which, however, very weak agnetism is observed.

With reference to the disappearance of the smaller periods, these xperiments do not admit, in my opinion, of any certain conclusion, ecause the charge of the battery was increased from 5 to 5 for the onger insertions, and from 2 to 2 for the medium, while they increased nly by 1 in the shortest. Where is the guarantee that in the longer ires single periods are not passed over? Hankel preserves silence n this point.

In relation to the influence of the coils, Hankel compares the result epresented by the second curve of fig. 70 with those which are given by 03 metres of the same wire wound into 70 coils. While, with straight ires, a normal period extends to 30, and is then followed by a long egative weak one, he observed, with coiled wires, 3 normal and 3 ab-ormal periods.

When 26 metres of a very thick (30.76 square millimetres in sec-ion) quadrangular copper wire were inserted, no change was seen in he succession of the periods, but they were generally feebler. When, n addition, 113 metres of a round (1.3 millimetre) wire were inserted, tretched in a straight line, the results represented in the third curve f fig. 70 were obtained. Nearly all reversions disappeared, the needles eemed but feebly magnetic.

When 94 metres of the thick wire were coiled into a spiral and nserted in the circuit, the results presented in the fourth curve of g. 70 were obtained. The enfeebling of the magnetism appeared ere in the thick coiled wires still more strikingly than in that ex-ended at length.

The influence of the coiling upon the thick and the thin copper wires is vidently very different; yet, says Hankel, (page 336 of his 2d Memoir,) he influence is the same in both cases. The discussion, by means of hich he seeks to prove this, is incomprehensible to me; indeed, I annot call Hankel's reasoning in general clear and precise.

7. The insertion of iron wires yields remarkable phenomena, producing anomalous periods of very considerable strength. Hankel found them particularly striking with thick, long iron wires. While a thick copper wire greatly weakens the magnetism, the latter is considerably strengthened by a thick iron wire. On introducing an iron wire 1.27 millimetre diameter and 131 metres long it gave, for instance, the result for a charge 6, a normal maximum 11; for a charge 36, an anomalous magnetism of the strength $9\frac{1}{2}$, taking for unity the magnetizing strength adopted in constructing the above curves.

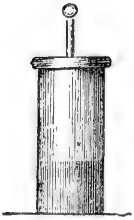
§ 71. *Leyden jars of thick glass.*—Winter, of Vienna, constructs Leyden jars which have a much greater striking distance than those in general use, and he accomplishes this by using vessels with very thick sides, (over 1 line,) and by leaving a very wide uncoated border.

Spontaneous discharge is prevented by the width of the uncoated border, and perforation of the glass is prevented by its thickness. In such jars the tension of the free electricity on the inner coating can reach a far higher degree than in the ordinary thin jars, in which, if a spontaneous discharge does not occur, a fracture of the glass is to be feared.

The mutual induction of opposite electricities of the two coatings, in consequence of the great thickness of the glass, is less perfect than with thinner glass. With the same quantity of coating, and with the same density of the free electricity on the inner coating, less electricity will be accumulated in thick glass jars than in those of thin glass; in general, therefore, the quantity of electricity which a thick glass jar can receive is less, but the tension of the free electricity on the inner coating, and consequently the striking distance, is greater.

It is to be expected that with the greater striking distance, other effects of the discharge will also suffer a change. All effects of the discharge stroke, in which it is chiefly desirable that a great quantity of electricity should be sent through a body, can be produced better with large, thin glass jars, but where the force of the shock is the main object, thick glass jars serve the purpose better; hence it appeared to me probable that the perforation of glass plates should take place much more easily with thick jars than with ordinary thin ones. Trial perfectly sustained my supposition. Formerly, in using large, thin jars, a great number of revolutions of the machine were necessary to charge the battery sufficiently for the perforation of glass, and even then the experiment did not always succeed satisfactorily; now, 20 revolutions of a very moderate electrical machine suffice to charge a thick glass jar so as to produce this effect with certainty.

Fig. 71.



The thickness of the glass jar, fig. 71, is about 1 line; each coating has a surface of about 9 square decimetres, and the uncoated border is 22 centimetres in height.

I have not studied carefully the influence of the thickness of the glass upon the effects of the discharge stroke, and only make this notice in order to draw the attention of other physicists to the point. It is much to be wished that Riess would take up this subject, since he has already labored in this field with such generally acknowledged good results.

§ 72. *Electrical figures.*—By means of electricity, figures can be produced on the surface of different bodies, which are either directly visible or are rendered visible by strewing dust, or by breathing upon them. Riess has made an extensive series of experiments (Pog. Ann., LXIX, 1) on these phenomena, the best known of which are the Lichtenberg figures, and he has determined very accurately the circumstances under which these figures and images appear.

Riess divides them into *primary electrical delineations*, or such as are caused by different parts on the surface of poorly conducting substances being placed in unlike electrical condition, and becoming visible on being sprinkled with powders; and

Secondary electrical delineations, which are produced when the film of foreign matter which covers nearly all bodies is affected by the electrical discharge; in this case the figures are made to appear by breathing upon the plate, or else visible marks may appear immediately, if the surface of the body itself has been in any way attacked.

We shall first consider the figures made visible by sprinkling powder upon them.

§ 73. *Dust figures.*—To produce the Lichtenberg figures Riess used square copper plates, covered on one or both sides with a coat of pitch about ½ line thick.

The formation of dust figures (Lichtenberg figures) is a consequence of the electroscopic action of electrified spots on the resinous surface upon the powder itself, electrified by shaking in the bag through which it is sifted. A mixture of flour of sulphur and minium is best for this purpose. Positively electrified places on the plate are covered with the sulphur, and therefore appear yellow; the minium, on the contrary, is collected on the negative spots, which thus appear red.

The spark having passed over the pitch surface, so that a dust figure would have appeared if it had been immediately dusted, no figure will be formed if the pitch surface is first exposed for a second to the flame of a spirit lamp, by which the electricity is removed from the plate.

The simplest mode of producing dust figures is the following, used also by Riess: A copper plate, covered on one side only with pitch, is touched by a conductor, and an insulated metallic point is placed on the pitch surface. The upper end of the point being touched by the knob of a *positively* charged jar, remove the insulated point, and on powdering with the above described mixture a round yellow sun, with dense rays, will appear.

The experiment being conducted in the same manner with a *negatively* charged jar, a perfectly red circular disk will appear.

This diversity in the appearance of the figures is well known; but Riess has directed attention to another remarkable distinction, namely, that the positive figure is much larger than the negative, though equally strong charges have been used.

With a given *positive* charge of the jar the yellow sun had (as a mean of 3 experiments) a diameter of 16.1 millimetres.

With an equally strong negative charge the red disk had a diameter (also a mean of 3 experiments) of 5.8 millimetres.

The diameters of the negative and positive figures, produced by equally strong charges of the jar, are, consequently, in the ratio of 1 to 2.77, or the surfaces covered by them are as 1 to 7.67.

A plate, coated on both sides with pitch, on being brought between the insulated point and the conducting wire, and subjected to the above process, the positive figure appears on one side and the negative on the other.

When the jar was charged with *negative* electricity, the disk appeared above and the sun below, but the yellow sun in this case was only 2.2 times as large as the red disk.

The cause of the negative figures being relatively greater than in the previous experiment was owing to the excess of negative electricity, which was transmitted to the upper surface; in fact, a sun appeared on the upper side, which was 3.3 times as great as the red disk on the under side, when a positively charged jar was used in a similar experiment.

Riess has shown that the dust figures appear only when the passage of electricity on the insulating plate is accompanied by a discontinuous discharge, which may be recognized generally by a peculiar hissing. By holding the pitched plate to the knob of a charged jar a spark passes with a crashing noise; a discontinuous discharge thus takes place, and a figure appears on dusting; but the plate being placed at such a distance from the knob of the jar that a spark cannot pass, some electricity still gradually goes over, producing a continuous discharge. If the plate is dusted after standing from 30 to 70 minutes opposite the knob of the jar, a number of round spots appear irregularly distributed—yellow, if the jar had a positive, red, if a negative charge. These spots exhibit no trace of rays; they are perfectly alike in size and form for both electricities.

Hence, electrical dust figures appear when electricity is transmitted by a discontinuous discharge to an insulating plate.

Upon this fact Riess founds a very ingenious explanation of the difference between positive and negative dust figures. In a discontinuous discharge passing over the surface of an insulator the condensed atmosphere, which covers the surface of all bodies, is forcibly penetrated, and a part of the stratum, containing vapor of water, is projected with violence against the surface of the body.

But Faraday has shown that, if moist air impinges forcibly against any body, the latter is negatively electrified; thus, then, in this case* the surface of the plate becomes negatively electrified in consequence of the discharge which takes place over the surface; the remaining electricity of this discharge then has only to spread over a negatively electrified insulating surface.

The surface being charged with negative electricity, it spreads from the point over an insulating surface already negative; the circumstances, therefore, not being favorable for the distribution of the negative electricity the figure cannot become enlarged, and a rounded form is assumed.

The jar being positively charged, the remainder of the positive charge spreads from the point over an insulating surface negatively

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[*] The experiments of Faraday referred to, scarcely allow of such a conclusion.—(Se Report for 1856, p. 364.) G. C. S.

electrified by the discontinuous discharge; the fact that electricity is already present on the surface, acting attractingly on that issuing from the point, occasions a greater diffusion of the positive electricity; but the circumstance that the positive electricity spreading forth is partially neutralized by the presence of the negative, causes the radiating form of the positive dust figure.

To sustain this view, Riess produced a modification of the phenomenon in rarified air. On a plate covered with pitch, placed under a glass receiver, was placed the blunt end of a wire, which received a spark from a jar charged with positive electricity. With the whole pressure of the air the sun appeared on dusting the plate; but when the air was exhausted to 27½ lines pressure, only an irregular yellow speck appeared; negative electricity behaved in like manner. The difference between the positive and negative figures was no longer observed at this degree of rarifaction.

When the air was exhausted to 2 or 3 lines the end of the wire left only a point, which, *with positive electricity was red, with negative, yellow;* and consequently caused, not by the transmission of electricity to the plate, but by induction.

The penetration of the stratum of air surrounding the plate is, therefore, the origin of dust figures.

§ 74. *Dust images.*—If a stamp (as simple as possible, having a few raised letters, and for this reason printing types will answer) be placed on a single pitch plate, (so Riess calls a copper disk coated on one side only with pitch,) and electricity be communicated to the stamp, it acts inductively on the pitch surface, the latter becoming electrified at the spot where touched; and this electricity is opposite to that of the stamp, for on removing it and powdering the plate with the mixture mentioned already, a red image of the letter is obtained, if the stamp is positive; a yellow one, if negative; for the flour of sulphur attaches itself to the positive, the minium powder to the negative spots of the resin plate.

The above described phenomenon underwent numerous modifications, according to the manner in which the stamp was electrified.

The stamp being touched by the knob of a charged Leyden jar, and then removed in an insulated condition, leaves an image as above indicated; it is, however, very little covered with dust; while the ground, by the formation of dust figures becomes yellow, if the letter is red, or red, if the letter is yellow.

The stamp being removed uninsulated, the dust figure changes, whereby the clearness of the image also suffers.

By electrifying too strongly, an actual passage of electricity in part occurs at the place where the stamp touches the plate, so that a dust image appears, partly red and partly yellow.

Then we have at the same time a dust image and dust figures. To obtain the dust image clearly, the formation of the dust figures must be avoided, which Riess accomplished in various ways.

The knob of a Leyden jar was exchanged for a four-inch ball, and the jar fastened horizontally, so that the pitch plate and the stamp could be placed under the ball; the stem of the stamp was half an inch from the ball. By the inductive action of the ball the end of the stamp touching the pitch was electrified like the ball; too strong an accumulation of electricity was prevented by providing the stamp with a point. After the stamp had been exposed from 20 to 30 minutes to the inductive action of the ball, a clear dust image appeared without any dust figure, but irregular spots appeared in the ground, which were not of the color of the image.

Similar results were obtained when the stamp was placed for several hours in connexion with one pole of a powerful dry pile, while the electricity of the other pole was conducted off as completely as possible.

In these cases, in which generally no dust figures appeared, it was indifferent whether the stamp was insulated or not, on its removal.

The color of the irregular spots showed that they originated in the electricity actually passing from the stamp to the pitch plate at the places which admitted of a slight current. To avoid these, more ready passage to a conducting medium must be furnished for this electricity, as in the case when the dust images were produced in rarified air. Riess obtained in this manner the most perfect dust images.

The *dust figures* and *images*, just considered, are, according to Riess, *primary electrical delineations;* the figures and images now to be considered are *secondary electrical delineations.*

§ 75. *Electrical breath figures.*—The surface of glass, mica, &c., over which an electrical discharge stroke has passed, gives, by breathing upon it, peculiar ramified figures, which stand out from the surface obscured by the breath with a mirror-like lustre.

The breath figure indicates the path taken by the electrical discharge over the surface; and its form differs therefore, according to the nature of this surface. On metal, it appears as a round disk; on resin, as serpentine stripes; on mica, as fine, many times ramified lines.

The breath figure *is independent* upon the *kind* of electricity employed.

That these figures do not originate in the electricity which continues to adhere to the surface is established by the fact that they are seen on metallic surfaces, on which they appear after the breathing, as distinct circles, surrounded by more or less obscure rings; the breath figures also appear a long time after the discharge stroke has passed over the surface, or after the surface has been passed over the flame of a spirit lamp. Hence, the breath figures cannot be owing to adhering electricity; *they are to be ascribed to a change of surface which the substance used has been subjected to, by the electrical discharge.*

On a fresh surface of mica, that is on such as is obtained by a fresh cleavage, breath figures do not appear. This depends upon a peculiar property of fresh mica surface, which Riess has described in the 67th volume of Poggendorf's *Annalen*, page 354.

A clean plate of mica being breathed on, or held over evaporating water, the result is, as with all bodies, that it will be covered with a rapidly disappearing stratum of water, consisting of very small drops, which are not in contact with each other.

But when the mica has received a fresh surface by cleavage, it remains perfectly clear, shining and transparent after being breathed on.

This phenomenon is by no means owing to the fresh surface not condensing vapor of water, for the breath causes it to show the colors of thin plates; it is consequently covered with a coherent stratum of water.

A drop of water which stands at rest on an old surface of mica at once spreads on a fresh surface, and completely covers it. Hence, a mica surface made by cleavage possesses, in consequence of its great purity, so great an attraction for the vapor of water that it condenses the water into a coherent stratum, while, had the mica been exposed a long time to the air, it would have condensed the water in separate drops.

While an old surface of mica is an excellent insulator of electricity a fresh surface discharges an electroscope in a few seconds; it acts hygroscopically by condensing the vapor of water of the atmosphere into a coherent stratum, which conducts electricity.

This remarkable peculiarity of fresh mica is preserved but a short time in the air; in a few days it may be clouded by breathing upon it.

Very powerful electrical discharges produce not only a change in the film of foreign matter covering the body, but they alter the surface of the body itself. This is the cause of the traces noticed in § 41, occasioned by the discharge spark on glass and mica (electrical colored stripes) and of the *rings of Priestley*, which occur when numerous discharges of a battery take place between a point and a polished metallic surface, whereby oxidation of the metal forms many colored concentric circles.

§ 76. *Karsten's Electrical Figures.*—The analogy which Riess describes in the VI volume of *Dove's Repertorium der Physik*, between electrical breath figures and the images of Moser, occasioned Karsten to examine whether such images could not be obtained in the electrical way.

For this purpose he placed (Pog. Ann., LVII, 492) a coin on a mirror, resting on a discharging metal plate, and caused sparks to strike from the conductor of the machine upon the coin, thence passing to the metal plate, (around the edge of the glass.) After 100 revolutions of the machine the coin was removed; the glass plate seemed wholly unchanged, but when breathed upon the image of the coin appeared distinctly.

Besides the memoir cited, Karsten has published two others, in Poggendorf's *Annalen*, (LVIII, 115, and LX, 1,) on electrical images, but as he has not succeeded in discovering their true nature, it is unnecessary to go further into the details of these memoirs; and the more, since Riess, as we shall see, has correctly ascertained the condition for producing electrical images. The report upon Riess' researches will therefore suffice to bring the facts at least, to the knowledge of the reader.

We must, however, briefly notice, by the way, Karsten's last treatise in one particular. In the beginning he adduces many experiments which have been made to explain the cause of Moser's images; besides Moser's own theory, he presents the opinion of Hunt, Know, Fizeau, Daguerre, Masson and Moore. Why is the excellent work of Waideles on this subject ignored? it appears in the first half of the 59th volume of Poggendorf's *Annalen*, and after these images had been the occasion of numerous theoretical extravaganzas, brought us back to the basis of a rational treatment of the subject. Could Karsten not have known of this work in drawing up the papers in the 60th volume of the *Annalen?*

The explanation which Karsten gives of Moser's images is altogether inadmissible and may be easily refuted. He thinks that, because similar images can be produced by the aid of electricity, Moser's images must be of electrical origin. He thinks that "if two bodies, differing in any respect from each other, come in contact, an electrical current is produced!" and that this is the cause of Moser's images.

The generation of an *electrical current* by the contact of two heterogeneous bodies, which Karsten seems to intimate in this passage, will not be granted by the most zealous of the adherents of the contact theory; but granting even the existence of such a current, it could not produce any image, as the researches of Riess prove.

That electrical tension alone, without repeated discharges between the body and the plate, is not sufficient to produce electrical images has been shown by Know in a paper "On electrical figures and thermography," (Pog. Ann., LXI, 569,) in which he has proved the untenableness of Karsten's view as to the electrical origin of Moser's images.

The rest of the contents of Know's memoir will be mentioned subsequently in the proper place.

§ 77. *Electrical breath images.*—Riess placed a metal stamp on a shining pitch surface, and upon the stamp a small metal weight connected by a silver wire with the knob of the spark micrometer, receiving electricity directly from the conductor of the machine, while the other knob of the spark micrometer, one-half line from the first, was in conducting connexion with the ground.

The machine being now turned, electricity accumulates upon the first knob of the micrometer and upon the stamp, until a discharge takes place by the passage of a spark between the two knobs; continued turning will charge and discharge the stamp anew. The discharges follow more rapidly the closer the knobs of the spark micrometer are together.

After several revolutions of the machine the stamp may be removed, the plate breathed upon, when a shining image of the stamp shows itself on the dull ground.

It is indifferent for the success of this experiment which electricity is used.

Such images may also be produced on glass and mica, but on these substances they are often imperfect.

The simple breath image, Riess says, in caused by repeated electrical discharges taking place in opposite directions between the model and the insulating plate. The electricity communicated to the model passes over to the plate, then back to the model, when the latter is discharged by the spark micrometer; thus a motion of the same kind of electricity arises, first downward and thus upward. Since the discharges between a bad and a good conductor are never perfect, electricity, both of the kind used and the opposite kind, remain upon the insulating plates, which are therefore in the condition to produce dust figures, often even dust images.

By simply electrifying the stamp, the arrangement being the same as for producing dust images, no breath image appears. The alternate charge and discharge of the stamp are essentially necessary for the formation of these images.

By laying a plate of mica on a pitch plate, and placing a metal stamp on this, a double discharge of the same kind of electricity takes place in the same direction in electrifying the stamp, namely, from the stamp to the upper surface of the mica, and from the under surface of the mica to the pitch plate. When a spark is communicated to the stamp from a positively charged jar, the pitch surface, when dusted, shows a yellow image of the stamp, surrounded by positive dust figures. If, therefore, in this arrangement of the stamp alternate charges and discharges are brought about, the conditions for forming *manifold breath images* are fulfilled.

A pitch surface being covered with a mica plate and a stamp placed on it, the latter was charged and discharged by the spark micrometer. After twenty revolutions the upper surface of the mica showed a perfect breath image, but the under surfaces and that of the pitch presented a most imperfect one.

These images are so frequently imperfect because pitch and mica adhere closely together in consequence of the electricity remaining after each discharge and subsequent discharges is conveyed to places which lie scattered beyond the image surface; but a metallic plate being substituted for the pitch plate, a perfect breath image is obtained on the upper and lower surfaces of the mica and on the metallic surface.

The visibility of the breath images is to be explained, according to Riess, by the fact that the surfaces are freed by electrical discharges from the film of foreign matter with which they are generally covered; and he has even proved such a cleansing of the surface by images on metal. On a perfectly insulating mica surface Riess produced a breath image, and the place where the image appeared conducted as well as a fresh surface of mica, thus showing that it had been freed from the stratum covering this spot.

In most cases breath images are produced by such a cleansing action, but they can be excited also by soiling the plate.

On a fresh mica surface an obscure image of a stamp was obtained on a shining ground. On an old surface, which electrified by forty revolutions, gave a bright breath image; one hundred revolutions produced a dull image.

The various kinds of dull breath images depend upon the condition of the plate used and of the stamp, and also upon the strength of the electricity; the clear images appear more frequently only because soiled plates and the least possible electricity are generally used.

The origin of the breath images, like that of the breath figures, is to be ascribed to a change which the electrical discharge produces in the stratum covering the plate, and consists in an increase or diminution of this stratum, according to circumstances.

A spark thrown upon a metallic surface injures it when perfectly clean, but leaves it unchanged if it is soiled or tarnished. This is the case, in forming breath images on metals. A very small number of discharges having passed between a metallic surface and one of mica covering it, the intermitting discharge begins in the foreign stratum on the surface of the metal, and the metal remains uninjured; but when the stratum is destroyed, and the breath image is produced, and the discharges are continued, the latter then begin on the metal itself, which is thus changed. Such images, appearing without breathing, and representing some parts of the stamp in brownish colors, Riess produced on silver with from fifty to sixty revolutions.

§ 78. *Electrolytic images.*—If the blunt point of a platinum needle be placed on a paper moistened with a solution of iodide of potassium, and lying on a metallic plate connected with the ground, a brown spot will appear under the point if the needle is electrified positively, but there will be no spot if it be negatively electrified. Using positive and negative electricity one after the other in any order, the coloring remains even when the quantity of negative electricity far exceeds that of the positive.

This fact explains the electrolytic images, which Riess has invented for proving the correctness of the view presented above, on the formation of breath images by alternating discharges.

A piece of card paper, moistened on one surface with a solution of iodide of potassium, was laid on a metallic plate connected with the ground, and then covered with a plate of mica. A stamp was placed on the mica, and, being loaded with a weight of 2 to 14 ounces, was connected with the spark micrometer, whose knobs were ½ a line asunder. After twenty revolutions of the machine, positive electricity continuing to pass between the knobs, a very sharp image appeared on the paper in which the letters of the stamp appeared with a brown color.

The explanation of this phenomenon, according to the above, is easy. As in breath images, the stamp being charged with positive electricity, it passes from the lower surface of the mica to the metal plate, and thence through the moist paper; by this passage of the + E to the metal plate the iodide of potassium is decomposed; as soon as a discharge takes place between the knobs of the spark micrometer, an opposite current sets in between the metal plate and the mica; the + E now returns to the mica, and the — E through the moist disk to the metal. While the + E goes to the metal the iodide of potassium is decomposed, and this effect is not destroyed by the discharge in the opposite direction.

It is to be remarked that the passage of the + E from the mica to the metal takes place gradually, while the discharge in the opposite direction happens instantaneously.

The same experiment being repeated in the same manner with — E, no image is obtained, but only irregular brown spots.

This also may be easily explained; the negative electricity goes gradually to the metallic plate, while the passage in the opposite direction is instantaneous; thus, a greater quantity of positive electricity returns at once to the metal plate, and passes more readily to such points as lie beyond the image surface.

To obtain an image with negative electricity, care has only to be taken that the quantity of + E which returns on the discharge between the knobs to the metal plate, shall be less, which is attained by bringing the knobs of the spark micrometer closer together.

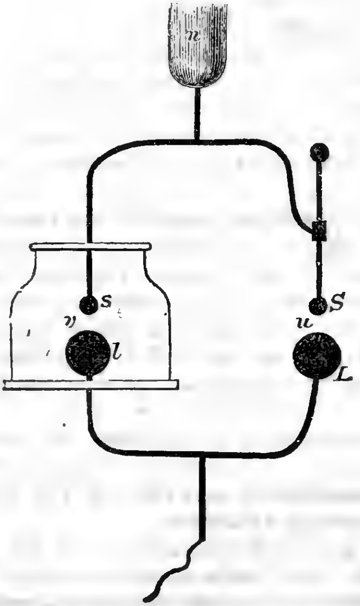
SECTION FOURTH.

ELECTRICAL SPARK AND BRUSH.

§ 79. *Faraday's researches on the spark and brush.*—Without going into the theoretical disquisition, mentioned in another place,* which Faraday has given upon the spark and brush, I will present here only the most important facts which he has obtained in his experiments upon these phenomena of light.—(Pog. Ann., XLVII and XLVIII.)

In order to compare the resistance which different gases presented to the passage of sparks, with the corresponding resistance of the air, Faraday used an apparatus, a sketch of which is represented in fig. 72 Two small knobs, *s* and *S*, connected with the conductor of an electrical machine, were placed opposite to two larger knobs, *l* and *L*, in conducting connexion with the ground. The diameter of the balls was as follows:

Fig. 72.



Ball *s*..................	0.93 of an inch.
Ball *S*..................	0.96 "
Ball *l*..................	2.02 "
Ball *L*..................	1.95 "

The constant interval *v* between *s* and *l* was 0.62 of an inch; the interval *u* between *S* and *L* was variable.

It would have been better if the two small balls *s* and *S* had been perfectly equal in size, and *l* and *L* also equal; much more reliable conclusions could then have been drawn from these experiments.

The two balls *s* and *l* were placed in a receiver, which could be exhausted and then filled with different gases.

The receiver being filled with air under the pressure of the atmosphere, the sparks passed alternately at *u* and *v*, when the intervals at *u* were between 0.6 and 0.79 inches. When the interval at *u* was less than 0.6 the sparks always passed here, but if it was greater than 0.79 the sparks then always passed at *v*.

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* See § 24 in the Report for 1856.

Similar results were obtained when other gases were in the receiver under the atmospheric pressure. There were two limits for the interval at u, between which the spark passed at one time at u, at another at v; the interval at u being less than the least of these limiting numbers, the spark passed always at u, but being greater than the greatest of these numbers it always took place at v. The following table indicates the limits at u for different gases, v having the constant value of 0.62 inch:

	Smallest.	Greatest.	Mean.
Air, *s* and S	+ 0.60	0.79	0.695
	— 0.59	0.68	0.635
Oxygen, *s* and S	+ 0.41	0.60	0.505
	— 0.50	0.52	0.510
Nitrogen, *s* and S	+ 0.55	0.68	0.615
	— 0.59	0.70	0.645
Hydrogen, *s* and S	+ 0.30	0.44	0.370
	— 0.25	0.30	0.275
Carbonic acid, *s* and S	+ 0.56	0.72	0.640
	— 0.58	0.60	0.590
Olefiant gas, *s* and S	+ 0.64	0.86	0.750
	— 0.69	0.77	0.730
Coal gas; *s* and S	+ 0.37	0.61	0.490
	— 0.47	0.58	0.525
Muriatic acid gas, *s* and S	+ 0.89	1.32	1.105
	— 0.67	0.75	0.720

A similar series of experiments gave for—

		Smallest.	Greatest.	Mean.
Hydrogen	*s* and S +	0.23	0.57	0.400
Carbonic acid		0.51	1.05	0.780
Olefiant gas		0.66	1.27	0.965

which does not coincide very well with the former results, a proof that these numbers do not afford sufficient grounds for forming a conclusion.

That within certain limits of distance at u the spark takes place alternately at u or v, and consequently that there is not a single permanent value of u for each gas, over which the spark always happens at v, but under always at u, depends upon accidents (such as particles of dust floating in the air) of which we can give no account.

If at one of the intervals a spark once passed there was generally a strong tendency in it to appear at the same interval again.

It is a remarkable circumstance that the range of distance u should be much less when s and S are negative than when these balls are psitive. This is exhibited in the following table, drawn from the rmer experiments. The range was—

	s and *S*.	
	+	−
In air	0.19	0.09
oxygen	0.19	0.02
nitrogen	0.13	0.11
hydrogen	0.14	0.05
carbonic acid	0.16	0.02
olefiant gas	0.22	0.08
coal gas	0.24	0.12
muriatic acid gas	0.43	0.08

Although, as Faraday himself remarks, these numbers require con-slerable correction, the general result is striking and the differences i several cases very great.

It appears clearly from these experiments that different gases have t equal capacities for insulation. Considering the mean values of *u* (for positive charges of *s* and *S*,) we perceive that a stratum 0.62 of a inch of—

Oxygen	insulates as well as a stratum of air, whose thicknes is	0.505
Nitrogen		0.615
Hydrogen		0.370
Carbonic acid		0.640
Olefiant gas		0.750
Coal gas		0.490
Muriatic acid gas		1.105

tat is, an electrical discharge passes as easily through a stratum of ar 0.370 of an inch thick, as through one of hydrogen of 0.62 of an ich; an electrical spark penetrates a stratum of air 1.105 inch thick as esily as one of 0.62 of an inch of muriatic acid gas; an electrical sark passes with decidedly more ease through oxygen, hydrogen, and cal gas than through an equal stratum of air; but muriatic acid gs and olefiant gas present a decidedly greater resistance to the transmission of the spark than an equal thickness of air does.

Similar results were obtained from later but less reliable experiments.—(Pog. Ann., XLVIII, 281.)

The mean values of *u* are not equal with positive and negative carges of *S* and *s*; for many gases *u* has a greater mean value with a positive charge of *S* and *s* than with a negative; for other gases it i the reverse; but to draw the conclusion from these experiments that many gases more readily allow the negative and others the positive dscharge through them, seems to me unwarranted, because the differeces of the above table in this respect are within the limit of errors o observation.

Thus, according to the table given above, the mean value of *u* with a positive charge of *s* and *S* is, for—

Hydrogen	0.37
Carbonic acid	0.64
Olefiant gas	0.75

while Faraday obtained from a subsequent series of experiments, similarly arranged, the following values:

Hydrogen	0.40
Carbonic acid	0.78
Olefiant gas	0.96

Evidently the corresponding values of u, obtained by positive charges of s and S, and which should be exactly equal, differ as much from each other as the corresponding values for the positive and negative charges of s and S; from which it appears that we are justified in assigning no great value to these differences. But there is a further reason for ascribing these differences to errors of observation, arising from the fact that when air is in the receiver, and the spark accordingly takes place through air, the positive and negative mean values for u are found unequal, namely: with s and S positive $u = 0.695$; with s and S negative $u = 0.635$. These differences can be ascribed only to accidental disturbances, which produce the errors of observation; for why should the spark, with a positive charge of s and S, pass more easily through the air at v, and with a negative charge, more easily at u, also through the air? Air being in the receiver, and + and — charges imparted to s and S, the values for u would be nearly identical, unless the errors of observation were too considerable.

Faraday himself does not consider these experiments decisive in this respect, but brings forward some facts which seem to indicate some such difference between the positive and the negative discharge; making $u = 0.8$ of an inch, and filling the receiver with muriatic acid gas, the discharge always took place, with a positive discharge of s and S, at u, through air, but with a negative charge of s and S at v, through the muriatic acid gas.

It also appeared that when the conductor was connected only with the muriatic acid gas apparatus the discharge occurred more readily with a negative discharge of the small ball s than with a positive; for in the latter case much of the electricity passed off as brush discharge through the air from the connecting wire; but in the former case it all *seemed* to go through the muriatic acid.—(Pog. Ann., XLVII, 287.)

§ 80. *Unequal striking distances of positive and negative discharge.*—Many known phenomena coincide in showing that positive and negative discharges do not take place with equal facility. When a small ball, connected with the conductor and thus made inductive, is placed opposite a larger one, which is uninsulated, a spark is obtained twice as long, the conductor being charged positively, as when negatively charged.

Faraday has closely investigated this phenomenon, and obtained the following facts:

He passed the discharges between two balls of the respective diameters of 2 inches and 0.25 of an inch. The larger ball being connected ith the conductor, and thus made inductive, there appeared with a ositive conductor—

parks alone up to an interval of..................................	0.49 in.
egative brush, from the small ball alone, when the interval was greater than..	0.52 "

With a negative conductor—

parks alone up to an interval of..................................	1.15 "
ositive brush, from the small ball alone, when the interval was greater than..	1.65 "

Between these limits he obtained sparks and brushes mixed.

The balls were then exchanged, the small ball being connected with he conductor, and the large one uninsulated. The result with a ositive conductor was—

parks alone to an interval of..................................	0.4 in.
egative brush alone, when the interval was greater than..	0.44 "

From these experiments it follows that—

1. Longer sparks are obtained when the small ball is positively lectrified.

2. Longer sparks are obtained when the large ball is the inducing, nd the small one the inducteous ball.

When the small ball discharges electricity in the form of brushes, hey are much more numerous, and each one seems to carry off much ess electrical force when the discharged electricity is negative than when positive.

This appears to indicate that a small ball requires a greater tension or discharging when positive than when negative.

To illustrate this important point, Faraday arranged an apparatus, epresented in fig. 73. A fork, A, carrying a large and a mall ball, was connected with the conductor of a machine; perfectly similar fork, B, was connected with a discharging train; the small ball on each fork was placed opposite he larger one on the other. The intervals at *n* and *o* were equal. The conductor being negative, the discharge always happened at *n*, which is not surprising, because the negative charge of the small inducing ball at *n* is always stronger than the positive charge of the small inductious ball at *o*. But had the discharge taken place at *o* with a positive charge of the conductor, it would have appeared that the weak negative charge of the small inducteous ball discharges with greater facility than the far stronger positive charge of the small inducing ball at *n*, which would have been a decisive proof of the more facile discharge of negative electricity. But such a decisive result the experiments did not give; when the intervals at *n* and *o* were 0.9 of an inch, or 0.6, the discharge always took place at *n*, whether the conductor was positive or negative.

Fig. 73.

The interval *n* being made 0.79 and *o* 0.58 of an inch, if the conductor was positive, the discharge at both *n* and *o* was about equal, but if negative, the discharges mostly happened at *n*, which signified, evidently, that the small ball discharged in the negative state somewhat more easily than in the positive, yet their result is not perfectly decisive.

A contrivance, similar to that of fig. 73, was placed inside a glass vessel, which could be filled with different gases. With equal intervals at *n* and *o*, Faraday obtained quite decided results for carbonic acid. When the conductor was positive the discharge took place mostly at *o*, when negative always at *n*; here, then, the negative discharge was decidedly the more easy, and in coal gas the preponderance of the negative discharge was just as decided. In air and in oxygen the greater facility of the negative discharge appeared somewhat doubtful; in nitrogen and in hydrogen there appeared some probability of an opposite relation.

Belli has made experiments, from which it follows that negative electricity escapes more easily into air than positive.—(Pog. Ann. XXXV, 73.)

After fastening a quadrant electrometer on a horizontal insulated conductor and electrifying it *positively*, he found, as a mean of three experiments, that the electrometer required a period of ten minutes to sink from 20° to 10°; but with negative electricity only 4.5 minutes were required.

§ 81. *Sparks in different gases.*—The phenomena attendant on sparks in different gases have been often observed and described. Faraday has made experiments on this subject also, and describes them in the twelfth series of his Experimental Researches.—(Pog. Ann. XLVII, 536.)

The gases were under the pressure of the atmosphere; the sparks passed between brass balls.

"In *air*," says Faraday, "the sparks have that intense light and bluish color which are so well known, and often have faint or dark parts in their course, when the quantity of electricity passing is not great.

"In *nitrogen* they are very beautiful, having the same general appearance as in air, but have decidedly more color, of a bluish or purple character, and, as I thought, were remarkably sonorous.

"In *oxygen* the sparks were whiter than in air or nitrogen, and I think not so brilliant.

"In *hydrogen* they had a very fine crimson color"—"very little sound was produced in this gas."

"In *carbonic acid gas* the color was similar to that of the spark in air, but with a little green in it. The sparks were remarkably irregular in form, more so than in common air.

"In *muriatic acid gas* the spark was nearly white. It was always bright throughout, never presenting those dark spots which happen in air, nitrogen, and other gases.

"In *coal gas* the spark was sometimes green, sometimes red, and occasionally one part was green and another red; black parts also occurred very suddenly in the line of the spark."

Sparks may be obtained in media, which are far denser than air—as in oil of turpentine, olive oil, resin, glass, spermaceti, water, &c.

§ 82. *The electrical brush.*—The most important facts which Faraday has obtained in reference to the brush are the following,) Pog. Ann., XLVII :)

"The *brush* and *spark* gradually pass into each other." (Faraday calls the electrical brush "a spark to air.") "Making a small ball positive by a good electrical machine with a large prime conductor, and approaching a large uninsulated discharging ball towards it, very beautiful variations from the spark to the brush may be obtained. The drawings of long and powerful sparks, given by Van Marum, (description of the large machine in Taylor's museum, German translation of 1786, Tab. III, fig. 1 ;) Harris, (Phila. Trans., 1834, p. 243,) and others, also indicate the same phenomena," namely, a ramification of the spark by which its transition to the brush is made.—(Faraday's Researches, § 1448.)

"If an insulated conductor, connected with the positive conductor of an electrical machine, have a metal rod 0.3 of an inch in diameter projecting from it outwards from the machine and terminating by a rounded end or a small ball, it will generally give good brushes ; or if the machine be not in good action, then many ways of assisting the formation of the brush can be resorted to ; thus, the hand or any *large* conducting surface may be approached towards the termination ;" "or the termination may be smaller and of badly conducting matter, as wood ; or sparks may be taken between the prime conductor and the secondary conductor, to which the termination giving brushes belongs ;" "or the air around the termination may be rarefied."—(1425.)

That the brush is not a continuous discharge is evinced in the gradual transition of the spark to the brush. By proper proportion, in the size of the small knob to the power of the machine, brushes are obtained which show immediately that they consist of ramified sparks rapidly following each other ; the machine being worked more rapidly, or with the same working of the machine substituting a still smaller discharging knob, the brush assumes a more uniform appearance, which Faraday very well describes in the following words : "A short conical bright part or root appeared at the middle part of the ball, projecting directly from it, which, at a little distance from the ball, broke out suddenly into a wide brush of pale ramifications, having a quivering motion, and being accompanied at the same time with a low, dull, chattering sound."—(1426.)

At first such a brush seems continuous, but Wheatstone has shown that it consists of successive intermitting discharges, (Philos. Trans., 1834, p. 586,) which was to be expected from the gradual transition of the spark to the brush. Faraday gives a very simple method for decomposing the apparently continuous brush into its elementary parts without the help of Wheatstone's rotating mirror ; he says : "If the eye be passed rapidly, not by a motion of the head, but of the eyeball itself, across the direction of the brush, by first looking steadfastly about 10° or 15° above, and then instantly as much below it, the general brush will be resolved into a number of individual brushes."—(1427.) This method of analyzing has not succeeded perfectly in my trials.

"On using a smaller ball, the general brush was smaller, and the sound, though weaker, more continuous. On resolving the brush into its elementary parts as before these were found to occur at much shorter intervals.

"Employing a wire with a round end, the brush was still smaller, but, as before, separable into successive discharges. The sound, though feebler, was higher in pitch, being a distinct musical note."

The sound is in fact due to the recurrence of the noise of each separate discharge, and these happening at intervals nearly equal, under ordinary circumstances, cause a definite note to be head, whose pitch rises with the increased rapidity and regularity of the discharge.

"By using wires with finer terminations, smaller brushes were obtained, until they could hardly be distinguished as brushes. But as long as sound was heard the discharge could be ascertained by the eye to be intermitting; and when the sound ceased the light became continuous as a glow."

To those not accustomed to use the eye in the above-described manner, Wheatstone's apparatus with the revolving mirror is recommended. Another excellent process for analyzing the brush is to produce it on the end of a rod, held in the hand opposite to the prime conductor, and then move the rod rapidly from side to side, whilst the eye remains still.—(1428—1423.)

§ 83. *The brush in various gases.*—The experiments on the brush in various gases Faraday made with brass rods, about one quarter of an inch thick, and whose rounded ends were placed opposite each other in a glass globe of seven inches diameter, containing the gas. One of these rods was connected with the prime conductor, the other with the ground.—(Pog. Ann., XLVII, 553.)

"*Air.* Fine positive brushes are easily obtained in air, at common pressures, possessing the well known purplish light. When the air is rarefied the ramifications are very long, filling the globe; the light is greatly increased and is of a beautiful purple color, with an occasional rose tint in it.

"*Oxygen.* At common pressures the brush is very close and compressed, and of a dull whitish color. In rarefied oxygen the form and appearance are better; the color somewhat purplish, but all the characters very poor compared to those in air."

"*Nitrogen* gives brushes with great facility at the positive surface, far beyond any other gas." "They are almost always fine in form, light, and color, and in rarefied nitrogen are magnificent. They surpass the discharges in any other gas as to the quantity of light evolved."

"*Hydrogen*, at common pressures, gives a better brush than oxygen, but does not equal nitrogen; the color was greenish gray. In rarefied hydrogen the ramifications were very fine in form and distinctness, but pale in color, with a soft and velvety appearance, and not at all equal to those in nitrogen. In the rarest state of the gas the color was a pale gray green."

"*Coal gas.* The brushes were rather difficult to produce." "They were short and strong, generally of a greenish color." "In rare coal gas the brush forms were better, but the light very poor and the color gray."

"*Carbonic acid* produces a very poor brush at common pressures." "In rarefied carbonic acid the brush is better in form, but weak as to light, being of a dull greenish or purplish hue."

"*Muriatic acid gas.* It is very difficult to obtain the brush in this gas at common pressures. On gradually increasing the distance of the rounded ends the sparks suddenly ceased when the interval was about an inch, and the discharge, which was still through the gas in the globe, was silent and dark. Occasionally, a very short brush could, for a few moments, be obtained, but it quickly disappeared. Even when the intermitting spark current from the machine was used a brush was obtained with difficulty, and that very short;" "in the mean time, magnificent brushes were passing off from different parts of the machine into the surrounding air. On rarefying the gas the formation of the brush was facilitated, but it was yet of a low, squat form, very poor in light, and very similar on both the positive and negative surfaces." "On rarefying the gas still more a few large ramifications were obtained, of a pale bluish color, utterly unlike those in nitrogen."—(1456—1462.)

§ 84. *Brush in denser media.*—Electrical brushes are produced, not only in air and gases, but in far denser media. Faraday procured it in *oil of turpentine,* (1452,) "from the end of a wire going through a glass tube into the fluid, contained in a metal vessel. The brush was small, and very difficult to obtain; the ramifications were simple, and stretched out from each other, diverging very much. The light was exceedingly feeble, a perfectly dark room being required for its observation. When a few solid particles, as of dust or silk, were in the liquid, the brush was produced with much greater facility."

§ 85. *Difference of the positive and negative brush discharge.*—On this subject I extract the following remarks by Faraday:

"When the brush discharge is observed in air, at the positive and negative surfaces, there is a very remarkable difference. The difference in question used to be expressed in former times by saying that "a point charged positively gave brushes into the air, whilst the same point charged negatively gave a star." This is true only of bad conductors, or of metallic conductors charged intermittingly. If metallic points project *freely* into the air the positive and negative light upon them differ very little in appearance."

These phenomena vary exceedingly under different circumstances, as Faraday shows:

"If a metallic wire, with a rounded termination in free air, be used to produce the brushy discharge, then the brushes obtained when the wire is charged negatively are very poor and small by comparison with those produced when the charge is positive. Or if a large metal ball, connected with the electrical machine, be charged *positively,* and a fine uninsulated point be gradually brought towards it, a star appears on the point when at a considerable distance, which, though it becomes brighter, does not change its form of a star until it is close up to the ball; whereas, if the ball be charged negatively, the point, at a considerable distance, has a star on it as before; but when brought nearer, a brush formed on it, extending to the negative ball; and when still nearer, the brush ceased and bright sparks passed."

As we have already seen, § 80, the spark discharge passes into the brush at far less distances if the surface on which the discharge begins (the small ball or the rounded end of a rod) is negative, than if it is positive; but on going further into the succession of charges we find that the positive brush passes into glow long before the negative.

" A metal rod 0.3 of an inch in diameter, with a rounded end pro-
brush. It was ascertained, both by sight and sound, that the succesisve
jecting into the air, was charged negatively and gave a short noisy
discharges were very rapid in their recurrence, six or seven times more numerous than when the rod was charged positively to an equal degree."

" When the rod was positive it was easy, by working the machine a little quicker, to replace the brush by a glow, but when it was negative no efforts could produce this change."—(1468.)

" A point opposite the negative brush exhibited a star, and, as it was approximated, caused the size and sound of the brush to diminish, and at last to cease, leaving the negative end silent and dark, yet effective as to discharge."—(1469.)

" When the round end of a smaller wire was advanced towards the negative brush, it (becoming positive by induction) exhibited the quiet glow at eight inches distance, the negative brush continuing. When nearer, the pitch of the sound of the negative brush *rose*, indicating quicker intermittances; still nearer the positive end threw off ramification and distinct brushes, at the same time the negative brush contracted in its lateral direction and collected together, giving a peculiar, narrow, longish brush, in shape like a hair pencil; the two brushes existing at once, but were very different in their form and appearance, and especially in the more rapid recurrence of the negative discharges than of the positive. On using a smaller positive wire for the same experiment the glow first appeared in it and then the brush, and the two at one distance became exceedingly alike in appearance." (1470.)

" In *air* the superiority of the positive brush is well known. In *nitrogen* it is as great or even greater than in air. In *hydrogen* the positive brush loses a part of its superiority, not being so good as in nitrogen or air, whilst the negative brush does not seem injured. In *oxygen* the positive brush is compressed and poor, whilst the negative did not become less; the two were so alike that the eye frequently could not tell one from the other. In *coal gas* the brushes are difficult of production;" " and the positive not much superior to the negative, either at common or low pressure. In *carbonic acid* this approximation of character also occurred. In *muriatic acid gas* the positive brush was very little better than the negative."—(1476.)

§ 86. *Glow discharge.*—The glow " seems to depend upon a quick and almost continuous charging of the air close to and in contact with the conductor."—(Faraday's Researches, 1526.) Faraday was never able to separate it into visible intermitting elementary discharges. The glow is produced by—

1st. *Diminution of the charging surface.*—At the end of a metal rod with a blunt conical point, a phosphorescent continuous glow is obtained the more readily as the point is finer.

2d. *Increase of power in the machine.*—Rounded ends, which give only brushes when the machine is in weak action, give the glow readily when the machine is in good order.

3d. *Rarefaction of the air.*—A brass ball 2½ inches in diameter being made positively inductive in an air-pump receiver, became covered with glow in part, "when the pressure was reduced to 4.4 inches. By a little adjustment the ball could be covered all over with this light. Using a brass ball 1.25 inch in diameter, and making it inducteously positive by an inductive negative point, the phenomena were exceedingly beautiful. The glow came over the positive ball, and gradually increased in brightness until it was at least very luminous; and it also stood up, like a low flame, half an inch or more in height."—(1529.)

The *negative glow* is difficult to obtain in air at common pressures; "and it is as yet questionable whether, even on fine points, what is called the negative star is not a very reduced, but still intermitting brush, or a glow."—(1530.)

In rarefied air the negative glow can easily be obtained. If the rounded ends of two metal rods about 0.2 of an inch in diameter are about four inches apart in rarefied air, the glow can be easily obtained on both rods, covering not only the ends but an inch or two of the part behind. Balls are also covered with the negative glow in rarefied air, whether their surface is inductive or inducteous.—(1531.)

The glow occurs in all the gases examined for it by Faraday. He thought he obtained it also in oil of turpentine, though it was very dull and small.—(1534.)

"The glow is always accompanied by a wind, proceeding either directly out from the glowing part or directly towards it; the former being the most general case." If the arrangements are made so that the ready and regular access of air to a part exhibiting the glow be interfered with or prevented the glow then disappears.—(1535.)

Frequently it is possible to change the brush given by the end of a rod into a glow, by simply aiding the formation of a current of air at its extremity.—(1535.)

§ 87. *Dark discharge.*—If to the rounded end of a metallic rod projecting from the prime conductor of a machine a similar rod be held at a little distance, it is easy to obtain the appearance of light at the ends of both rods, while the intervening space between the positive and negative light remains dark; besides this familiar phenomenon, Faraday notices a very remarkable case of dark discharge.

"Two brass rods, 0.3 of an inch in diameter, entering a glass globe on opposite sides, had their ends brought into contact, and the air about them very much rarefied. A discharge of electricity from the machine was then made through them, and while that continued the ends were separated from each other. At the moment of separation a continuous glow came over the end of the negative rod, the positive termination remaining quite dark. As the distance was increased a purple stream or haze appeared on the end of the positive rod, and proceeded directly onward towards the negative rod, elongating as the interval was enlarged, but never joining the negative glow, there being always a short dark space between. This space, of about one-sixteenth or one-twentieth of an inch was apparently invariable in its extent and its position relative to the negative rod; nor did the negative glow vary. Whether the negative ends were inductive or inducteous the same effect was produced.''

Similar phenomena were obtained with balls instead of the rounded ends of rods.

§ 88. *Convective discharge.*—The dielectric being penetrated by the spark, the brush, and also by the glow, Faraday calls this form of discharge the *disruptive discharge.* With the brush, and still more with the glow, another form of discharge appears, making itself manifest by the so-called electrical wind. This is owing to the particles of the dielectric, in close contact with the charged conductor, (on the end of the electrified rod,) receiving an electrical charge, in consequence of which they are repelled; and by a repetition of this action the conductor is discharged.

"Why a point should be so exceedingly favorable to the production of currents is evident. It is at the extremity of the point that the intensity necessary to charge the air is first acquired; it is from thence that the charged particle recedes; and the mechanical force which it impresses on the air to form a current is in every way favored by the shapes and position of the rod whose point forms the termination.''—(1573.)

Particles of dust floating in the air favor the escape of electricity.

"On using oil of turpentine as the dielectric, the action and course of small conducting, carrying particles in it, can be well observed.''

"A very striking effect was produced on oil of turpentine, which, whether it was due to the carrying power of the particles in it, or to any other action of them, is, perhaps, as yet doubtful. A portion of that fluid in a glass vessel had a large uninsulated silver dish at the bottom, and an electrified metal rod, with a round termination, dipping into it at the top. The insulation was very good. The rod end, with a drop of gum water attached to it, was then electrified in the fluid; the gum water soon spun off in fine threads, and was quickly dissipated through the oil of turpentine. By the time that four drops had in this manner been commingled with a pint of the dielectric, the latter had lost by far the greatest portion of its insulating power;'' "the fluid was slightly turbid. Upon being filtered through paper only, it resumed its first clearness, and now insulated as well as before.''—(1571.)

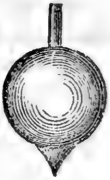
"Conducting fluid terminations, instead of rigid points, illustrate in a very beautiful manner the formation of the currents, with their effects and influence in exalting the conditions under which they were commenced. Let the rounded end of a brass rod, 0.3 of an inch, or thereabouts, in diameter, point downwards in free air; let it be amalgamated and have a drop of mercury suspended from it, and then let it be powerfully electrized, the mercury will present the phenomenon of *glow;* a current of air will rush along the rod and set off from the mercury directly downwards, and the form of the metallic drop will be slightly affected, the convexity at a small part near the middle and lower part becoming greater, whilst it diminishes all round at places a little removed from this spot.''—(1581.)

Fig. 74.

"Take next a drop of strong solution of muriate of lime; being electrified, a part will probably be dissipated, but a considerable portion, if the electricity be not too powerful, will remain, forming a conical drop, (fig. 74,) accompanied by a strong wind. If glow be produced the drop will be smooth on the surface. If a short low brush is formed a minute tremulous motion of the liquid will be visible."

"With a drop of water the effects were of the same kind, and were best obtained when a portion of gum water or syrup hung from a ball, (fig. 75.) When the machine was worked slowly a fine, large, quite conical drop, with concave lateral outline and a small rounded end, was produced, on which the glow appeared, whilst a steady wind issued from the point of the cone of sufficient force to depress the surface of uninsulated water held opposite to the termination. When the machine was worked more rapidly some of the water was driven off, the smaller pointed portion left was roughish on the surface, and the sound of successive brush discharges was heard. With still more electricity, more water was dispersed; that which remained was alternately elongated and contracted," and "a stronger brush discharge was heard. When water from beneath was brought towards the drop, it did not indicate the same regular, strong, contracted current of air as before; and when the distance was such that sparks passed the water beneath was *attracted* rather than driven away, and the current of air *ceased*."—(1584.)

Fig. 75.



"That the drop, when of water, or a better conductor than water, is formed into a cone principally by the current of air, is shown, amongst other ways, thus: A sharp point being held opposite the conical drop, the latter soon lost its pointed form, was retracted and became round; the current of air from it ceased, and was replaced by one from the point beneath, which, if the latter was held near enough to the drop actually blew it aside and rendered it concave in form." With still worse conductors, as oil, or oil of turpentine, the fluid was "spun out into threads and carried off, not only because the air rushing over its surface helped to sweep it away, but also because its insulating particles assumed the same changed state as the particles of air, and, not being able to discharge to them in a much greater degree than the air particles themselves could do, were carried off by the same causes which urged these in their course. A similar effect with melted sealing-wax on a metal point forms an old and well known experiment."—(1588.)

"A drop of gum water in the exhausted receiver of the air pump was not sensibly affected in its form when electrified," which was partly owing to the diminished current of air, and partly, perhaps, that the tension of the electricity on the ball is not so great in rarefied as in dense air.

"That I many not be misunderstood," says Faraday, "I must observe here that I do not consider the cones produced as the result *only* of the current of air or other insulating dielectrics over their surface. When the drop is of badly conducting matter a part of the effect is due to the electrified state of the particles," &c.—(1594.)

"When the phenomena of currents are observed in dense insulating dielectrics they present us with extraordinary degrees of mechanical force. Thus, if a pint of well rectified and filtered oil of turpentine be put into a glass vessel and two wires be dipped into it in different places, one leading to the electrical machine and the other to the discharging train, on working the machine, the fluid will be thrown into violent motion, whilst, at the same time, it will rise 2, 3, or 4 inches up the machine wire, and dart off in jets from it into the air."—(1595.)

"A drop of mercury being suspended from an amalgamated brass ball preserved its form almost unchanged in air, but when immersed in the oil of turpentine it became very pointed and even particles of the metal could be spun out and carried off. The form of the liquid metal was just like that of syrup in air."—(1597.)

"If the mercury at the bottom of the fluid be connected with the electrical machine, whilst a rod is held in the hand terminating, in a ball three quarters of an inch in diameter, and the ball be dipped into the electrified fluid, very striking appearances ensue. When the ball is raised again so as to be at a level nearly out of the fluid, large portions of the latter will seem to cling to it, (fig. 76.) If it be raised higher a column of the oil of turpentine will still connect it with that in the basin below, (fig. 77.) If the machine be excited into more powerful action this will become more bulky, and may then also be raised higher, assuming the form, (fig. 78.)

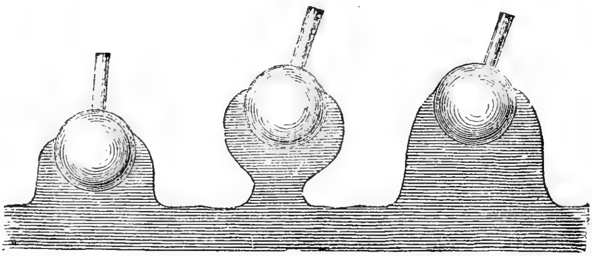


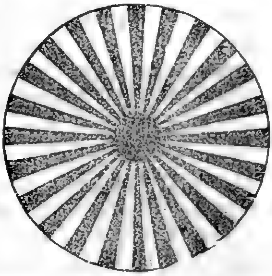
Fig. 76. Fig. 77. Fig. 78.

"A very remarkable effect is produced on these phenomena, connected with positive and negative charge and discharge, namely, that a ball charged positively raises a much higher and larger column of the oil of turpentine than when charged negatively."—(Faraday Researches, series XIII, 1600.)

§ 89. *Laws of the brightness of the electrical spark.*—Masson published in the 14th volume of the *Anneles de Chimie et de Physique*, page 129, (1845, 3d part,) his researches upon the brightness of the electrical spark, under the title: "*Etudes de Photometrie Electrique.*"

The ordinary photometre can be used only for permanent and not for momentary sources of light; for measuring the brightness of the electrical spark, which gives only a momentary illumination, Masson was obliged to contrive a new photometric principle. In fact he solved the problem in a very ingenious manner.

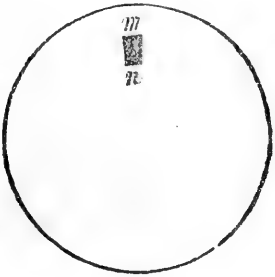
Fig. 79.



If a disk be divided into sectors equally large and alternately black and white, as in fig. 79, and be put into rapid rotation, the different sectors cannot be distinguished when the disk is illuminated by a constant source of light; but if it be illuminated by an electrical spark for an instant the sectors of the rotating disk will become visible again, and as much more so as the electrical spark is brighter. But if the illumination by the electrical spark be gradually weakened, while that from the constant source of light remain the same, a point will be attained where the sectors *just* cease to be distinguishable, and in this case the power of the illumination by the electrical spark is a determinate fraction of the illumination by the constant source, its magnitude depending upon the peculiarity of the observer's eye.

We will now consider in what manner this limit of the ability to distinguish may be ascertained.

Fig. 80.



A part of a sector on a white disk, (fig. 80,) being blackened, and the disk turned rapidly about its centre, the black piece will form a ring somewhat darker than the white ground of the disk. The ring will appear as much fainter as the black spot is narrower, and if the experiment be made with a series of such disks, each successive one having a narrower black end-portion of a sector *m n*, we will at last find one in which the dark ring ceases to be distinguishable.

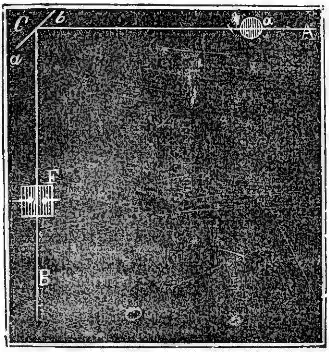
Let us suppose this to be the case when the breadth of the sector is $\frac{1}{100}$ of the entire circumference; it is evident that the brightness of the ring is less than the brightness of the disk by $\frac{1}{100}$; in this case the eye cannot distinguish a difference of $\frac{1}{100}$ in illumination.

Masson made his experiments with disks upon which the breadth of the sectors were $\frac{1}{50}$, $\frac{1}{60}$, $\frac{1}{70}$, $\frac{1}{80}$, $\frac{1}{90}$, $\frac{1}{100}$, $\frac{1}{110}$, $\frac{1}{120}$, of the whole circumference, and by means of them he found that for weak eyes a difference of illumination of $\frac{1}{50}$ to $\frac{1}{70}$ was the limit of perceptibility. For ordinary eyes this limit was $\frac{1}{80}$ to $\frac{1}{100}$; for very good eyes $\frac{1}{100}$ to $\frac{1}{120}$.

On varying the intensity of the illumination Masson found that the sensibility for the same individual did not change if the illumination was sufficient for reading ordinary print.

The rotating plate being illuminated with colored light, Masson found that the limit of perceptibility of difference of illumination is independent of the color.

Fig. 81.



We now pass to the particular object of Masson's investigation. The arrangement of his experiments was essentially as follows: A rotating disk, *a b*, fig. 81, (the rotation being produced by clock-work,) divided into white and black sectors, as in fig. 79, was illuminated in the direction of *A C* by the constant light of a lamp *L*, which was movable in the line of this direction. This lamp was placed in a black case so that it could throw its light on the rotating disk only through a tube. In the direction of the line *B C* a movable spark micrometre *F* was placed. One of the knobs of this micrometer was in conducting connexion with the upper coating of a horizontal glass plate, the other knob with the lower coating; the spark always passed between the two knobs as soon as the charge of the plate had reached a certain limit, which depended upon the distance of the knobs from each other.

Masson first satisfied himself that, for the instantaneous light of the electrical spark, the intensity of the illumination was also, as in other cases, in the inverse ratio of the square of the distance.

The lamp *L* being at a given distance from the disk *a b*, the spark micrometer was gradually removed from the disk, until at the passage of the spark the sectors of the rotating disk were no longer distinguishable, and the distance of the spark from the disk was determined. The lamp was then moved, and the same experiment repeated, the distance between the knobs of the spark micrometer remaining unchanged. The following table gives the results of such an experimental series; Z denotes the distance of the lamp, Y the corresponding distance of the spark micrometer from the middle of the disk *a b*:

Z.	Y.	$\frac{Z}{Y}$.
mm.	*mm.*	
540	407	1.32
640	489	1.30
740	569	1.30
840	648	1.29
940	737	1.28
1040	826	1.25
Mean......	....	1.29

Since Z and Y increase in an equal (or very nearly equal) ratio, it is evident that, with increasing distances, the illumination for both sources of light decreases according to the same law; hence the illumination by an electrical spark is likewise inversely proportional to the square of the distance.

The same result was given by several other series of experiments, which Masson has arranged in tables. It will be sufficient to present here only *one* of the many series, serving to establish each of the laws determined.

The values of Y, as given in the tables, are always the mean of two experiments. After the distance Y of the spark micrometer from the rotating disk at which the sectors could be no longer distinguished had been once determined the micrometer was brought considerably nearer the disk again, and then removed the second time, until the sector disappeared. The two values of Y, thus determined, differed in the various series at most by one centimetre, a proof of the exactness attainable by this method of observation.

§ 90. *Variation of the brightness of the spark at different striking distances.*—On this point Masson made numerous experiments. The following table contains the results of one of them:

X.	Y.	$\frac{Y}{X}$
mm.	*mm.*	
2.5	318	127
3.5	447	127
4.5	572	127
5.5	697	126
6.5	830	127
7.5	957	127
	Mean......	127

Here X denotes the striking distance, Y the corresponding distance of the spark from the rotating disk, at which the sectors cannot be distinguished, under the condition that the constant illumination of the rotating disk from AC remained unchanged during the whole series of experiments.

It is evident, from the above table, that the striking distance and the corresponding distance of the spark from the rotating disk must vary in a constant ratio, the illumination of the disk remaining the same. Or, for double and treble striking distances, he spark must be removed two and three times as far from the disk, if its illumination by the spark is to remain the same.

By doubling the distance, the intensity of the illumination becomes four times feebler, but it remains unchanged if the striking distance is doubled, consequently the brilliancy of the spark mus tbe four times greater at double the striking distance. For the distance n the illumination by the electrical spark is n^2 times feebler, but it remains unchanged if the striking distance is made n times greater; hence, for a striking distance n the brilliancy of the spark must be n^2 times greater, or in other words, *the brightness of the electrical spark increases as the square of the striking distance.*

§ 91. *Influence of the size and form of the surface of the condenser.*—The form of the condenser (that is, the glass plate with metallic coating on both sides, the discharge of which passes through the spark micrometer) has no influence upon the brightness of the electrical spark if the extent of the coating remain the same. The size of the plate, however, has considerable influence.

With unchanged distance of the constant light and of the striking distance, and with the same thickness of glass, the surface of the coating was varied, and each time the corresponding distance of the spark from the rotating disk, at which the sectors just ceased to be perceived, was observed. The results of such a series of observations are given in the following table:

Surface in square millimetres.	Ratio.	Y.	Y^2.	Ratio.
		mm.		
22500	....	314	98596	....
40000	1.77	420	176400	1.78
60000	2.66	514	264196	2.67

The first vertical column contains the size of the surface of the coating, the second is the ratio of the first and second surfaces, and then of the first and third. The third column gives the corresponding Y, the fourth the square of this distance, and the last the ratio of the numbers of the first Y^2 to the second, and of the first to the third.

Comparing the second and fifth columns we have very plainly

$$\frac{F}{Y^2} = n, \tag{1}$$

that is, the superficial content F of the coating of the condenser is in proportion to the square of the distance Y, the illumination of the disk *ab* by the electrical spark remaining constant.

But the constant illumination of the disk is

$$J = c\, Y^2$$

J denoting the intensity of the light of the spark, and c a constant factor, or

$$\frac{J}{Y^2} = c. \tag{2}$$

Combining equations (1) and (2) we get

$$J = \frac{c}{n} F;$$

or, *the brightness of the electrical spark is proportional to the surface of the coating.*

§ 92. *Relation between the intensity of the electrical spark and the thickness of the condenser.*—The surface of the coating remaining the same, the thickness of the glass plate was changed; and for each plate the distance Y was observed at which the sectors just ceased to be visible, the illumination by the lamp remaining constant. The following table contains a few of the results obtained.

No.	Thickness of plate d.	Square root of thickness $\sqrt{d}$.	Y.
	mm.		*mm.*
1	1.31	1.14	1044
2	1.83	1.35	904
3	2.51	1.57	775

Now, $\frac{135}{114} = 1.18$ and $\frac{1044}{904} = 1.15$, that is, the two quotients are nearly equal, or $\frac{\sqrt{d''}}{\sqrt{d'}} = \frac{Y'}{Y''}$; moreover, $\frac{157}{114} = 1.27$ and $\frac{1044}{775} = 1.35$, or very nearly $\frac{\sqrt{d'''}}{\sqrt{d'}} = \frac{Y'}{Y'''}$; and, finally, $\frac{157}{135} = 1.16$, and $\frac{904}{775} = 1.17$, or $\frac{\sqrt{d'''}}{\sqrt{d''}} = \frac{Y''}{Y'''}$, therefore the values of Y are nearly in the inverse ratio of the square roots of the corresponding thicknesses of the glass; that is

$$\sqrt{d} = \frac{n}{Y}$$

or

$$d = \frac{p}{Y^2},$$

but we have $J = c\,Y^2$, hence

$$d \times J = c.\,p,$$

or

$$J = \frac{c\,p:}{d}$$

that is, *the intensity of the spark is inversely proportional to the thickness of the condenser.*

The remaining experiments which Masson made on this point did not coincide generally so well with the above deductions. This he ascribes to the circumstance that he could not measure the thickness of the glass with sufficient accuracy, and that the different condensers may have had unequal "capacities for condensation."

§ 93. *Influence of the nature of the pole on the electrical spark.*—Masson found that the spark is somewhat more intense, if, under circumstances otherwise the same, it be passed between lead, zinc, and tin balls, than when the balls (equal in size) are of copper, brass, or iron. Masson thinks that this depends upon the unequal tenacity of the metals. In all his experiments there were traces of a transportation of the metal from one pole to the other; now since lead, for example, is less tenacious than copper, more lead will be carried off than copper with the same tension of the electricity; the conducting circuit then will have its capacity for conduction suddenly increased, and the light must become more brilliant in consequence.

This opinion is sustained by the fact that the intensity of the spark is very considerably increased if polished brass balls be exchanged for such as have their surface amalgamated, where evidently the transference is greatly facilitated.

The spark, with the carbon used for Bunsen's battery, is very white in the middle, reddish at the edges, and looks a little like a flame.

§ 94. *Nature of electrical light.*—There are two hypotheses as to the nature of the electrical spark; the first regards it as a motion which is communicated to the ether by the electrical spark; according to the second hypothesis, electrical light is produced by incandescent ponderable matter transported by the electricity.

Masson inclines to the first hypothesis, with which also his experiments coincide, since the intensity of the spark depends in no respect upon the fusibility or oxidibility of the balls, but upon their tenacity. If, in consequence of the lower tenacity of the metals, more particles are carried off, the facility of the circuit for conduction is increased; hence the same quantity of electricity is discharged in a shorter time, whereby a more brilliant light is produced. All of the laws of the brightness of electrical light just mentioned are comprised by the following formula:

$$\mathrm{J} = \mathrm{H}\frac{\mathrm{X}^2 s}{\mathrm{Y}^2 e} \tag{1}$$

in which

J denotes the intensity of the spark;

X the striking distance;

s the surface of the condenser;

Y the distance of the spark from the rotating disk of the photometer;

e the thickness of the condenser, and H a constant factor depending upon elements which are not yet determined.

Substituting in equation (1), $\mathrm{X} = p\frac{q}{s}$, which is allowable, since Riess has shown that the striking distance is proportional to the electrical density (§ 31), we have

$$\mathrm{J} = \frac{m}{\mathrm{Y}^2} \cdot \frac{q^2}{s^2} s \tag{2}$$

by making $\frac{\mathrm{H}p^2}{e} = m$, that is, equal to a constant factor which is admissible so long as the thickness e of the condenser does not vary.

Hence the intensity of the electrical light is proportional to $\frac{q^2}{s^2}$ the square of the electrical density, or which is the same, to the tension of the electricity and the surface s of the condenser.

Equation (1) may also be written

$$\mathrm{J} = \frac{\mathrm{H}}{\mathrm{Y}^2 e}\mathrm{X}\, s\, \mathrm{X}$$

Substituting for the last X its value $p\frac{q}{s}$, we get

$$\mathrm{J} = \frac{p\,\mathrm{H}}{\mathrm{Y}^2 e}\mathrm{X}\, q. \tag{3}$$

or in words, the intensity of the spark is proportional to the striking distance and quantity of electricity.

According to equation (2),

$$J = \frac{m}{Y^2} \quad \frac{q^2}{s},$$

or

$$J = P \frac{q^2}{s}.$$

But Riess has shown that,

$$W = Q \frac{q^2}{s},$$

is the quantity of heat which is set free in the wire by discharging through it a quantity of electricity q, collected on the surface s.

Hence *if the discharge stroke of an electrical battery produces a spark at any interruption of the circuit, the intensity of the light is proportional to the heat which the same discharge produces in a piece of wire forming part of the circuit.*

At the conclusion of his memoir, Masson proposes the spark generated under determinate conditions as the photometric unit, by which it will be possible to compare the intensity of the most diverse constant sources of light with a common standard.

SECTION FIFTH.

ELECTRICAL ODOR.

§ 95. *Ozone and its reactions.*—When we are in the neighborhood of a powerful electrical machine we perceive, when the electricity issues from points, or when a series of sparks are passed from the conductor, a very peculiar odor, which, for sake of brevity, we will term *electrical odor*, or *ozone odor*. This electrical odor is very probably that which is observed after a stroke of lightning; and which, by those who do not know how to characterize it properly, is termed a sulphurous smell. Schönbein observed in the vicinity of a place where lightning had struck a decided odor of ozone, even some time after the stroke.

Until recently we were quite in the dark as to the nature of this odor. Some physicists supposed that it was owing to a peculiar affection of the organs of smell, produced by electricity; an explanation which, in addition to its error, did great injury, by preventing further investigation and discussion.

Others advanced the hypothesis that electrical odor was owing to fine metallic particles carried off by the escaping electricity. But this view also is entirely inadmissible, because the nature of the emitting points does not in the least change the nature of the odor.

Schönbein has the great credit of having restored this question to the current of scientific activity. He has shown that the electrical odor comes from a peculiar gas, produced during the electrical emission, which he calls *ozone*. He has investigated the properties of this substance for years with the greatest zeal, and although, as yet, it has not been obtained in an isolated state, many of its important chemical and physical relations have been ascertained, and further researches on the subject promise most interesting discoveries in the field of chemistry.

The first memoir of Schönbein on ozone is in the "*Denkschriften der Münchener Akademie.*" It is also printed in Poggendorf's Annalen. Bd. L. p. 616.

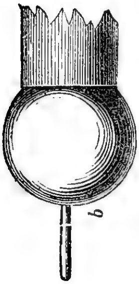
A small pamphlet with the title, "*On the production of ozone in the chemical way,*" evidently by Schönbein, was published in 1844 by Schönbein & Schweighaüser, in Basel.

The most important treatises on this subject which then followed are to be found in Poggendorfs Annalen, by reference to the index of names, appended to the LXXV volume.

In these papers the historical course of Schönbein's discoveries may be followed out. I will omit this historical investigation on account of its great extent, and I will not refer to the contents of the separate papers, but describe the most essential experiments which show the nature and most important relations of ozone, in the order in which Professor Schönbein had the goodness to show them to me in the year 1849, and, passing over their earlier phases, present his views upon its nature as now held, after many years investigation.

The prime conductor of an electrical machine being provided at the end with a round-pointed wire, *a*, *b*, about 1 line in diameter, (fig. 82.) When the machine is turned the peculiar *electrical odor* will be perceived in the vicinity of the end *a* of the wire.

Fig. 82.



That this odor is not to be ascribed to a mere subjective affection of the organ of smell, but is owing to a peculiar gas, is certain from the fact that this odorous principle produces a series of chemical and physical effects, having the greatest similarity to the chemical reactions and physical relations of other gases. Indeed, Schönbein has succeeded in preparing this odorous principle, *ozone*, in a purely chemical way, and in producing the same reactions with it which are observed when electricity is issuing from points.

If we hold before the point, at the distance of about $\frac{1}{2}$ or 1 inch, a piece of paper covered with a paste of starch and iodide of potassium, the paste will at once turn blue.

To make this preparation two teaspoons full of starch with a small crystal of iodide of potassium are to be boiled to a paste, with ten times their volume of water.

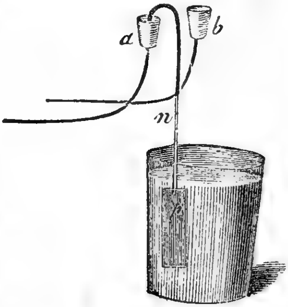
The ozone acts upon this paste as chlorine does; it decomposes the iodide of potassium, and the iodine set free, colors the starch blue.

This phenomenon (of turning the paste of iodide of potassium blue) takes place in the same manner whether the point emit positive or negative electricity; it is also perfectly immaterial of what substance the point is made, if only an emission of electricity occurs, thus refuting the view of those earlier physicists who maintained that the odor was owing to metallic particles carried off by the issuing electricity.

On holding a platinum or gold plate before the point while the machine is turned, the plate has imparted to it negative galvanic polarization, which can be demonstrated in the following manner:

Connect the two mercury cups *a* and *b*, Fig. 83, with the wire ends of a multiplier. Into the cup *a* dip a copper wire, to the other end of which a platinum plate *p* is fastened, the plate having been first soldered with gold to a platinum wire, and this to the copper wire at *n*. This platinum plate hangs in a glass vessel containing water slightly acidified.

Fig. 83.



After having exposed a perfectly similar platinum plate for a time to the electricity issuing from a point, immerse it also in the water of the glass vessel, and as soon as the copper wire of the second plate is immersed into the cup of mercury *b*, a considerable divergence of the galvanometer needle takes place, and in a direction which indicates that the platinum plate which had been exposed to ozone behaves negatively toward the other; that is, the deflection is in the same direction which would have been indicated had a zinc wire been placed in *a*, a copper wire in *b*, and these wires then immersed in the liquid of the glass vessel. This current, however, is only transient.

The whole subject of galvanic polarization we will discuss in another place;* it is only mentioned here as one of the effects which accompany the emission of electricity from points.

All these reactions disappear when sulphuretted hydrogen, ammonia, olefiant gas, &c., are diffused in the air of the room where the experiment is made.

If the emitting point be raised by the flame of a spirit lamp to a red heat, and the machine put in operation immediately after the removal of the lamp, all the above described phenomena, which had accompanied the escape of electricity, disappear; that is, the electrical odor is no longer perceived, the iodine preparation does not turn blue, platinum or gold plates are not polarized. All the phenomena reappear, however, gradually, as the point cools.

In order to make the experiment distinct, with reference to the odor, it must be made with wires of one of the precious metals, because the easily oxidable metals diffuse a peculiar smell simply by being heated. Very thin wires are not suitable for this experiment; but as thick

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* See report for 1855, p. 377.

ones may not always be at hand, it will do to use a thin platinum wire having its end fused into a small knob about one line in diameter.

§ 96. *Electrical odor in the electrolysis of water.*—The electrical odor appears not only on the escape of electricity from points, but also in the electrolytic decomposition of water, where we find it accompanied by the same reaction and effects which were considered in the preceding paragraph.

On closer investigation it appears that electrical odor manifests itself at the positive pole, where oxygen is given off; for on collecting the gases resulting from the decomposition of water separately, the odor in question was perceived only in that vessel which contained the oxygen, no trace of it being found in the one containing the hydrogen. The gases when obtained together have the electrical odor.

On suspending a paper covered with the paste of iodide of potassium in oxygen, or in the mixed gases to which the ozone odor has been imparted by electrolysis, the paper turns blue. A platinum plate exposed for a time to the action of this, gas indicates the same electro-negative polarization as though it had been acted on by the electrical brush.

Chemically pure oxygen gas produces none of these effects; it has not the odor, does not turn the iodide paste blue, and is not in the condition to polarize a platinum plate negatively.

The gas obtained by electrolytic decomposition produces, in all these cases, the same effects as the air which issues from a strongly electrified point.

§ 97. *Production of ozone in the chemical way.*—The so-called electrical odor can be produced by purely chemical means without any aid from electricity. A piece of phosphorus made perfectly dry by blotting paper, so that it has a clean surface, emits a peculiar alliaceous odor. Placing such a piece of phosphorus in a jar of air, the vapor of phosphorus will in the cold soon diffuse itself through the whole jar. A platinum plate being then suspended in the jar a short time it will be polarized *positively.*

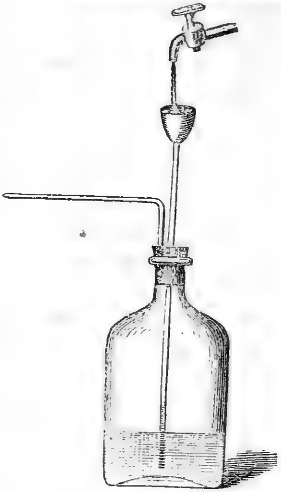
The polarization of the platinum plate is to be ascribed to the phosphoric vapor diffused in the jar, but the odor very probably is due to the phosphoric acid, which is formed by the partial oxidation of the phosphorus vapor.

If a little water be now introduced into the jar, (as much as will half cover the piece of phosphorus,) the phosphoric odor becomes weaker and weaker, and at length wholly disappears, and in its place a decided *ozone odor* will be perceived. At rather high temperatures the ozone smell appears very soon.

This odor is not to be distinguished from that produced in the electrical way, and it is accompanied by all the reactions and effects which characterize the agency of the electrical odor. A paper with the iodide paste on it becomes blue when suspended in the jar, and a platinum plate exposed to its action is polarized *electro-negatively.*

With the ozone obtained in the chemical way the reactions can be produced almost exactly in the same form as with a point emitting electricity. For this purpose a bottle of the capacity of several quarts is filled with air containing ozone, and closed with a cork, (Fig. 84.) having two holes bored in it. Through one of the holes a tube passes nearly to the bottom, having a funnel at its upper end; through the other hole a tube passes, which merely goes through the cork, and above the cork is bent horizontally, ending in a tolerably fine opening; water being poured through the funnel in a regulated stream, the air containing the ozone is driven out through the point of the other tube. This point now behaves exactly like a metallic point from which an electrical brush issues. By holding the nose to it the *electrical odor* will be observed; the iodide paper held before it turns *blue*, and a platinum plate exposed to the jet is polarized *electro-negatively*.

Fig. 84.



We have seen above that all the effects of ozone disappear when the point emitting the brush is heated, in like manner all the reactions of ozone disappear as soon as the horizontal part of the escape tube is strongly heated by a spirit lamp. The air which escapes from the opening of the hot tube has no longer any smell, it will not turn the iodide paper blue, nor polarize the platinum plate. But all these effects reappear on the cooling of the tube.

§ 98. *Chemical nature of ozone.*—Schönbein, the discoverer of ozone, has observed and investigated for years, with unwearied industry, the relations of this remarkable substance, and has found that it bears the greatest resemblance to the hyper oxides; he has finally come to the opinion that ozone is nothing else than a *gaseous peroxide of hydrogen.*[*]

Ozone is therefore formed by a further oxidation of the vapor of water contained in the air. Thus it is explained why water, or rather the vapor of water, is absolutely necessary to the formation of ozone. In perfectly dry air ozone cannot be obtained by means of phosphorus.

Electricity prepares the vapor of the atmosphere to oxidize further

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[*] At the present time, however, the view of nearly all of the chemists who have studied this subject is different from that given by the author. It is now generally conceded that ozone is nothing but oxygen, but there are two different views in regard to its nature; according to one, ozone is simply oxygen thrown into a condition of *activity* by the instrumentality of electricity or other agents above named.

The other view considers ozone as formed of two or more equivalents of oxygen. If, as some hold, gaseous oxygen be o_2, it could be easily shown that this double molecule undergoing decomposition, (even by reducing agents as phosphorus, the essential oils, &c.,) sets free o_1, (oxygen in the *nascent state,*) which might unite with o_2 to form $O\,o_2$, similar in properties to $S\,o_2$, (sulphurous acid,) sulphur and oxygen being elements capable of replacing each other to form analogous compounds as in the sulphurets and oxides.

We deem it moreover quite possible, in a measure, to reconcile the views of Schönbein with those last named, but this whole subject, being a purely chemical question, would be out of place in a report upon physical science, and has only been mentioned because the bare statement in the text might lead those not familiar with the matter into erroneous views. G. C. S.

and form ozone; in like manner phosphorus effects the combination of the vapor of water with oxygen, but, as yet, we are not able to tell *how* it is done.

Ozone is decomposed into its components, oxygen and hydrogen, by heat, as shown by the experiment noticed above.

De la Rive and Berzelius, indeed, regarded ozone as modified oxygen, and maintained that it could be produced by an electrical jet in dry oxygen, but this is contrary to all Schönbein's analogies. Schönbein presented the following experiment as the most striking proof of the presence of hydrogen in ozone: if air containing ozone be dried as perfectly as possible and then heated, it yields water on cooling to hydroscopic bodies over which it is passed. The ozone is decomposed by heat, and the vapor of water which it contained is set free.

Ozone is one of the most powerful means of producing oxidation which is known. Air containing ozone being passed for a long time over finely divided metallic silver, the latter is converted into *peroxide of silver.* The vapor of phosphorus is rapidly oxidized under the influence of ozone, and converted into phosphorous acid and phosphoric acid.

The fact that the passage of the electrical spark through moist atmospheric air forms nitric acid was discovered by Cavendish, in the year 1785. Schönbein has proved that under like circumstances ozone also is always formed.

Since ozone can be produced in moist oxygen by the help of the electric spark, it is evident that the formation of ozone is independent of that of nitric acid. On the contrary, Schönbein has made it appear highly probable that the formation of nitric acid is not a direct effect of electricity, but a secondary effect produced by the oxidizing influence of ozone on the nitrogen of the atmosphere.

The formation of nitric acid by electricity may be shown in the simplest manner, by exposing, for a time, a paper moistened with a solution of carbonate of potash to a jet of electricity escaping from a wire; the carbonate, under these circumstances, is converted in part into nitrate of potash.

The ozone formed by means of phosphorus also produces nitric acid. The mixture of phosphorous and phosphoric acids, which forms in a receiver containing a piece of phosphorus, water, and atmospheric air, is absorbed by water. If this water be colored by a solution of indigo, the color of the latter is immediately destroyed, an effect which neither phosphorous nor phosphoric acid alone can produce. The decoloring is effected by a small quantity of nitric acid, which, formed under the influence of the ozone, is also dissolved in the water.

That it is actually nitric acid which is here in question is proved by shaking the water with milk of lime; insoluble salts of lime are formed with the phosphorous and phosphoric acids, while a nitrate of lime remains in solution.

Davy observed that traces of nitric acid appeared at the positive pole of a pile when a voltaic current passed through water containing air or nitrogen. Here, also, the formation of nitric acid is a secondary effect of electricity. Ozone is first formed by the action of the current, and the ozone then oxidizes the nitrogen.

§ 99. *Illumination of phosphorus produced by ozone.*—It is well known that at low temperatures, slow combustion of phosphorus does not take place in air free from ozone, and there is therefore no illumination in the dark; this, however, appears as soon as ozone is brought into contact with the phosphorus. In a receiver containing ozonized air phosphorus shines at a very low temperature.

Schönbein has shown this very beautifully by presenting a stick of phosphorus, at a low temperature, to an electrical brush, which, in accordance with the above, determines the formation of ozone. The manner in which the experiment was made is as follows: (Pog. Ann., lxviii, 38.)

A piece of phosphorus an inch long, having a clear surface, was placed on a board in conducting connexion with the earth, and the free end of a wire, connected with the conductor of an electrical machine, brought within a few lines of the phosphorus. At a temperature of —2° the phosphorus by itself did not shine in the dark; but when the machine was put in motion, so that an electrical brush played against the piece of phosphorus, a light flame at once issued from its whole length, and, like the tail of a comet, extended far beyond the piece of phosphorus. If the machine be stopped the illumination of the phosphorus ceases in a few seconds.

Schönbein obtained a very beautiful illumination by the following arrangement: A copper wire was coiled around a stick of phosphorus an inch long, so that the end of the wire extended about a line beyond the phosphorus, as shown in fig. 85. The other end of the wire is connected with the conductor of an electrical machine. At a temperature below 0° the phosphorus did not shine at all in the greatest darkness; but in turning the electrical machine, so that a strong brush appeared at the end of the coil, a luminous cone protruded from the middle of the brush, which attained a length varying from a few inches to some feet, according to circumstances. The longest cone obtained by Schönbein was $2\frac{1}{2}$ feet. With powerful machines such cones should be obtained of still greater length.

Fig. 85.

It may be assumed without hesitation that this luminous train is nothing else than the vapor of phosphorus in slow combustion.

The luminous train vanishes with the electrical brush.

GALVANISM.

[Continued from page 423 of the Report of 1855.]

SECTION FOURTH.

GALVANIC PHENOMENA OF LIGHT AND HEAT.

§ 54. *Production of heat by the galvanic current*—The laws of the development of heat produced by the galvanic current in metallic wires, have been investigated by Joule, (Phil. Magazine, Oct., 1841,), and by Lenz, (P. A. LIX, pp. 203 & 407, LXI, p. 18.)

The memoir of Joule not being within my reach, I shall only report on the researches of Lenz, and this will be sufficient, since the results of the Russian and of the English physicist agreee.

The first two sections of the memoir of Lenz, in vol. LIX of Pog. Ann., contain only introductory matter, to which we shall but briefly refer.

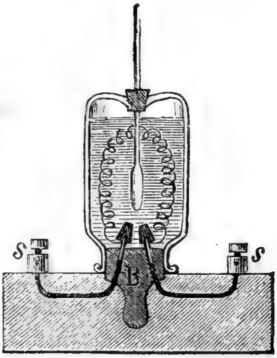
To measure the strength of the current Lenz made use of a Nervander's tangent compass, which was most carefully constructed and tested. He found by accurate experiments that up to 40° the strengths of the currents are proportional to the tangents of the angles of deflection.

Lenz also compared his tangent compass with the decomposition of water. It results, from his numerous and accurate experiments, that the tangent of the observed angle of deflection is to be multiplied by 39.3 in order to obtain the reduced quantity of detonating gas from the same current per minute, expressed in cubic-centimetres. Lenz takes for his unit a current which causes a deflection in his tangent compass of 1°, and this produces 0.686 c. c. of the mixed gases in a minute. Since our unit of current is that which gives 1 c. c. per minute, it is evident that Lenz's values of strength of current must be multiplied by 0.686 to reduce them to our unit. In what follows I shall always make use of the reduced values for the strength of current, instead of those of Lenz.

As the unit of resistance Lenz takes the resistance of one wind of his rheostat (agometre) of German silver, which, according to his statement, is equal to the resistance of a copper wire of 6.358 English feet in length, and 0.0336 English inch in diameter. Hence, it appears that this unit of resistance is equal to 2.66 of our own; the values of Lenz must therefore be multiplied by 2.66 to reduce them to our unit.

To measure the heat produced by the galvanic current in a metallic ire, Lenz used the apparatus represented in Fig. 47.

Fig. 47.



In the middle of the board is fastened the lass stopper B, ground to fit into the neck f a glass jar which, by means of some grease, ay be fitted upon it air and water-tight. brass clamp, omitted in the figure, presses he lower rim of the neck of the jar to the oard, so that it cannot be displaced even by iolent motions of the apparatus. The jar as ground in its bottom a cylindrical hole, nto which the fluid can be poured, and hrough which, also, a thermometer can be inserted by means of a cork. The thermometer used was divided to $\frac{1}{5}$ of a degree. Two pieces of wire of about 1 line in diameter are passed through perforations in the glass stopper and cemented there. Their upper extremities projecting into the jar are somewhat conical, and made of platinum; these platinum cones are soldered to copper wires of equal diameter, which, let into the board, pass to the screw-clamps *s*, into which the conducting wires from the poles of the battery are screwed. The wire to be heated is previously coiled into a spiral around a cylinder of 1—2 lines in diameter, and has its ends clamped upon the cones by means of two little pieces of platinum. It remains erect by its own elasticity, its coils not touching anywhere.

The fluid with which the jar was filled, so far at least as entirely to cover the wire-spiral, was spirit of wine containing 85 to 86 per cent. of alcohol, for water is so good a conductor that a part of the current would pass through it and not through the wire, as becomes immediately apparent from the feeble evolution of gas.

After the wire-spiral was properly fastened and a measured quantity of spirit of wine poured into the jar the apparatus, together with the multiplier (Nervander's tangent compass) and the rheostat, were inserted in the circuit of a Daniell's battery. By means of the rheostat the current was always kept at a constant strength; and then the time required to raise the thermometer in the spirit of wine a certain number of degrees was noted. By turning round the apparatus in a small circle, the fluid was made to rotate, whereby an equal distribution of the temperature throughout its mass was produced.

In order to avoid the errors arising from the loss of heat to surrounding bodies, the spirit of wine was previously cooled below the temperature of the air, and the experiment finished when its temperature was just as many degrees above that of the surrounding air as it had been below it at the commencement.

To give a clear idea of the course of the investigation, the individual steps for one series of experiments will be described at length.

The temperature of the air being 16° R, the spirit of wine was cooled by means of ice down to 7° and poured into the jar; the circuit was closed and the needle by means of the rheostat constantly kept at 35°; next, with a watch marking seconds, the exact instant was observed when the temperature of the spirit was 10, 11, 12, 13, 14, and

15 degrees, and also the instant when it was 16, 17, 18, &c., to 2 degrees. In this way it was found that the time required to raise th temperature of the spirit of wine from—

15	to	17	viz:	2°	was	1.05	minutes.
14	"	18	"	4	"	2.22	"
13	"	19	"	6	"	3.25	"
12	"	20	"	8	"	4.30	"
11	"	21	"	10	"	5.42	"
10	"	22	"	12	"	6.53	"

and hence it follows that the time *t*, necessary to raise the temperature of the spirit of wine 1°, was on an average 0.542 minutes.

The resistance to conduction of the spiral wire was ascertained by observing, (after the removal of the apparatus of fig. 47 from the circuit,) how many turns of the rheostat had to be inserted, in order to bring the current again to the same strength that it had with the heating apparatus in the circuit.

The following table contains the results of a great number of such experiments:

No. of set of experiments.	Kind of wire.	*s*.	*t*.	*l*.
1.	German silver, *a*.	6.93	1.349	93.50
2.	do	10.53	0.571	93.63
3.	do	14.30	0.300	93.94
4.	German silver, *b*	10.53	0.920	58.76
5.	do	14.30	0.481	58.64
6.	do	18.32	0.288	59.01
7.	do	14.30	0.457	60.16
8.	German silver, *c*	18.32	0.384	44.59
9.	Platinum	14.30	0.555	50.45
10.	do	18.32	0.325	51.41
11.	Iron	22.69	0.435	24.92
12.	Copper	18.32	1.301	13.90
13.	do	22.69	0.835	13.90
14.	do	27.52	0.575	13.92
15.	do	32.98	0.381	14.01
16.	do	27.52	0.544	14.31

Three different wires of German silver were used in the experiments; that designated by *a* was the thinnest; *b* was a little thicker than *a* and *c* a little thicker than *b*.

In this table *s* denotes the force of the current; *l* the resistance to conduction of the wire, expressed in units; and *t* is the time necessary to raise the temperature of the spirit of wine 1°. How the value of *t* was determined each time from a series of experiments has already been stated above.

The quantity of spirit of wine poured into the jar was always nearly the same, or 90 grammes on an average.

If we compare all those series of experiments in which the force of he current was the same, it appears that the product of t and l remains pretty nearly constant. It is—

For the current 10.53:
(2.) German silver, *a*.......................... $t\,l = 53.46$
(4.) German silver, *b*.......................... $t\,l = 54.06$

For the current 14.30:
(3.) German silver, *a*.......................... $t\,l = 28.18$
(5.) German silver, *b*.......................... $t\,l = 28.11$
(7.) German silver, *b*.......................... $t\,l = 27.49$
(9.) Platinum .... $t\,l = 28.00$

For the current 18.32:
(6.) German silver, *b*.......................... $t\,l = 16.99$
(8.) German silver, *c* .... $t\,l = 17.12$
(10.) Platinum .... $t\,l = 16.71$
(12.) Copper...................................... $t\,l = 18.08$

For the current 22.69:
(11.) Iron.. $t\,l = 10.84$
(13.) Copper...................................... $t\,l = 11.60$

The equality of the values of $t\,l$ for one and the same current is so apparent that we may safely assume that the time of heating is inversely proportional to the resistance to conduction, or in other words, that the heat produced in a given time is directly proportional to the resistance to conduction, and independent upon other properties of the metal.

In order to find out how the production of heat depends on the force of the current, we must compare the experiments that were made with the same wire, and with different currents; from these it appears that the value of s^2t is nearly constant for the same wire. The results are as follows:

For the German silver wire *a:*
1 .... $s^2t = 64.8$
2 .... $s^2t = 63.3$
3 .... $s^2t = 61.3$

For the German silver wire *b:*
4 .... $s^2t = 102.0$
5 .... $s^2t = 98.4$
6 .... $s^2t = 96.7$
7 .... $s^2t = 93.5$

For the platinum wire:
9 .... $s^2t = 113.5$
10 .... $s^2t = 109.1$

For the copper wire:
12 .... $s^2t = 436.6$
13 .... $s^2t = 429.9$
14 .... $s^2t = 435.5$
15 .... $s^2t = 414.2$
16 .... $s^2t = 412.0$

By these experiments, therefore, it is demonstrated that:

1. *The production of heat is proportional to the resistance of the wires to conduction.*

2. *The production of heat is proportional to the squares of the forc of the currents.*

If, therefore, t denotes the time which is required for the current with the resistance to conduction l, to raise the temperature of a give quantity of spirit of wine 1° R. then $s^2 t l$ will be the time necessary t produce the same amount of heat in the same quantity of spirit, b the unit of the strength of current with the unit of resistance to con duction. Since now in all the experiments the quantity of spirit c wine was nearly the same, the product $s^2 t l$ must also be nearly th same for all of the series in the above table. The product $s^2 t l$ ha the following values for the different series of experiments:

Series.	$s^2 t l$.
1	6059
2	5927
3	5758
4	5994
5	5770
6	5706
7	5625
8	5747
9	5726
10	5609
11	5975
12	6069
13	5976
14	6062
15	5803
16	5896
Mean	5856

The quantity of spirit heated in these experiments together with that of the glass, reduced by the relation of the specific heats to spirit was 118 grammes.

The unit of the force of current produces, therefore, when passing through a wire which offers the unit of resistance to conduction, as much heat as would be required to raise the temperature of 118 grammes of spirit of wine 1° R. in 5856 minutes.

The specific heat of the spirit used in the above experiments is 0.7 to raise, therefore, the temperature of 118 grammes of spirit to a given degree requires the same quantity of heat as to raise 118.07 = 82.6 grammes of water to the same degree. For 1 gramme of water therefore, that time amounts to:

$$\frac{5856}{82.6} = 70.9 \text{ minutes;}$$

or if instead of Reaumer's scale that of Celsius is employed, 70,9 . 0,8 = 56.72 minutes,* *i. e.*, when the unit of the force of current passes through a wire, the resistance of which is equal to that of a copper wire of 1 meter in length and 1^{mm} in diameter, the quantity of heat produced is such as would raise the temperature of 1 gramme of water 1° C. in $56\frac{3}{4}$ minutes.

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* In the memoir of Lenz, an error occurs in this calculation, (Pog. Ann., LXI, 42,) occasioned probably by mistaking minutes for seconds.

If we take for the unit of heat, as is usually done, that quantity which raises the temperature of one kilogramme of water 1°, then it follows from the above investigations that the unit of the force of current, in passing through the unit of resistance produces in it 0.001057 units of heat in one hour and 0.0000176 in one minute.

§ 55. *Observations on the results obtained by Lenz.*—After Lenz had determined the relation between the force of current and the production of heat in a metallic circuit, the idea naturally occurs that we might compare the heat produced in the circuit wire with the quantity of detonating gas produced by decomposition of water in the exciting cells, but a more intimate study of the subject soon proves that such a comparison cannot lead to a constant result.

If there be a fixed relation between the quantity of detonating gas and the production of heat for any given arrangement of the Voltaic battery and a given closing wire, it will be changed as soon as—*cœteris paribus*—either the specific resistance to conduction of the battery or its electromotive force is changed; for by either of these changes the strength of current is altered, and the evolution of gas changes proportionally with the force of current, while the production of heat increases as the squares of this force; and the relation between the quantity of gas and the heat developed must necessarily become different from what it was before. The heat produced in the closing circuit, therefore, can by no means be considered as a thermal equivalent of the detonating gas evolved in the exciting cells, and consequently there can be no definite relation between the heat produced by exploding a certain quantity of detonating gas, and that set free in the closing circuit during the evolution of an equal quantity of gas in the exciting cells of a galvanic battery.

The attempt to compare, even with only approximate correctness, the quantity of electricity of the electrical machine with that of Volta's apparatus, has always, hitherto, been unsuccessful. After Lenz's accurate researches on the production of heat by the galvanic current, and Riess' reliable quantitative determinations of the heat set free in a wire by the passage of the discharge of a Leyden jar, at first sight it would seem that a basis was found for this comparison. But here too the result on examination is a negative one.

From the rather large quantity of heat produced in metallic wires by the discharge of the jar, we should be disposed to infer that a rather large quantity of electricity was brought into action thereby; according to the experiments before mentioned* the increase of heat in the platinum wire of the air thermometer for $\frac{q^2}{s} = 1$ is equal to 0.3787, or in round numbers equal to 0.4. That wire had a diameter of $0.072'''$ and a length of $59.7'''$ and therefore it weighed about 60 milligrammes; to raise the temperature of this wire 0.4° requires, as can easily be computed, 0.000000768 units of heat.

Let us now consider what quantity of heat would have been set free in the same platinum wire by the unit of galvanic current. In the

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* See Report of 1856, p. 437.

unit of resistance, the unit of current produces 0.0000176 units of heat per minute; but the resistance to conduction of such a platinum wire, as can easily be calculated, is equal to 6 and consequently by the unit of current, $0.0000176 \times 6 = 0.0001$ units of heat would have been produced in it. The increase of temperature in the platinum wire from the discharge of the jar for $\frac{q^2}{s} = 1$, viz: 0.00000768 is therefore nearly $\frac{1}{100}$ of that produced by the unit of force of the current during one minute in the same wire. When $s = 1$, *i. e.* when the electricity is accumulated in *one* of the jars (mentioned in the experiment above quoted,) q must also be equal to 1. For $s = 1$ and $q = 10$, *i. e.* when the jar is charged with 10 sparks from the measuring jar under the circumstances formerly explained, then its discharge must produce in a metallic wire an increase of heat nearly equal to that produced by the unit of current during one minute in the same wire. But to charge the jar with $q = 10$, the machine will scarcely require to be turned for one minute, and therefore the inference might be drawn from a superficial investigation of the production of heat, that turning the machine for one minute would produce a quantity of electricity equal to the chemical unit of the galvanic current.

But that such a comparison, or rather such a conclusion from the comparison can not at all be admitted, is evident from the fact, that by means of the electrical machine no perceptible decomposition of water can be obtained, while one cubic centimetre of detonating gas ought to be readily evolved per minute.

But a more careful investigation soon shows that the discharge of the jar and the galvanic current act under entirely different and not comparable conditions, in producing heat in the wire.

The same charge of the jar when passing more slowly through a wire produces less heat in it, and the increase of temperature becomes imperceptible as soon as the time of discharge reaches a measurable duration; if, therefore, the quantity of electricity, obtained by turning the machine for one minute, when accumulated in the jar produces by its discharge perceptible heat, the same quantity of electricity discharged through the wire in a continuous current during one minute, will not perceptibly raise the temperature of the wire. But only such a current can be compared with the galvanic. In order to compare the electricity of the machine with that of the battery in relation to quantity, we should be able to measure the quantity of heat which is produced in a metallic wire by the electricity passing through it from the conductor of the machine. The instantaneous discharge of an accumulated quantity of electricity cannot directly be compared with a continuous current. That the process by which heat is evolved in the discharge of the Leyden jar is entirely different from that of the galvanic current, is also evident from the fact, that with the former not only the quantity of electricity discharged through them is concerned, but also the area of surface upon which it was previously distributed; thus, in the production of heat by the discharge of the jar, factors come into question which with the current do not appear at all. The galvanic current and the discharge of the jar have, as far as regards the production of heat in metallic wires only this in common, that the rise of temperature is proportional to the square of the quantity of electricity and to the resistance of the conducting wire.

§ 56. *Ignition of metallic wires by the galvanic current.*—While the phenomena of the ignition of metallic wires by means of the discharge of the Leyden jar have been elucidated by the ingenious researches of Riess, corresponding investigations are wanting in reference to the galvanic current, though the latter might probably offer less difficulties than the former.

In Casselmann's treatise (already mentioned) "On the galvanic carbon-zinc battery, Marburg, 1844," the following remark occurs on page 43:

"A platinum wire of considerable length used for closing the circuit, does not become red hot, but when shortened to a certain length it does. Lessening this, however, by shortening it more and more it reaches finally a length at which it does not become red hot any more, and from this it follows that the ignition of the closing wire reaches a maximum only when its resistance to conduction bears a certain proportion to the quantity of electricity forcing its way through it."

If the current of a battery makes a wire red hot by passing through it, still the force of this current must increase by shortening the wire, and it therefore appears not quite probable that the stronger current should no longer heat the shorter piece of wire to redness. To throw some light on this point, I made a series of experiments myself, since, as above remarked, no thorough investigations have been made on this law of ignition in the galvanic current.

My experiments were made in the following manner: In the circuit of the battery S (fig. 48) there was inserted at H, a wire-holder, which will next be described, and at B, a tangent compass. At Q there was a little mercury cup, by means of which the circuit could readily be opened and closed.

The wire-holder is represented in fig. 49. Upon a board two brass rods were fastened, on each of which were two screw clamps capable of sliding up and down.

Fig. 48.

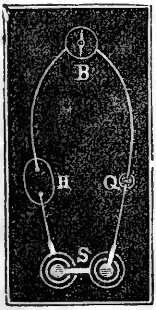
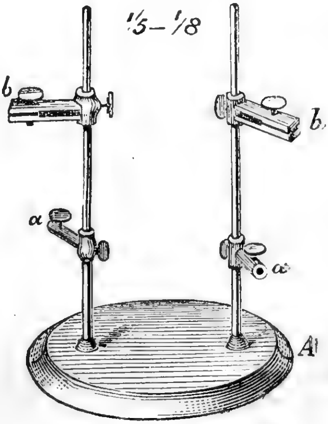


Fig. 49.

1/5 – 1/8



In one of the clamps *a*, the connecting wire from one pole of the battery was screwed and in the other that leading to the tangent-compass. Between the clamps *b*, the experimental wires were extended and this was always done before closing the battery. The connecting wires between *S*, *H*, *B*, *Q* and *S*, were copper wires about ¾ line in diameter, and of a total length not exceeding 5 metres, so that their resistance was not considerable.

After the wire to be experimented upon was properly inserted at *H* and all the other connexions properly made, the circuit was closed at *Q;* and, after the compass needle had come to rest, its deflection was observed and at the same time the appearance of the ignition in the wire.

The course of the experiments will become evident from the following tables which contain the results of the observations.

The first three sets of experiments were made with platinum wire of 0.45 millimetres in diameter.

FIRST SERIES.

Battery of 40 *carbon-zinc cups.*

Length of wire.	Deflection of compass needle.	Appearance of ignition.
Metres.	°	
1.5	45	
1.3	46	Feeble, only in some spots.
1.1	47	Feeble throughout the whole length.
1.0	48	Red hot.
0.8	50	Bright red.
0.5	56	Nearly white hot.

SECOND SERIES.

Battery of 24 *carbon-zinc cups.*

0.6	44	
0.5	45	Feeble, only in some spots.
0.4	46	Somewhat increased.
0.3	48	Red hot throughout the whole length.
0.1	51	Bright red.

THIRD SERIES.

Battery of 12 *carbon-zinc cups.*

0.3	46	Feeble, nearly throughout the whole length.
0.3	47	Still feeble throughout.
0.2	48	Red hot.
0.1	50	Bright red.

Two series of experiments with an iron wire of 0.42 millimetre in ameter gave the following results:

FOURTH SERIES.

Battery of 24 carbon-zinc cups.

Length of wire.	Deflection of compass needle.	Appearance of ignition.
Metres.	°	
1	32	In some places.
0. 8	33	Not quite throughout the entire length.
0. 6	34	Red hot.
0. 4	35	Bright red.
0. 3	----------------	Melted.

FIFTH SERIES.

Battery of 12 carbon-zinc cups.

0. 5	32	In some places.
0. 4	33	Somewhat increased.
0. 2	35	Intensely red hot.
0. 1	----------------	Melted.

In reference to the experiments with iron wire it is to be remarked hat in each one a new piece was inserted, because by ignition the urface was oxydized, and consequently the wire was altered.

These experiments prove *that one and the same wire produces, with he same strength of current, the same phenomena of ignition, whatever nay be its length.*

In the platinum wire of 0.45 metre in diameter a partial ignition s produced by a strength of current corresponding to a deflection of 45° to 46°. With 40 elements this is effected in a wire of 1.3 netre in length, with 24 cups in one of 0.5 metre, and with 12 cups n one of 0.4 metre.

The red heat appears in all these experiments with a force of current of 48°, while in the first series the length of wire is 1 metre, in he second 0.3 metre, and in the third 0.2 metre.

The light red heat occurs with a strength of current of 50 to 51°.

Quite similar are the results from the experiments with the iron wire. Partial ignition appears with a force of current of 32° to 33°, intense red heat with 35°. These experiments therefore do not show the peculiarity mentioned by Casselmann. It is to be regretted that he gives no more exact details, from which perhaps the reason of the anomaly observed by him could be explained. I presume, however, that it is caused by the great conduction of heat by the mass of the metal in the wire clamps, which has a considerable influence with very short wires.

Casselmann used a wire-holder similar to that represented in fig. 4 By observing attentively a wire held by it while it is red hot, w perceive that in the immediate vicinity of the clamps its glow is cor siderably less than in the middle. If now the wire be so far shortene that the cooling influence of the clamps extends to its middle it seem easy to explain how, by shortening the length of the wire, the phe nomena of ignition finally disappear. This is also seen from th following observation:

A platinum wire 0.21 metre in diameter was inserted in the circui of a single carbon-zinc cup. With a length of 3 centimetres it be came feebly red hot, while the tangent compass indicated 26°; bu when the same wire was shortened to 1 centimetre no ignition was produced, even with a current of 34°.

When, instead of the single element, two Bunsen's cups were used the appearances of ignition were entirely identical with the length of both 3 and 1 centimetre, though the corresponding deflection i the former case was 34°, and in the latter (the shorter wire) 44°.

§ 57. *Relation between the diameter and force of current in metalli wires ignited by the galvanic current.*—The above experiments do no illustrate the relation between the force of current and the diamete of the wires, as corresponding to a certain degree of ignition, becaus only the length, but not the diameter of the wire, was varied.

The following table gives the results of a set of experiments mad with platinum wires of 1 decimetre in length and variable diameters

Diameter, D.	Degree of ignition.	Deflection, v.	Force of current, $s = 70$, tang. v.	$\frac{s}{D}$
mm.		°		
0.3	Feeble	34	47.18	163.9
	Red hot	36	50.82	169.4
	Bright red	38	54.67	182.2
	Very bright red	42	63.00	210.0
0.39	Feeble	43	65.24	163.7
	Red hot	46	72.45	185.5
	Bright red	48	77.77	199.5
0.45*	Feeble	47	75.06	166.6
	Red hot	48	77.77	172.2
	Bright red	50.3	84.42	187.6
	Nearly white hot	56	103.74	230.3
0.75	Red hot	60	121.24	161.7
	Bright red	66	157.22	209.3

The experiments marked * are taken from the former series, (o page 420.)

From this series of experiments we may assume that, *in order t produce the same degree of ignition, the force of current must increas proportionally to the diameter of the wires.* According to this law, fo th same degree of ignition the quotient of the diameter of the wire ito the corresponding force of current should be a constant quantity. Te last column of the previous table contains this quotient. It is:

For feeble ignition—

With the diameter.		Deviation from the mean.
0.3	163.9	— 0.8
0.39	163.7	— 1.0
0.45	166.6	+ 1.9
Mean.........	164.7	

For red heat—

0.3	169.4	— 2.8
0.39	185.5	+ 13.3
0.45	172.2	0
0.75	161.7	— 10.5
Mean.........	172.2	

For bright red heat—

0.3	182.2	— 12.4
0.39	199.5	+ 4.9
0.45	187.6	— 7.0
0.75	209.3	+ 14.7
Mean.........	194.6	

For very bright red, nearly white heat—

0.3	210.0	— 10
0.45	230.0	+ 10
Mean.........	220.0	

The deviations from the mean are so irregularly distributed, in spect to their quantity as well as to their sign, that without hesitaon we may attribute them to errors of observation. That these eviations are so considerable, varying up to 7 per cent. of the corsponding quotients, will not surprise us if we consider that the egrees of ignition are not measured, but only *estimated*.

A set of experiments similar to the above, with iron wire, gave the llowing results:

Diameter. D	Degree of ignition,	Deflection. v.	Force of current. $s = 70$, tang. v.	$\frac{s}{D}$.
0.2	Feeble.	19°	24.08	120.4
"	Red.	20	25.41	127.0
0.255	Feeble.	24	31.15	122.1
"	Red.	25	32.62	127 9
0.38	Feeble.	34	47.18	124.1
"	Red.	38	55.67	146.1
0.75	Feeble.	52	89.6	119.4
"	Red.	56	103.74	131.3

The quotient $\frac{s}{D}$ is therefore:

For feeble ignition—

With the diameter.		Deviation from the mean.
0.2	120.4	— 1.1
0.255	122.1	+ 0.6
0.38	124.1	+ 2.6
0.75	119.4	— 2.1
Mean.........	121.5	

For red heat—

0.2	127.0	— 7.8
0.255	127.9	— 6.9
0.38	146.1	+ 11.3
0.75	138.3	+ 3.5
Mean.........	134.8	

This series therefore confirms the results we obtained from the experiments with the platinum wire.

With *copper* wire the following results were obtained:

Diameter.	Degree of ignition.	Deflection.	Force of current.	$\frac{s}{D.}$
D.		$v.$	$s = 70.\ \text{tang.}\ v.$	
0.2	Feeble.	48°	77.77	388.8
"	Red.	52	89.60	448.0
0.255	Red.	59	116.48	418.3
With *silver* wire:				
0.2	Red.*	51	86.45	432.2
0.255	Feeble.	57	107.80	422.7

§ 58. *Comparison of the laws of galvanic ignition with those of Len for the development of heat.*—According to the laws of Lenz, the quantity of heat liberated in a metallic wire increases proportionally t the square of the force of the current, and to the resistance to conduction of the wire. But with equal length the resistance to condu tion is inversely proportional to the square of the diameter. I therefore—all the other conditions remaining unchanged—the forc of current increases as the diameter of the wire, the quantity of hea developed must remain the same.

But if in a thicker wire just as much heat is evolved as in a thinne one, we should certainly expect that the former would not attain th same degree of ignition as the latter, because the thicker wire impart more heat to the surrounding air; therefore, in order to obtain a equal degree of ignition in a wire of n times the diameter, we shoul have to employ a current more than n times stronger, while accordin to the above experiments a current with n times increased force sufficient.

Let us more accurately determine this relation. According to th researches of Lenz, above discussed, the heat produced in metalli

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* Melted after a while.

wires by a galvanic current is proportional to the square of the force of current and to the resistance to conduction of the wire. We can, therefore, put

$$W = s^2 \, l \; . \; . \; . \; . \; 1.)$$

where W denotes the quantity of heat produced (within a given time) in a wire, the resistance of which is l for the strength of current s. We may now consider W the quantity of heat which must be produced in a given time in the wire in order to make it red hot. If this wire be replaced by one of the same metal and of equal length, but n times the diameter, its surface will also be n times as great, and this surface gives to the surrounding air—*cœteris paribus*—n times as much heat, and therefore n times as much heat, viz: n W, must be evolved in the thicker wire in order to produce the same appearance of red heat. But the resistance to conductions of the wire of n times greater diameter is $\frac{l}{n^2}$. Denoting by s' the strength of current which makes it red hot, we obtain the equation:

$$n \, W = s'^2 \, \frac{l}{n^2} \; . \; . \; . \; .$$

therefore,

$$W = s'^2 \, \frac{l}{n^3} \; . \; . \; . \; . \; . \; . \; . \; 2)$$

and by combining the equations 1) and 2)

$$s'^2 = n^3 \, s^2$$

or

$$s' = s \, \sqrt{n^3} \; . \; . \; . \; . \; . \; . \; 3).$$

Thus, according to this reasoning, a current of 2.83 and 5.19 times the strength should be necessary in order to make red hot, wires, the diameter of which is twice or three times as great, while, according to my observations, a two and three times stronger current proves sufficient; in short, instead of equation 3), according to my observations, that of $s' = n \, s$ holds good. The deviations are far too considerable to allow of the supposition that they proceed from errors of observation.

How this difference is to be accounted for I am at present unable to decide. It is, indeed, conceivable that with thicker wires and an equal strength of current the outermost stratum reaches so low a temperature that the loss of heat is not greater than from thin wires, but that towards the interior the temperature increases so rapidly that the outer colder strata have no perceptible influence upon the appearance of the wire. Small differences, too, are lost by the defective estimation of ignition, and it is therefore to be expected that deviations from the above law relating to the thickness will be found, when the diameter is more varied than in these experiments. I intend to continue the investigation of this subject.

The laws of ignition by the galvanic battery and by the discharge of the Leyden jar differ entirely. While the strength of current must be increased in equal, or at least nearly equal proportions to the diameter, the charge in the Leyden jar has to be augmented in proportion to the fourth power of it, if the degree of ignition is to be kept unchanged. This difference already shows that the galvanic ignition is essentially of another nature from that produced by the discharge of the jar.

§ 59. *Determination of the voltaic combination required to produce ignition in given metallic wires.*—The mean values above obtained for the quotient $\frac{s}{D}$ indicate the force of current necessary to bring a wire of 1 millimetre in diameter into the corresponding degree of ignition. Therefore, for a platinum wire 1 millimetre in diameter, to make it feebly red the force of current required is 165; to make it red hot the force of current required is 172; to make it nearly white hot the force of current required is 220.

For an iron wire 1 millimetre in diameter to make it feebly red the necessary force of current is 121; to make it red hot the necessary force of current is 135. To make a copper wire 1 millimetre in diameter red hot a force of current of 433 is required; for silver this value is 432.

I consider these numerical values only as first approximations.

Denoting by s the force of current which is required to bring a wire 1 millimetre in diameter to a certain state of ignition, then $s.d$ indicates the force required to produce an equal amount of heat in a wire of the same metal whose diameter is d.

If once we know the force of current a required to produce a certain degree of ignition in a piece of wire of given diameter, and also the resistance to conduction r, which this wire in connexion with the other part of the closing circuit offers, then it is easily computed what com- bination of voltaic elements, of a known nature, has to be employed for the purpose.

Let e denote the electro motive force, w the specific resistance of one of the cups employed. These have to be so combined that they form a battery of n elements, each consisting of m cups placed together. Now, the values of n and m are to be determined.

The cups must be so combined that the resistance of the battery is equal to that of the closing wire; the total resistance, therefore, must be equal to $2r$. We have, therefore,

$$\frac{ne}{2r} = a,$$

and

$$n = \frac{2ra}{e}$$

But the specific resistance of our battery is

$$\frac{n}{m} w = r.$$

Therefore,

$$m = \frac{n}{r} w;$$

and the value for n being substituted,

$$m = \frac{2wa}{e}$$

If, for instance, a platinum wire of 1.5 metre in length and 0.5 millimetre in diameter is to be heated to redness, how many Bunsen's cups, of the electro motive force of 800 and the resistance of 10, must be used and how are they to be combined?

The resistance to conduction of a copper wire 1 millimetre in diameter and 1.5 metre in length is 1.5; that of a like platinum wire is 5.1,5 =7,5. But the resistance of a wire of one-half the diameter is four times as great, viz : 30. This would be the resistance at the usual temperature; but when the wire is red hot it is at least twice as great, viz : 60. If we suppose that the resistance of the other part of the closing circuit is comparatively so little that it may be neglected, we have $r = 60$, and, for our case, $a = 172.0{,}5 = 86$. Therefore,

$$\frac{n.800}{120} = 86, \text{ consequently, } n = 12{,}9$$

$$\frac{12.9}{m}\,10 = 60, \text{ consequently, } m = 2{,}1\,;$$

from which it follows that a battery of 12 double elements has to be employed.

It is evident from this example that in the above mentioned experiments the arrangement was not the most advantageous.

If a copper wire 1 millimetre in diameter and 0.5 metre in length is to be heated to redness, its resistance would be 1, supposing it to be twice as great at a red heat as it is at the usual temperature. If the resistance of the rest of the closing circuit is also equal to 1, its total will be equal to 2; but a in this case is 433, and therefore

$$n = 2.16, \quad m = 10.8.$$

We have, therefore, to use a battery of two elements, each of which consists of 11 cups.

A more accurate knowledge of the resistance to conduction of metals at a red heat would be necessary to give a greater degree of exactness to these calculations.

In general more cups in a series will be required for producing ignition if the wires are bad conductors and of greater length, and more cups, side by side in each element, if they are good conductors and of greater diameter.

§ 60. *Ignition of metallic wires in different gases.*—Grove has made the remarkable observation that platinum wire heated to redness by the voltaic current in atmospheric air, is apparently extinguished when covered with a bell-glass, filled with hydrogen.—(Phil. Transact., 1847, pt. 1; Pog. Ann., LXXI, 196.) Since the resistance to conduction is greater in a wire intensely ignited than in one the heat of which is less intense, it was to be expected that, *cæteris paribus*, the same wire when in hydrogen would conduct a stronger current than in atmospheric air.

Grove proved the correctness of this conclusion in the following manner: In the circuit of a constant battery besides a platinum wire, which could conveniently be surrounded by an atmosphere of different gases, a voltameter was inserted. The intensity of ignition in the platinum wire was found to be very different in the different gases, but, at the same time, the rate of the decomposition of water in the voltameter was also changed, so that in equal times the quantity of detonating gas obtained was greater as the heat evolved by the wire was less. The following quantities of detonating gas were obtained per minute in the voltameter when the platinum was immersed in the gases enumeated:

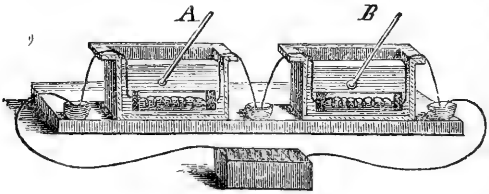
In hydrogen	7.7	cubic inches.
olefiant gas	7.0	"
carbonic oxide	6.6	"
carbonic acid	6.6	"
oxygen	6.5	"
nitrogen	6.4	"
atmospheric air	6.4	"
do. condensed	6.5	"
do. rarified	6.3	"
chlorine	6.1	"

With the appearance of light in the wire, the heat produced in it also is greater, as is demonstrated by the following experiment: The bulb of a thermometer was placed at a certain distance from a coil of wire, which was heated to redness by a battery of 4 cells. When the coil remained in atmospheric air the thermometer rose 15° in five minutes, but when it was immersed in hydrogen the rise, during the same interval, was only 7.5°.

Poggendorf, in a note, expresses the opinion that this phenomenon may be connected with the observation formerly made by Dulong and Petit, that a heated body is more rapidly cooled in hydrogen than in atmospheric air. To me this view seems inadmissible, for if the wire in hydrogen gives out more rapidly the heat developed in it, the thermometer ought to rise more rapidly when the wire is placed in this gas, provided the quantity of heat produced in the wire by the galvanic current is always the same in whatever gas it is placed.

This experiment, however, is not yet decisive; but another one, described by Grove in a later memoir on the same subject, beyond a doubt refutes the above explanation of Poggendorf.—(Phil. Magazine, XXXV, 114; *Pog. Ann.* LXXVIII, 366.) Two glass tubes, A and B, fig. 50, 1.5 inch in length and 0.3 inch interior diameter, were closed at both ends with corks, which were penetrated by copper wires, connected inside of the tube by a spiral of platinum wire $\frac{1}{80}$ inch in diameter and 3.7 inches in length. The tube A was filled with oxygen, B with hydrogen, and the tubes were then placed in separate vessels, similar in every respect, and containing

Fig. 50.



about 3 ounces of water. A thermometer was immersed in the water of each of the vessels, and the copper wires were so connected that they formed part of the closing circuit of a constant zinc-platinum battery of 8 cells, each of 8 square inches acting surface.

When the battery was closed the wire in the oxygen became incandescent, while that in the hydrogen was not visibly ignited. The temperature of the water, which was 60° F. in both vessels at the beginning of the experiment, rose within 5 minutes to 70° in that around the hydrogen tube, and to 81° in that around the one containing the oxygen.

When both the tubes were filled with the same kind of gas the temperature in both vessels rose to the same degree.

This experiment decidedly proves that the appearance of less heat in the wire immersed in hydrogen, with perfectly identical strength of current, cannot be caused by a more rapid absorption of heat by the hydrogen, because then, on the contrary, the water surrounding the hydrogen tube ought to be heated sooner. All this indicates that, in fact, a less production of heat takes place in the wire when surrounded by hydrogen.

Grove has proved that this phenomenon is not caused by a small amount of conduction of electricity by the hydrogen; he has also demonstrated that it cannot be brought into any connexion with the other physical properties of the gases, their density, specific heat, &c.

As to the explanation of this peculiar fact, Grove endeavored in vain to find a tolerable one, and in the course of his somewhat dilated and obscure discussion arrives himself quite inconceivably at the conjecture that the difference of the gases might have a similar effect to a difference in the condition of the surfaces. This would essentially coincide with Poggendorf's above mentioned opinion, which was propounded, however, before the experiment with the two glass tubes of fig. 50, which in the most distinct manner refutes such a view, was known to him. But Grove gives his consent to it immediately after he has himself made and described the experiment, which proves that this basis of explanation is inadmissible, and that the phenomenon cannot be deduced from differences in conduction and radiation of heat.

In my opinion the phenomenon is still entirely isolated and unexplained. I do not think it profitable in such cases to cover up our want of knowledge with dilated disquisition, in which the physical scape-goat of our days, *molecular action*, has to play the principal part.

§ 61. *Effect of ignited platinum wires on different gases.*—It is a known fact that some of the compound gases suffer decomposition in red hot tubes. Grove has produced similar effects upon these gases by the action of ignited platinum wires.—(Phil. Trans., 1847, pt. 1; Pogg. Ann. LXXI, 194.) The following is the apparatus he used for this purpose:

Into the upper end of an eudiometer tube, fig. 51, a curved platinum wire was fused, from whose extremities copper wires conducted to the two mercury cups which connected them with the poles of the battery. The gas to be examined was confined over water, and, to prevent the glass from becoming too much heated, the whole eudiometer tube was immersed in a wider vessel filled with water. Sometimes the water was covered with a layer of oil one inch in depth.

Fig. 51.

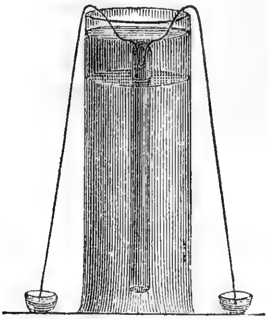
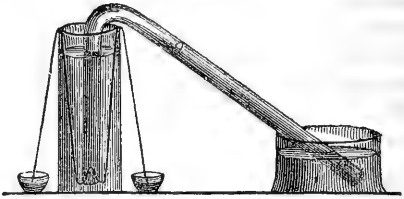


Fig. 52.



When the gases had to be confined over mercury, or when a longer continuation of the ignition was necessary, the apparatus of fig. 52 was used. Here the eudiometer tube is bent, and its closed end, containing the platinum wire, immersed in a vessel filled with water or oil; the open end dipping into another vessel containing the water or mercury, used for confining the gases. With this apparatus the following results were obtained:

Nitric oxide, over distilled water, contracted in varying proportions to the heat. (The volume, of course, was not measured before the apparatus had entirely cooled.) In the best experiments the contraction amounted to one-third of the original volume. The remaining gas was nitrogen, and nitric acid was found dissolved in the water.

Nitrous oxide was decomposed into nitrogen and oxygen; the volume increased by 0.35 of the original. The full equivalent proportion or 0.5 could not be obtained.

Carbonic acid did not show any perceptible change.

Ammonia increased to double its original volume; the gas could no longer be absorbed by water, and consisted of 3 vol. of hydrogen and 1 vol. of nitrogen.

Olefiant gas contracted a little, and deposited carbon. The remainder was hydrogen and olefiant gas; the greater the heat the more hydrogen was formed.

Nitrogen remained unchanged.

Oxygen contracted but very little, about one-fiftieth of its volume; it might, perhaps, have contained a minute quantity of hydrogen.

Chlorine over water gave white fumes, and a grayish-yellow insoluble powder collected on the sides of the tube, near the platinum wire; this was afterwards found to be chloride of platinum. The greatest part of the chlorine combined with the hydrogen of the aqueous vapor, and the muriatic acid formed was absorbed by the water. When the experiment was finished the volume of gas was reduced to about one-half, and the remainder was oxygen.

With *bromine and iodide of chlorine* oxygen was evolved, (how the experiments with these bodies were performed I could not perfectly understand.) The residue could not be examined, because it acted both upon the platinum and upon the glass.

Hydrogen contracted very much, sometimes to one-tenth of the original volume. The cause of this contraction was a small quantity of oxygen, with which hydrogen gas is nearly always contaminated. Phosphorus brought in to the most carefully prepared hydrogen emits vapors of phosphorous acid, shines in the dark, and produces a slight contraction. But even after this, the ignited wire produces a further contraction. The phosphorus, therefore, cannot remove all the oxygen from the hydrogen.

After this experience Grove doubts the correctness of the values ascertained for the atomic weight of hydrogen.

According to these experiments it seems that it would be more advantageous to use the platinum wire ignited by the galvanic current, than the electrical spark in eudiometric experiments.

Hydrogen and carbonic acid mixed in equal volumes were easily affected by the ignited wire. They contracted to 0.48 of the original volume; the residue was carbonic oxide. One equivalent of oxygen and 1 of hydrogen had, therefore, combined together.

Carbonic oxide exhibited a remarkable phenomenon. Carefully purified from any carbonic acid, it was exposed to the action of the ignited wire over distilled water, and its volume increased from one-fifth to one-third, according to the intensity of ignition.

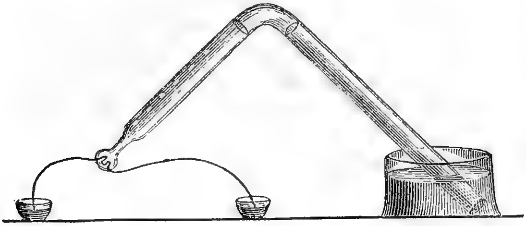
When the gas was dry and confined over mercury, this increase of volume did not take place; it must have been dependent, therefore, upon the presence of aqueous vapor; and, in fact, the increase of volume was found to be caused by the formation of carbonic acid. By agitation with caustic potash or lime water the gas was reduced to exactly its former volume; but then it was found to be mixed with a volume of hydrogen equal to that of the carbonic acid absorbed. This is explained in the following manner: "Half a volume or one equivalent of oxygen derived from the vapor of the water had combined with one volume or equivalent of carbonic oxide, and formed one volume or equivalent of carbonic acid, leaving in place of the carbonic oxide, with which it had combined, the one volume or equivalent of hydrogen with which it had been originally associated."

On comparing this experiment with the previous one, the singular inversion of affinity under circumstances so nearly similar will appear surprising; in the former case hydrogen abstracted oxygen from carbonic acid in order to form water, leaving carbonic oxide, while in the latter the carbonic oxide takes the oxygen from the aqueous vapor to form carbonic acid and leaves hydrogen.

A more exact idea of the nature of these reactions has not yet been obtained. By the latter experiment, in which a decomposition of aqueous vapor also took place, Grove was led to the idea that it might be possible to decompose aqueous vapor and produce detonating gas simply by means of the ignited wire. He succeeded in this as will be seen in the following:

§ 62. *Decomposition of aqueous vapor by ignited platinum wire.*—Grove discusses the decomposition of aqueous vapor into its elements in the same memoir in which he treats of the action of the ignited wire upon the different gases. After many unsuccessful experiments this decomposition was effected by means of the following apparatus: A bent glass tube, open at one end, (fig. 53) was connected at its other end by a narrow neck, with a bulb into which the platinum wire passed, as represented in the figure. The whole tube was filled with water previously freed from air, and its open end immersed in a vessel of water. On applying a battery of two zinc-platinum cells, the air in the bulb was expanded and expelled so that the water entered it and then soon boiled, and at a certain period the wire became ignited in the vapor. "At this instant a tremulous motion was perceptible, and separate bubbles of the size of pin-heads ascended and collected in the bend of the tube. It was not a continuous evolution of gas as in electrolysis, but appeared to be a series of jerks; the water in returning through the narrow neck formed a natural valve, which cut off by an intermitting action portions of the atmosphere surrounding the wire." The collected gas was detonating gas.

Fig. 53.

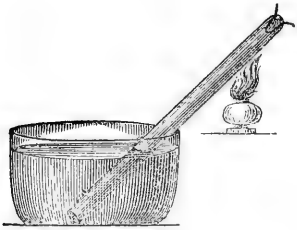


That this evolution of detonating gas can certainly not be attributed to electrolysis has been satisfactorily demonstrated by Grove. I give below the most important of his arguments.

1. A battery of two cups produces in distilled water, even under the most favorable conditions, a scarcely perceptible electrolysis.
2. The decomposition did not commence until the wire became ignited.
3. When the wire was divided no gas was evolved.

Grove now endeavored to produce the decomposition of aqueous vapor in such a manner that the red hot platinum wire could only come in contact with the vapor. A glass tube, as in fig. 54, which at its closed end had a curved platinum wire melted in, was filled with water which had been carefully freed from air by long boiling and the air pump; it was then inverted in a vessel of the same water, and a spirit lamp applied to its closed extremity until the upper half was filled with vapor, which therefore surrounded the platinum wire. The wire was then brought to full ignition. After the connexion was broken and the lamp removed, the water gradually ascended again, but a bubble of the size of a mustard seed remained in the tube, and detonated when touched by a lighted match at the surface of the water trough. The experiment was repeated, the wire being

Fig. 54.

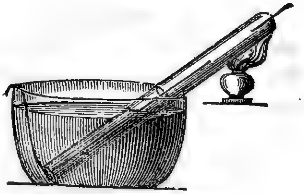


kept ignited for a longer time, but the gas could not be increased beyond a very limited quantity.

The experiment just described was repeated and the gas bubble transferred to another tube, the wire was then again ignited in vapor, the bubble formed again removed, until a sufficient quantity of gas was collected for analysis, which required the labor of ten hours. This gas was now detonated in a eudiometer and left a residue of 0.35 of its original volume, which consisted of nitrogen. The experiment was repeated several times with the same result; sometimes a trace of oxygen was found in the residue.

Here electrolysis was completely excluded ; the wire was ignited in dry steam.

Fig. 55.



When in the apparatus of fig. 55 the sparks of a large hydro-electric machine were passed between platinum points through the vapor, a small bubble of detonating gas was also formed.

As in the previous experiments a whole day's work did not increase the bubble, but when it was transferred, another instantly formed. The gas similarly collected detonated and left a residue of 0.4 of its original volume of nitrogen with a trace of oxygen.

By an estimation, which could of course only be approximate, the detonating gas formed, was found to be about $\frac{1}{2400}$ of the volume of the vapor.

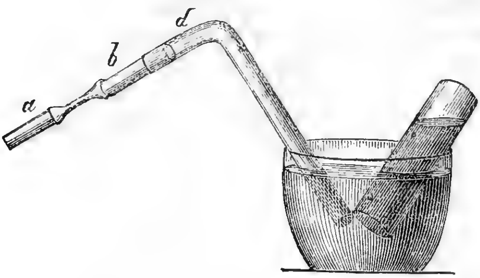
Grove considered this evolution of detonating gas not to be a specific effect of electricity at all, but of heat alone, and indeed, succeeded also in decomposing aqueous vapor merely by heat without electricity.

Omitting the less successful experiments, we shall at once proceed to those that gave very decisive results. With a constant battery of 30 zinc-platinum cells the end of a thick platinum wire was melted into a globule of the size of a pepper corn ; between this and the carbon point of the negative pole the voltaic arc was taken until the gobule was again near its melting point. It was then rapidly plunged into water, freed from air, that was kept boiling by means of a spirit lamp, and into which a tube filled with the same water was inverted. Separate bubbles of gas rose into the tube. This process was repeated until a sufficient quantity of gas was collected, which, after explosion, once left a residue of 0.4 ; another time only 0.25 of the original volume, consisting, as usual, of nitrogen and traces of oxyen. The galvanic battery here served evidently only to bring the platinum to ignition. When melted and heated by means of the oxy-hydrogen blow-pipe, it acted exactly in the same manner. In this way more than ½ cubic inch of detonating gas was obtained.

The heated globule is evidently, when immersed in the water, immediately surrounded by a stratum of vapor, from which then the small quantity of detonating gas is developed.

To obtain a continuous evolution of the mixed gases from water subjected to the action of heat alone, Grove constructed the apparatus shown in fig. 56; *a* and *b* are tubes of silver 4 inches in length and 0.3 in diameter, connected by two platinum caps to a tube of a perforated platinum wire 0.125 inches diameter, the bore having the diameter of a large pin; *a* is closed at the extremity, and to the extremity of *b* is fitted, by means of a coiled strip of bladder, the bent glass tube *d*. The whole apparatus is filled with water freed from air, and, after having expelled the air from *a* by heat, the end of the glass tube was immersed in a vessel of boiling water. Heat is now applied by a spirit lamp, first to *b* and then to *a*, until the whole boils; after this the flame of an oxy-hydrogen blowpipe is directed upon the middle part of the platinum tube *c*, and when this has obtained a high degree of ignition gas is evolved which, mixed with vapor, soon fills the whole apparatus, and escapes through the open end either into the open air or into a gas collector.

Fig. 56.



The gas thus obtained left, after its detonation, a residue of 0.3 of its volume, consisting of nitrogen and a trace of oxygen.

That, in all these cases, the remnant consists of nitrogen is caused by the great difficulty or even impossibility of absolutely removing all the air from the water.

This series of phenomena is very remarkable. While the detonating gas, under the influence of heat, is condensed to vapor of water, we have here exactly the opposite action, though to a very limited extent only. The elaboration of the more intimate conditions and relations of this decomposition of aqueous vapor, which might lead to an explanation of the phenomenon, we must leave to the future.

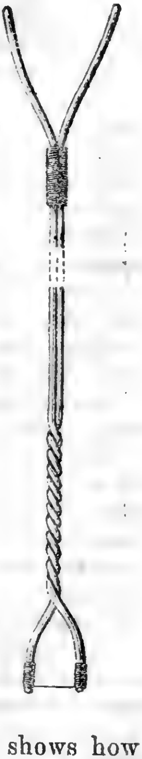
When Grove says "that these experiments afford some promise of our being, at no distant period, able to produce mixed gases for purposes of illumination, &c., by simply boiling water and passing it through highly ignited platinum tubes, or by other methods," I cannot help expressing my doubts whether, even if the manufacture on a large scale should succeed, the detonating gas thus produced could give more light and heat than the fuel consumed in its formation.

§ 63. *Application of galvanic ignition to blasting rocks.*—It has for a long time been known that gunpowder can be ignited by the electric spark, as shown long ago by Franklin, and still repeated as one of the usual experiments in the lecture room. But, although blasting by means of frictional electricity is therefore possible, still there are too many difficulties in the way of the process to allow us to expect its introduction into practice.

Hare was the first to employ the ignition of metallic wires by the galvanic current in blasting. But his apparatus was too complex and unsuited for every day use by common laborers, and, therefore never was used to a great extent.* In consequence of the many fatal accidents in mines and quarries, Roberts, of England, directed his attention to this subject. After many endeavors he succeeded in making the application of the galvanic current to blasting so simple that his process deserves general commendation. It was first described in the Mechanics' Magazine, May, 1842, p. 353.—(Dingler's Polytech. Journal, LXXXV, 275.) We shall be brief in this notice, as probably much that is contained in the article mentioned is well known.

In order to avoid the necessity of arranging before each charge the fine iron wire between the conductors, Roberts invented cartridges, a number of which can always be prepared in advance. They are made in the following manner: two copper wires, each 10 feet long and 1 line thick, well covered with waxed cotton or woolen yarn, are placed side by side close together; at one end they are twisted together for about 6 inches, as represented in Fig. 57, and their extremities left to form a fork, a little over ½ inch long, with its extremities ½ inch apart; the ends of this fork are then laid bare, cleaned by filing, and the fine iron wire is stretched between them. The iron wire is wound around the extremities of the copper wires, and may then be soldered with tin.

Fig. 57.



The iron igniting wire is, of course, destroyed by each explosion; to save the conducting copper wires they are firmly tied together with twine, as indicated in the figure, and then wound around with fine binding wire.

The body of the cartridge is a tin tube, 3 inches in length and ¾ to 1 inch in width, soldered and perfectly water tight. (A glass tube might probably answer.) The fine iron or steel wire is placed at about the middle of the cylinder, and is kept in its place by means of a cork which closes the cylinder, and through which the twisted copper wires pass. It is best to cut this cork lengthwise, and after putting the wire between the two halves, to press them into the tube. But on account of the thickness of the conducting wires it will probably be found more convenient to make a groove in the cork for their reception. The cork being put in so that the fork is nowhere in contact with the sides of the tube, it is covered with a good cement. Roberts recommends a mixture of one part beeswax and two parts rosin.

The tube is then to be filled through its open end with dry sporting powder, and closed by another cork, which must also be covered with the cement.

Figure 58 represents the entire cartridge. Figure 59 shows how the cartridge is placed in the hole.

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[*] Our author could not possibly have seen Dr. Hare's description of his apparatus when he wrote this sentence. The original notice (Am. Jour. Science and Arts, vol. 21, p. 139, 1832,) shows that Dr. Hare's apparatus was not complex, and that it was essentially the same as that here described as the contrivance of Roberts. G. C. S.

After all dust and moisture are properly removed from it, one half of the intended charge is put into the hole, the cartridge is inserted and the remaining gunpowder filled in above it. Thus, the cartridge is in the middle of the charge, and the long conducting wires still project several feet above the rock. The charge is not tamped in the usual way.

Fig. 58.

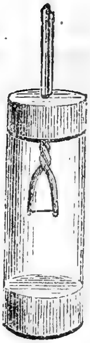
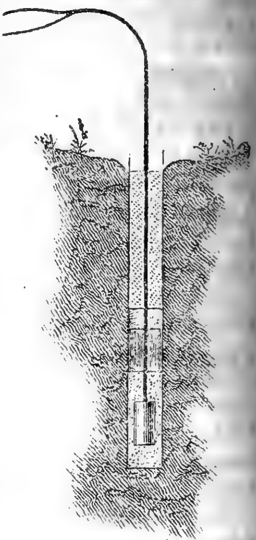


Fig. 59.

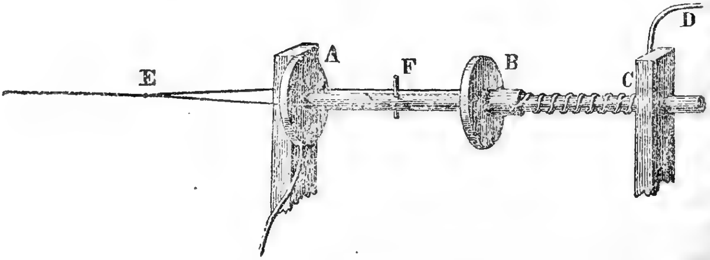


A wadding of straw or tow is carefully pushed down the hole, so that a space filled with air, of variable size according to circumstances, remains between it and the charge. Upon this wad dry sand is poured until the bore is entirely filled.

The two separate ends of the cartridge wires must now be brought into connexion by conducting wires with the battery 60 to 90 feet off. The conductors are also covered wires about one line in diameter, placed side by side and kept close together by being wound over with twine throughout their whole length, with the exception of their extremities, where they are to be connected with the battery and with the cartridge wires.

It is sometimes necessary that the person who has to ignite the charge should still be further off from the charge than the battery is, and for this purpose an arrangement must be made by which the circuit may be closed from a distance.

Fig. 60.



Roberts contrived the following arrangement for this purpose: upon two opposite ends of the box which contains the battery two wooden posts are erected, connected above by a wooden rod of one inch in diameter. At one end a tin disk, A, fig. 60, three to four inches in diameter, is fastened, to which a wire is soldered conducting to one, say the positive pole of the battery. Another tin disk, B, is fastened to a tin tube, made to slide easily on the rod, and this is kept from A by a spiral spring. One end, D, of this spiral is connected with one of the conducting wires, while the other conducting wire leads to the negative pole of the battery. The disk B is therefore connected through a long circuit, including the fine igniting wires, with the negative pole, so that B may be considered the negative pole and A the positive. The current circulates and produces ignition in the iron wire as soon as A and B come into contact.

In order to pull the disk B towards A from a distance, two pieces of twine fastened to B pass through holes in the disk A, and at E are connected with the long string that reaches to the place whence the person who is to close the circuit stands. An accidental discharge is prevented by a peg F between A and B, which must be removed before the two disks can come in contact. But besides lessening the danger this method of blasting offers other considerable advantages; it enables us without much difficulty to explode powder under water. For this purpose the entire charge is to be enclosed in a water-tight tin box and this put in the place where its action is desired.

The application of galvanic ignition is also very advantageous when great masses of rock are to be blasted. Formerly, in such cases, it was necessary to use a heavy charge in one great mine, but several smaller properly distributed charges would produce a much greater effect if they could be ignited simultaneously. This can now be done by the aid of the galvanic current; the connecting wires have only to be so arranged that all the holes are at the same time in the circuit. In this way immense effects have been obtained in England.

What power the battery must have in each case can easily be ascertained from preceding sections. From section 59 can be ascertained what force of current is required to make the thin iron wire incandescent, (the diameter of which must of course be known,) and after computing the resistance in the conducting wires, it is easy to determine how many cups or pairs of plates of any give point must be used and how they must be arranged to produce this force of current.

§ 64. *The voltaic arc.*—By the construction of the constant battery, the production of the arc of light which Davy was the first to observe is greatly facilitated, and hence this interesting phenomenon has been several times investigated, though much is still left for further researches.

De la Rive paid great attention to the galvanic arc; we take the following from his elaborate treatise on this subject, published in Phil. Trans., f. 1847, (Pogg. Ann., LXXVI, 170.)

The voltaic arc can be produced not only between carbon points but also between points of different metals. It is greater with the more fusible or oxydisable metals, as zinc or iron, than with platinum or silver. The size of the arc of light is proportioned to the greater or less facility with which the substance of the electrode disintegrates; for since this phenomenon is produced by minute particles of matter carried over from one electrode to the other, its formation must necessarily be favored by a less cohesion of the electrodes; this is also the reason why, under otherwise like conditions, the greatest arc of light is always obtained between carbon points. The transference of the matter is always from the positive to the negative pole. In the air and with metallic electrodes, the deposit upon the negative pole always consists of oxydized particles of the metal used as the positive electrode.

If the negative pole has the form of a plate, while the positive pole is a point, the deposit of the transferred matter upon the plate forms a very regular ring, the centre of which is the projection of the point upon the plate.

When the arc of light is taken between a metallic point and an opposite surface of mercury, the latter, when positive rises in a cone, but forms a cavity when negative. In this case it is very difficult to observe accurately the minutiæ of the phenomenon, on account of the great quantity of mercurial vapor evolved.

De la Rive made experiments with plates and points of platinum, iron, silver, and copper, but I cannot enter upon the details of the experiments, because there is much that is not clear to my mind; in many cases, for instance, I cannot see in the individual experiments the proof and confirmation of the generalizations announced. A repetition of these experiments and an accurate description, illustrated when practicable with figures, seems therefore very desirable.

§ 65. *Intensity of light of the voltaic arc.*—Casselmann has made experiments upon the intensity of light of the voltaic arc, which have been described in the memoir already mentioned. They were afterwards also copied into Poggendorf's Annals.—(*Pog. Ann.*, LXIII, 576.) The photometer used in his experiments was constructed upon the same principles as that described in the third edition of my *Lehrbuch der Physik*, vol. II, 674. The carbon pieces, between which the arc was taken, were of the same composition as that used in the cylinders of Bunsen's battery, but prepared also in other ways, as some of them were saturated in solutions of nitrate of strontium, boracic acid, &c., and then intensely ignited. Thus prepared they gave a very steady light, differently colored, according to the solution employed; and the carbon points could (with a Bunsen battery of 44 cups) be removed to a distance of 7 to 8 millimetres before it disappeared, while the unsteady light of unprepared carbon went out at a distance of 5 millimetres.

A tangent compass was at the same time inserted into the circuit, so that for each measurement of the intensity of light the corresponding force of current could be determined.

The brightest parts of the whole light, it is well known, are at the points of the two pieces of carbon, upon which the arc rests. In the following table the intensity of the whole light is compared with that of a stearine candle, and for each kind of carbon, with the points once at a very small, and then at the greatest possible distance. The values of the force of current are reduced to the chemical unit.

	Distance of the carbon points.	Force of current.	Intensity of light.
	mm.		
Unprepared carbon	0.5	95	932
	4.5	68	139
Carbon with nitrate of strontium	0.5	120	353
	6.75	88	274
Carbon with caustic potash	2.5	101	150
	8.0	82	75
Carbon with chloride of zinc	1.0	80	624
	5.0	67	159
Carbon with borax in sulph. acid	1.5	72	1171
	5.0	64	165

This table shows that on increasing the distance of the points the intensity of light and the force of current decrease. By most of the substances with which the carbon had been prepared, the arc of light was made more steady and allowed of a greater distance of the points, but the intensity was not greater, except with the carbon prepared with borax and sulphuric acid.

But the results in the above table are only approximately accurate, since the changeable position of the most brilliant points at the origin of the arc may have prevented the light from acting with its full intensity upon the photometer. In another series of experiments, an abstract of which is given in the following table, this error was avoided, the arc of light having been directed towards the photometer by means of a magnet. In these experiments only 34 Bunsen's cups were used, the distance of the carbon points was not changed, and the intensity of the light was measured for different degrees of force of current.

	Force of current.	Intensity of light.
Carbon with boracic acid	41	198
	52	252
	57	298
Carbon with sulphate of soda	38	178
	41	203
	52	346
	60	460

The carbon saturated with sulphate of soda was not heated to redness before use.

It follows from these experiments that the intensity of light increases in a somewhat greater ratio than the force of the current.

It is to be regretted that we have no measures of the intensities of the galvanic light, when different metals are used instead of the carbon points.

Fizeau and Foucault have also made comparative experiments on the intensity of the galvanic arc light, but from another point of view.—(Ann. de Chim. et de Phys. ser. III, T. XI, pp. 370; Pog. Ann., LXIII, 463.) They did not compare the intensity of the light from different sources, but its chemical effect. In this way they compared the galvanic light with that of the sun, and of lime incandescent in detonating gas. The experiment was conducted in the following manner: An iodized silver plate was inserted in a camera obscura, in the place where the image of the sun or of the light, emanating from the carbon or lime, was formed. After a short action of the light the camera obscura was closed, and the position changed, so that another image of the object was shown upon the prepared silver plate beside the first one; the exposure was somewhat longer than before; for a third place still longer, &c. The plate was then put into the mercury bath and examined, in order to find which one of the images became visible by the action of the mercurial vapor. In this way it was ascertained how long the light had to act in order to produce that change in the iodide of silver, which is necessary for the condensation of the mercurial vapor.

If all the other circumstances were entirely identical, the time required for the production of the Daguerrean image would be nearly inversely proportional to the chemical intensity of the corresponding sources of light.

But Fizeau and Foucault used for their experiments with the artificial light lens of shorter focus than for obtaining images of the sun; the aperture of the lens also was varied by means of diaphragms. These circumstances have, therefore, to be taken into account.

If the image is n times further from the lens, it will, cæteris paribus, be n times greater in its linear dimensions, and will, therefore, cover a surface n^2 times as large, and consequently the intensity of light at each point of the image will be n^2 times less. The chemical power of the source of light may, therefore, be considered proportional to the square of the distance of the image formed from the lens.

But it is also, as easily perceived, inversely proportional to the surface of the opening of the lens, *i. e.*, to the square of its radius, and therefore

$$J = \frac{d^2}{t.\, r^2}$$

when J denotes the chemical power of the source of light, d the distance of the image from the lens, r the radius of its opening, and t the time required to produce a Daguerrean image.

If we denote by α the angle which the radius of the aperture of the lens subtends at the place of the image, then

$$\frac{r}{d} = \text{tang. } \alpha$$

therefore
$$J = \frac{1}{t.\ \text{tang. } \alpha}$$

By this, or rather by a similar equivalent formula, Fizeau and Foucault computed the results of their observations, and thus obtained the following relative values for the intensity of the sources of light.

Sun-light, in August and September, at noon, with a clear sky	1000
Carbon-light, produced by 46 Bunsen's zinc-carbon cups........	235
Lime-light..	6.8

The lime-light appears to be surprisingly little; but Fizeau and Foucault found with the common photometrical method a similar relation between the lights from lime and carbon. No other comparative measurements are known to which these can be referred; a careful experimental re-examination of the matter is, therefore, desirable.

In reference to the change of the intensity of the carbon-light with the number and magnitude of the galvanic elements we find the following data in this memoir: While a battery of 46 Bunsen's elements gave an intensity of light of 235, this was increased to 238 only when the number of cups was augmented to 80; but a battery of 46 triple cups gave an intensity of 385, after having been already in action for one hour.

In consequence of the rapid alteration of the fluid—the diluted sulphuric acid becoming gradually a solution of sulphate of zinc—the force of the battery, and with it the intensity of the arc of light produced by it, decreases rapidly. While 80 cups afforded at first an intensity of 238, this after three hours was diminished to 159.

It is to be regretted that these physicists have not measured the force of current corresponding to the intensity of light, whereby the value of the above given numerical relations would have been very much enhanced.

§ 66. *Production of heat by the voltaic arc.*—The heat developed at the poles, between which the arc is taken, is entirely too great to be attributed to the mere passage of the electric current through these conductors. According to the experiments mentioned in § 57, a current, to make a platinum wire of 0.75 *mm.* in diameter incandescent by its passage, must have at least a force of 160. Therefore, to make a platinum wire of 3 *mm.* in diameter only white-hot requires, at the very least, the enormous force of current of 640; and yet with the current of a Bunsen's battery of 44 cups and a force of 80 to 100, we can produce an arc in which the point of a platinum wire of more than 3 *mm.* in diameter may easily be melted into a globule, if used as one pole of the battery while the other is formed by a carbon point. The combustion of carbon is so trifling that it cannot essentially contribute to the great heat produced; besides, the fusion of the platinum wire by the galvanic arc takes place in a vacuum as readily as in the open air.

The electric current, therefore, besides producing heat by its mere passage through the conductors, in forming the arc must act at the pole itself to produce heat in some other way, of which as yet we know nothing.

The development of heat is not equal at the two poles of the arc; it is greater at the positive than in the negative. De la Rive, in his treatise already mentioned, in § 64, adds, in reference to this fact, the following observations:

When, in forming the arc, a positive metallic point is opposite to a negative plate, the point becomes ignited throughout, while on inverting the poles the negative point is heated at its extremity only.

If two points of the same metal are opposed to each other the positive one becomes more intensely ignited, and over a greater length. If they are of different metals, of course that one becomes most intensely ignited which is made of the worst conducting metal.

To this category belongs also an observation of Walker, made with a Daniell's battery of 160 cups.—(Trans. of the Lond. Electr. Soc., pp. 65 and 71; Pog. Ann., LV, 62.) He laid the pole wires crosswise, but so that after the contact they were again moved to a little distance from each other, and a short arc of light passed between them. Under these circumstances the positive end of the wire, from the point of crossing, became so intensely hot that it softened and bent, while the negative end remained comparatively cold.

Experiments on the heating effects of the voltaic arc have been made on the greatest scale by Despretz. He collected, in Paris, 500 zinc-carbon cups, and arranged a battery of 124 elements, each consisting of four Bunsen's cups. When a piece of sugar carbon, in a glass globe exhausted to 5 millimetres, was brought between the poles it became intensely ignited and the globe was covered with a dry, crystalline black powder. Carbon from gas retorts produced the same effects. This shows a sublimation of the carbon.

Despretz thinks too that he observed traces of fusion of the carbon. At any rate his experiments show that carbon evaporates more readily than it melts. He believes that it could be melted in metallic vessels in an atmosphere of compressed nitrogen. Similar in behavior to carbon are lime, magnesia, oxide of zinc, &c. Alumina, rutil, anatase, nigrine, oxide of iron, &c., form at first small globules, but afterwards evaporate.

Previous to these experiments with 496 cups Despretz had used a battery of 165 elements, and combined the heat of its arc with that of the oxy-hydrogen blow-pipe and of the sun concentrated through a sectional lens 90 centimetres in diameter. The effect of the galvanic battery was increased by the addition of the other sources of heat.—(Comptes Rendus, July, 1849, No. 3; Dingler's Polytechnic Journal, CXIV, 342.)

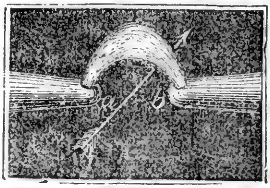
§ 67. *Influence of magnetism upon the voltaic arc.*—That magnetic forces have an influence upon the position and form of the arc has already been observed by Davy, and it is known that this arc is affected by a magnet in the same manner as a movable conductor when a galvanic current is passing through it; the terrestrial magnetism, therefore, must also act upon it. By the motion of the heated air the arc of light is always carried upwards, so as to form a curve, convex above. If we conceive a perpendicular plane to be passed through the carbon points lying horizontally, the action of terrestrial magnetism will be such that the highest point of the arc will never be in this plane, but on one side or the other.

Casselmann, in his treatise already mentioned, in § 56, gives experiments on this subject. If, with opposite horizontal carbon points, the current was passing—

From	The deviation of the apex was towards
N. to S.	E.
W. to E.	N.
S. to N.	W.
E. to W.	S.

This can be easily deduced. In fig. 61 *a* and *b* represent the two horizontal carbon points between which the arc is produced. If now we imagine a perpendicular plane passed through *a* and *b*, and a straight line to pass perpendicularly through the plane between these points, as indicated by the arrow, then a steel needle placed in this line would be magnetized by the current of the arc, and its N. end would be at the point of the arrow when the positive current is passed from *a* through the arc towards *b*. But by the influence of the terrestrial magnetism the N. end of the needle would dip, and in like manner also the arc will be inclined from the vertical plane towards the direction of the N. end of the needle.

Fig. 61.



If *a* is to the west, and *b* east, the inclination will be toward the north when the current is passing from *a* to *b*; but with a direction of the current from east to west, the north end of the supposed magnetic needle would be on the south side of the arc, and the latter, therefore, would incline toward the south.

By means of this supposed magnetic needle we can, under all circumstances, determine in what manner the arc will be affected by terrestrial magnetism or either pole of a magnet, or what must be its position when placed between the two poles of a horse-shoe magnet.

If, instead of one of the carbon poles, a magnetic bar is used, so that the arc is formed between carbon and steel, the arc rotates around the magnetic pole according to the same laws which apply when a movable current rotates around a fixed magnet. The first notice in reference to this rotation of the arc is given by Walker, in the "Transactions of the London Electrical Society" from 1837 to 1840.—(Pog. Ann., LIV, 514.) De la Rive also has made experiments on the influence of magnetism upon the voltaic arc, but in a different way. Their description is found in the memoir mentioned already in § 64.

I shall quote here from De la Rive's memoir literally, in order to give a characteristic example of his want of precision in writing, by which his papers are frequently rendered obscure, as before mentioned:

"If two points of soft iron, acting as electrodes, be both placed within a helix formed of thick copper wire of several coils, the voltaic arc developed between the two points of iron ceases the moment a strong current is passed through the wire of the helices, and reappears if this current be arrested before the points have become cold. The arc cannot be formed between the two iron points when they are magnetized, whether by the action of the helices or by that of a powerful magnet, unless they be brought much nearer to one another, and the appearance of the phenomenon is then entirely different. The transported particles appear to disengage themselves with difficulty from the positive electrode, sparks fly with noise in all directions, while in the former case it was a vivid light without sparks and without noise, accompanied by the transfer of a liquid mass, and this appeared to be effected with the greatest ease. It is of little moment with respect to the result of the experiment whether the two rods of magnetized iron present to that part of their extremities between which the luminous arc springs the same magnetic poles or different poles.

"The positive electrode of iron, when it is strongly magnetized, produces, the moment that the voltaic arc is formed between it and a negative electrode of whatever nature, a very intense noise, analogous to the sharp hissing sound of steam issuing from a locomotive engine. This noise ceases simultaneously with the magnetization.

"For the purpose of better analyzing these different phenomena, I placed an electro-magnet of large dimensions and great power in such a manner as to enable me to place on each of its poles, or between them, different metals destined to form one of the electrodes of the pile, while one point of the same metal, or another substance, acted as the other electrode. I have alike employed as electrodes, placing them in the same circumstances, two points of the same metal, or of different metals. The following are the results which I have obtained: A plate of platinum was placed on one of the poles of the electro-magnet, and a point of the same metal was placed vertically above it; the voltaic arc was produced between the plate and the point, the plate being positive and the point negative. As soon as the electro-magnet was charged a sharp hissing was heard. It became necessary to bring the point nearer to the plate to enable the arc to continue, and the bluish circular spot which the platinum plate presented became larger than when the experiment was made beyond the influence of the electro-magnet.

† "The plate was made negative, and the point positive. The effect was then totally different. The luminous arc no longer maintained its vertical direction when the electro-magnet was charged, but took an oblique direction, as if it had been projected outwards towards the margin of the plate.†† It was broken incessantly, each time accompanied by a sharp and sudden noise, similar to the discharge of a Leyden jar. The direction in which the luminous arc is projected depends upon the direction of the current producing it, as likewise on the position of the plate on one or other of the two poles, or between the poles of the electro-magnet. A plate and a point of silver, a plate and a point of copper, and generally a plate and a point of any other metal, provided it be not metal too easily fused, present the same phenomena.

"Copper, and still more silver, present a remarkable peculiarity. Plates of these two metals retain on their surfaces the impression of the action that took place in the experiments just described. Thus, when the plate is positive, that portion of its surface lying beneath the negative point presents a spot in the form of a helix, as if the melted metal in this locality had undergone a gyratory motion around a centre, at the same time that it was uplifted in the shape of a cone towards the point."

The first part of this is clear; not so the last two paragraphs. The passage between † and †† appears to indicate that the oblique direction of the arc of light only occurs when the plate is negative and the point positive; but somewhat further on we read that the direction in which the luminous arc is projected depends upon that of the exciting current. It should, therefore, take place when the plate is positive and the point negative. Besides, an obscure allusion to the rotation of the arc is found in this passage, but so obscure that one not previously acquainted with the phenomenon could form no idea of it from this representation. That the Genevan physicist, in penning this passage, actually had this rotation in view is evident from the conclusion of the last paragraph. Similar faults frequently occur in De la Rive's treatises; his description rarely gives a clear and intelligible representation of the phenomenon. It is much to be regretted that in this way the results of many a beautiful and difficult experimental research are only imperfectly presented to those engaged in physical studies.

§ 68. *Use of the galvanic light for illumination.*—It was to be expected that the great intensity of the galvanic carbon light would soon lead to the idea of employing it for illumination after its production was so much facilitated by the invention of the constant batteries.

Deleuil several times made public experiments with this kind of illumination. At first he illuminated the pavilion of a mansion at the Pontneuf, in Paris, with 98 zinc-carbon elements. Acherau made similar experiments in the Place de la Concord.—(Dingler's Polytech. Journal, vol. 91, p. 324.)

Though the intensity of the galvanic carbon light is enormous, and although a battery of 48 Bunsen's elements produces as much light as 63 common gas burners, yet the use of the galvanic light for public illumination appears unfit for practical application for the following reasons:

An immense quantity of light is here emanating from one single point, and therefore very strong contrasts between light and shade will be produced; the darkness in the shade will be the more unpleasant just on account of its contrast to the dazzling light. At any rate, the illumination obtained from 63 gas burners, perfectly distributed, will be more uniform and agreeable than an equivalent light concentrated in one point.

Another objection to the application of the galvanic carbon light, is the difficulty of keeping its intensity uniform for a long time.

In consequence of the formation of sulphate of zinc the conducting power of the fluid decreases so rapidly that the force of the current, even in half an hour, becomes considerably weaker than it was at the beginning. But, apart from this, the maintenance of the battery is extremely expensive, because much more zinc is consumed than the current itself requires, and the nitric acid acts destructively upon the metallic rings around the carbon cylinders. It is true the disadvantages of this action of the nitric acid could be avoided by the use of Daniell's elements, but then the battery must be considerably enlarged to obtain the same effect.

In an economical point of view, therefore, the galvanic illumination of streets, halls, theatres, &c., does not appear advantageous. But there is yet another difficulty; the management of the battery and of the whole apparatus is too complicated to be confided to such persons as generally have charge of the illumination; the carbon points are continually changing, and their position, therefore, must be continually regulated in order to keep the light uniform and prevent its extinction. It is difficult to accomplish this regulation by mechanical means, though different contrivances have been proposed for the purpose. Le Molt, for instance, obtained a patent in England, in 1848, for an apparatus for galvanic illumination, in which carbon disks, with the form represented in fig. 62, take the place of the points. Two of these disks are placed with their sharp edges opposite each other; their axes rotate uniformly by means of clock work, and their distances are regulated by a metallic spring.

Fig. 62.

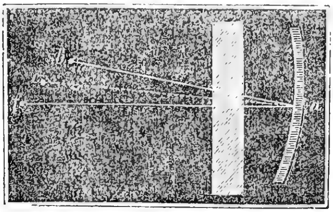
It is therefore scarcely to be expected that the application of galvanism to public illumination will have any practical success. But Donné and Foucault have obtained very favorable results from their experiments, in which the galvanic carbon light was substituted for the incandescent lime in the so called gas microscope.

A tolerably complete description of the photo-electric microscope of Donné and Foucault may be found in the 4th edition of Pouillet, Elements de Physique Experimentale, &c., vol. II, pp. 746. We can here only indicate the most essential parts of the apparatus. The luminous arc is produced between sticks of carbon cut from the hard carbon of gas retorts; they are made in the shape represented in fig. 63, the negative electrode being pointed and the positive blunt. These carbon pieces are so held that their position can easily be regulated.

Fig. 63.

A general idea of the arrangement of the illuminating apparatus of this microscope may be gathered from the diagram fig. 64. *a* is a concave mirror of an aperture of about 1 decimetre, and a radius of 1.6 decimetre. The carbon light is at *b*, a little nearer to the mirror than *c*, the centre of its curvature, and somewhat higher, so that the rays emanating from *b* are collected at *f*, where the minute object to be magnified is intensely illuminated. The system of lens through which the magnified image of the object is thrown upon a screen 4 to 5 metres distant is precisely the same as in the solar microscope.

Fig. 64.



To diminish the great heat at *f*, a vessel is placed between the mirror and *b*, the sides of which are made of polished plate glass; it it is filled with a solution of alum by which a great part of the calorific rays is absorbed without sensibly lessening the intensity of the light.

The image of the arc of light itself, as produced at *f* by the concave mirror, may be taken as the object to be magnified through the lens, but then the magnifying power must be lower. Thus, a highly magnified image of the arc of light is obtained upon the white screen, and all the phenomena accompanying it can be observed with ease.

But the magnified image of the galvanic arc of light can also be produced by much simpler means; it has only to be brought directly near the focus of a lens of 1 to 3 centimetre focal distance. Of course, care must be taken that the carbon light is so inclosed that no light falls upon the screen, except that which passes through the lens.

§ 69. *Galvanic illumination of mines.*—The remarks on galvanic illumination in general are also applicable to the proposal to illuminate mines by the light produced by means of galvanism; there is scarcely much practical success to be expected. Because the galvanic carbon light can be produced in a vacuum and even under water. Boussingault believed that it could be used instead of Davy's safety lamp in mines where inflammable gases make open lamps dangerous. But in mines an intense light at any one place is never wanted, but a feeble one at many different places. The same objection is to be made to De la Rive's proposal to pass in a hermetically closed glass balloon the positive current from an upright carbon cylinder to a metallic one placed vertically above it.—(Dingler's Polyt. Journal, XCVIII, p. 158, and 232; Moniteur industr., 1845, No. 961 & 965.)

Grove proposed, instead of the carbon light, the ignition of a platinum wire by galvanism in a hermetically closed glass vessel.—(Dingler's Polytechnic Journal, XCIX, p. 201; Phil. Magazine, Dec., 1845, p. 442.) He gives to the wire the form of a spiral, and thus employs a greater length of it in a smaller space; and this arrangement has the further advantage that on account of the less rapid cooling the coiled wire is more intensely heated with an equal force of current than the same wire when extended in a straight line.

Grove does not give any details as to the length and diameter of the wire used, or of the precise construction of the spiral. With two to three constant elements a uniform light was obtained during several hours. Grove experimented (and read) by this light; but this notice gives only a very imperfect idea of the illuminating power of the apparatus. In mines this light will probably be sufficient, and the proposition therefore appears to be a more practical one than the application of the carbon light, especially on account of the small number of constant elements required for the purpose. But still, even this apparatus will be more expensive and complicated than Davy's safety lamp, and consequently its general introduction into use is scarcely to be expected.

King uses, instead of the platinum spiral, a strip of very thin platinum foil, and makes it incandescent by the galvanic current.—(London Journal of Arts, June, 1846, p. 348; Dingler's Polytechnic Journal, CI, p. 12.)

§ 70. *The galvanic spark.*—Most of the observers who have experimented with the galvanic arc have noticed that the two poles must first be brought into contact before the current can be produced. After the carbon points have once been in contact, they may be separated from each other and then the luminous arc is formed. The arc also can be produced by discharging the spark of a Leyden jar between the carbon points, instead of bringing them into contact, as has been observed by Daniell, (Phil. Trans., 1839, 89; Pog. Ann. LX, 379,) and previously by Sturgeon.—(Ann. of Electr., VIII, 507; Pog. Ann. XLIX, 122.) The latter believes that this experiment originated with Herschel. The formation of the current in this case is evidently caused by conducting particles carried from one pole to the other by the spark.

Even the powerful batteries which have been used to produce the luminous arc have not yet sufficient tension to effect the passage of a spark through the smallest distance.

Jacobi found by accurate measurement that the poles of a battery of 12 zinc-platinum elements could be brought to within 0.00005 inch of each other without a spark passing.—(Bulletin of the Petersburgh Academy; Pog. Ann., XLIV, 633.)

Gassiot obtained distinct sparks from his great water battery.—(Phil. Trans , f. 1844, pt. I, pp. 39; Pog. Ann , LXV, 476.) This remarkable battery consisted of 3,520 glass tumblers, each containing a zinc rod and a copper cylinder. They were charged with rain water. The tumblers were distributed upon 44 oaken boards, every 11 of which were combined in a stand, similar to the shelves of a book case, and were supported by four strong pillars. Especial care was taken to secure perfect insulation, the glasses were varnished and placed upon glass plates, and these as well as the boards were in like manner covered with varnish.

It might be expected that this battery, when the circuit was unclosed, should exhibit in a decided manner the phenomenon of tension, and, in fact, the leaves of a gold leaf electroscope diverged already, when yet at a distance of 2 or 3 inches from one of the poles.

As soon, however, as the battery was closed, all signs of tension disappeared. When the poles of the battery were brought within 0.02 inch of each other sparks continually passed between them. In one case this phenomenon continued day and night for five weeks without interruption. Several months after its construction the battery showed no signs of decrease in strength.

Since the ordinary galvanic batteries have no striking distance at all, it is evident that the appearance of light observed in opening and closing even simple batteries, must be an entirely different phenomenon from that of the common electric spark.

In the memoir just mentioned, Jacobi states it as his opinion that the usual galvanic spark is a phenomenon of ignition and combustion; the extremely fine points which first come into contact and permit the conduction of the current, become incandescent and burn, and thus produce, according to Jacobi's opinion, the phenomenon of light. There is no doubt that with more vivid sparks such ignition and combustion really do occur, but then the phenomenon is no longer a simple one; in closing and opening a battery the spark is observed under circumstances which make ignition and combustion very improbable.

Neef has shown that this appearance of light, when occurring simply without the action of secondary currents, is neither a common electric spark, viz., a spark passing from one pole to the other, nor can it be attributed to a combustion of metal.—(P. A. LXVI, 414.)

In his so called magnet electrometer, as described in the 3d edition of my "*Lehrbuch der Physik*," vol. II, p. 251, a continual closing and breaking of the current takes place at *c* which is accompanied by a corresponding appearance of the light. But in this form of the apparatus the observation of the phenomenon is rendered difficult by the width of the hammer which strikes the platinum plate. In a very convenient modification of this apparatus by Desaga, in Heidelberg, which will be described hereafter, a platinum point is substituted for the hammer, so that the contact is made and broken in rapid alternation between a platinum point and plate.

When the apparatus is in action, light is observed, at the place of separation, which, on account of the rapidity of the oscillation, seems to be continuous. To the naked eye, when protected from the daylight, the light appears violet, whether the positive current pass from the point to the plate or inversely; but the point of light is so extremely small that Neef was induced to examine the phenomenon with the microscope. By the aid of this instrument he found that the light always appears at the negative pole only.

These observations are best made with a microscope which magnifies 25 to 50 times, which permits the objective to be removed to at least 1½ inch from the point of light.

When the positive current passes from the plate to the point, the latter appears enveloped in violet light, while the plate remains entirely dark.

At the lowest extremity of the point within the continuous violet light there appear single, extremely fine, dots of dazzling white light with a sort of swarming motion; and towards the upper extremity of the violet envelope there is also seen light of the same color but of much greater intensity, flashing out, and yet no passage to the other pole could be observed. The last mentioned flashing gradually disappears as the force of the current decreases.

When the current passes in the opposite direction, and the point, consequently, is positive, it remains quite dark and the violet light is spread upon the plate around the point of nearest approach. In this case, too, there is no spark, strictly so called, to be observed, and the uniform violet glimmering light can scarcely be attributed to a combustion of the platinum. Besides, Neef also especially remarks that this phenomenon of light takes place at the negative pole only, while the greatest heat is always developed at the positive pole.

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