S. I. A.

REPORT

OF THE

FIFTY-FOURTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

MONTREAL IN AUGUST AND SEPTEMBER 1884.

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OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and* *all future years* the privilege of receiving the volumes of the Association *gratis:* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s.* 6*d.* per volume.[1]

Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained.[1] *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first

[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or

meeting. The Sectional Presidents of former years are *ex officio* members of the Organizing Sectional Committees.[1]

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organizing Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner :—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.[5]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis

before.........................., addressed thus—'General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and Abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.

[2] Revised by the General Committee, Swansea, 1880.

[3] Passed by the General Committee, Edinburgh, 1871.

[4] The meeting on Saturday was made optional by the General Committee at Southport, 1883.

[5] These rules were adopted by the General Committee, Plymouth, 1877.

of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.[1] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxv), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they

[1] This and the following sentence were added by the General Committee, 1871.

can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[1]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting: nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken,[2] and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] Passed by the General Committee at Sheffield, 1879.

[2] The meeting on Saturday may begin, if desired by the Committee, at any time not earlier than 10 or later than 11. Passed by the General Committee at Southport, 1883.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.
3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Corresponding Societies.[1]

(1.) Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

(2.) Applications may be made by any Society to be placed on the List of Corresponding Societies. Application must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

(3.) A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

(4.) Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule,

[1] Passed by the General Committee, 1884.

properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

(5.) There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognizance of one or other of the various Sections of the Association.

(6.) A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

(7.) The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

(8.) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

(9.) The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

(10.) It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. ...... York, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. ...... Cambridge, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich. Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. Southampton, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford .... Oxford, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University. Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. .... Swansea, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. Birmingham, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews .... Edinburgh, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh. The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal .... Ipswich, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT.. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. .. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. ...... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge .... CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. .... NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

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PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq. M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D , F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood Esq., LLD., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
	MATHEMATICAL AND PHYSICAL SCIENCES.	
	COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.	
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
	SECTION A.—MATHEMATICS AND PHYSICS.	
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S.............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.......	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.,	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S	C. Carpmael, W. M. Hicks, Prof. A. Johnson, Prof. O. J. Lodge, Dr. D. MacAlister.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

Date and Place	Presidents	Secretaries
1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.

Date and Place	Presidents	Secretaries
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	H. B. Dixon, Dr. W. R. Eaton Hodgkinson, P. Phillips Bedson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.

Date and Place	Presidents	Secretaries
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page xlviii.

Date and Place	Presidents	Secretaries
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S.............	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham......................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xlvii.

Date and Place	Presidents	Secretaries
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see pp. xlvii, xlviii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

Date and Place	Presidents	Secretaries
1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal[2]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard..........................	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844 York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] By authority of the General Committee, Anthropology was made a separate section, for Presidents and Secretaries of which see p. liii.

SECTION E.—PHYSIOLOGY.

Date and Place	Presidents	Secretaries
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xlii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. xlv). The Section being then vacant was assigned in 1851 to Geography.

[2] *Vide* note on page xlvi.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S.L.&E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

Date and Place	Presidents	Secretaries
1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841 Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.

Date and Place	Presidents	Secretaries
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne. F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.

Date and Place	Presidents	Secretaries
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton.	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S.	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.

List of Evening Lectures.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson......................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.............	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.

Date and Place	Lecturer	Subject of Discourse
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.............	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B.Airy,F.R.S.,Astron.Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S..........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.

Date and Place	Lecturer	Subject of Discourse
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S.	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F R.S.	The *Challenger* Expedition.
1877. Plymouth ...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvani and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge., D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.

Date and Place	Lecturer	Subject of Discourse
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877 Plymouth...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L. Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE MONTREAL MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.L. & E., F.R.A.S.

Vice-Presidents.—Professor J. C. Adams, F.R.S.; Professor R. S. Ball, F.R.S.; Professor J. B. Cherriman, M.A.; J. W. L. Glaisher, F.R.S.; Professor O. Henrici, F.R.S.; Professor S. Newcomb.

Secretaries—Charles Carpmael, M.A.; Professor W. M. Hicks, M.A.; Professor A. Johnson, LL.D.; Professor Oliver J. Lodge, D.Sc.; D. MacAlister, M.D. (*Recorder*).

SECTION B.—CHEMICAL SCIENCE.

President.—Professor Sir H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.

Vice-Presidents.—Professor Dewar, F.R.S.; Professor Wolcott Gibbs; Professor B. J. Harrington, Ph.D.; W. H. Perkin, F.R.S., Pres.C.S.

Secretaries.—Professor P. Phillips Bedson, D.Sc. (*Recorder*); H. B. Dixon, M.A.; T. McFarlane; Professor W. H. Pike, M.A.

SECTION C.—GEOLOGY.

President.—W. T. Blanford, LL.D., F.R.S., Sec.G.S.

Vice-Presidents.—Professor J. Geikie, F.R.S.; Professor J. Hall, LL.D.; Major J. W. Powell; Professor T. Rupert Jones, F.R.S.; A. R. C. Selwyn, F.R.S.

Secretaries.—F. Adams, B.Ap.Sc.; Professor E. W. Claypole, B.Sc.; W. Topley, F.G.S. (*Recorder*); W. Whitaker, F.G.S.

SECTION D.—BIOLOGY.

President.—Professor Moseley, M.A., LL.D., F.R.S., F.L.S., F.R.G.S.

Vice-Presidents.—G. E. Dobson, F.R.S.; Professor George Lawson, LL.D.; William Carruthers, F.R.S.; Professor A. Milnes Marshall, D.Sc.; Professor Schäfer, F.R.S.; P. L. Sclater, F.R.S.

Secretaries.—Professor W. Osler, M.D.; Howard Saunders, F.L.S. (*Recorder*); A. Sedgwick, M.A.; Professor R. Ramsay Wright, B.Sc.

SECTION E.—GEOGRAPHY.

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THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from September 19, 1883 (commencement of Southport Meeting), to the commencement of the Montreal Meeting, August 27, 1884.

RECEIPTS.

1883–84.		£	s.	d.
	By Balance of account presented at Southport Meeting	800	11	11
	Received for Life Compositions to date	1340	0	0
	,, ,, New Annual Members to date	854	0	0
	,, ,, Subscriptions to date	931	0	0
	,, ,, Associates' Tickets	1105	0	0
	,, ,, Ladies' Tickets	839	0	0
	Dividends on Stock	249	13	10
	Sale of Publications	159	1	10
	By Rent from Mathematical Society, year ending September 29, 1883	12	15	0
1883.	,, Interest on Exchequer Bills	29	7	6
Nov. 6.	,, Unexpended balance of grant for the Exploration of Caves in South of Ireland	5	0	0
		£6325	10	1

Signed on behalf of Alex. W. Williamson,
W. H. F. Crookshank.

PAYMENTS.

1883–84.		£	s.	d.	£	s.	d.
	By paid Expenses of Southport Meeting, also Printing, Advertising, and sundry Incidental Expenses				428	5	5
	,, Messrs. Spottiswoode & Co.'s account for printing—year 1883–84				798	15	6
	,, Salaries (1 year)				505	0	0
	,, Rent of Office at Albemarle Street				117	0	0
	,, Purchase of Exchequer Bills, £2000				2027	5	5
	,, Grants made at Southport Meeting:—						
1883.							
Nov. 9.	Zoological Literature Record	100	0	0			
,, 16.	Fossil Polyzoa	10	0	0			
,, 16.	Exploration of Mt. Kilima-njaro, E. Africa	500	0	0			
,, 24.	Anthropometric Committee	10	0	0			
,, 24.	Fossil Plants of Halifax	15	0	0			
,, 24.	International Geological Map	20	0	0			
,, 24.	Erratic Blocks of England	10	0	0			
,, 24.	Natural History of Timor Laut	50	0	0			
Dec. 8. July 21.	Coagulation of Blood	100	0	0			
Dec. 18.	Naples Zoological Station	80	0	0			
1884.							
Feb. 27.	Bibliography for Groups of Invertebrata	50	0	0			
May 12.	Earthquake Phenomena of Japan	75	0	0			
,, 12.	Fossil Phyllopoda of Palæozoic Rocks	15	0	0			
,, 30.	Meteorological Observatory at Chepstow	25	0	0			
June 6.	Migration of Birds	20	0	0			
,, 10.	Collecting and Investigating Meteoric Dust	20	0	0			
,, 17.	Circulation of Underground Waters	5	0	0			
July 8.	Ultra Violet Spark Spectra	8	4	0			
,, 30.	Tidal Observations	10	0	0			
Aug. 9.	Meteorological Observations on Ben Nevis	50	0	0			
					1173	4	0
	*Balance at Bank of England, Western Branch	£1222	0	5			
	In hands of Assistant Treasurer	53	19	4			
					1275	19	9
					£6325	10	1

* Plus £8500 invested in Consols.

John Evans.
William Huggins. Feb. 26, 1884.
G. Griffith.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20

...t Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 3 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1538 0 0	1173 4 0	1884

* Ladies were not admitted by purchased Tickets until 1843. † Tickets of Admission to Sections only.
‡ Including Ladies. § Fellows of the American Association were admitted as Honorary Members for this Meeting.

OFFICERS AND COUNCIL, 1884–85.

PRESIDENT.

The Right Hon. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S.

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Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres.Z.S., F.G.S., Director of the Natural History Museum.

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LOCAL TREASURERS FOR THE MEETING AT ABERDEEN.

John Findlater, Esq. Robert Lumsden, Esq.

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Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., Pres. G.S., 22 Albemarle Street, London, W.

GENERAL TREASURER.

Professor A. W. Williamson, Ph.D., LL.D., F.R.S., F.C.S., University College, London, W.C.

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The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.

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Prof. Williamson, Ph.D., F.R.S.
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Sir John Hawkshaw, F.R.S.
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Dr. Michael Foster, Sec. R.S.
George Griffith, Esq., M.A., F.C.S.
P. L. Sclater, Esq., Ph.D., F.R.S.

AUDITORS.

George Griffith, Esq., M.A., F.C.S. | John Evans, Esq., D.C.L., F.R.S. | W. Huggins, Esq., D.C.L., F.R.S.

REPORT OF THE COUNCIL.

Report of the Council for the year 1883–84, *presented to the General Committee at Montreal, on Wednesday, August* 27, 1884.

The Council have received reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

Since the meeting at Southport, Dr. F. Lindemann and Dr. Ernst Schröder have been elected Corresponding Members of the Association.

The present meeting of the British Association, the fifty-fourth in number, is likely to be long memorable in its annals, as the first held beyond the limits of the United Kingdom. It marks a new point of departure, and one probably never contemplated by the founders of the Association, although not forbidden by the laws which they drew up. The experiment was doubtless a hazardous one, but it seems likely to be justified by success; and it may be hoped that the vigour and vitality gained by new experience may ultimately compensate for the absence from this meeting of not a few familiar faces among the older members; there will, however, be as large a gathering of members of more than one year's standing as is usual at a successful meeting in Great Britain, and the efforts which have been made by our hosts to facilitate the coming of members, and render their stay in Canada both pleasant and instructive, call for the warmest acknowledgment.

The inducements offered to undertake the journey were indeed so great that the Council felt that it would be necessary to place some restriction upon the election of new members, which for many years past, though not unchecked in theory, has been almost a matter of course in practice. Obviously these offers of the Canadian hosts of the British Association were made to its members, not to those on whom they might operate as an inducement to be enrolled amongst its members. The Council, therefore, before the close of the Southport meeting, published the following resolution:—'That after the termination of the present month (September 1883), until further notice, new members be only elected by special resolution of the Council.' Applications for admission under these terms were very numerous, and were carefully sifted by the Council. Still, although the Council, as time progressed and the number augmented, increased the stringency of their requirements, it became evident that the newly-elected members would soon assume an unduly large proportion to those of older standing, so that on May 6, after electing 130 members under this rule, it was resolved to make no more elections until the commencement of the Montreal meeting, when it would be safe to revert to the usual practice.

The details of the arrangements made for the journey have already been communicated to the members, so that it is needless to make any further special reference to them; but the Council have to acknowledge the great liberality of the Associated Cable Companies in granting, under certain restrictions, free ocean telegraphy to the members of the Association during the meeting.

The death of Sir William Siemens has deprived the Association of one of its most earnest supporters and friends. It was during his presidency at Southampton that the invitation to Montreal was accepted, and he was appointed at Southport a Vice-President for this meeting. The Council nominated Sir J. D. Hooker a Vice-President, but he was unfortunately obliged, for domestic reasons, to resign the nomination in the early part of the summer.

It has been the custom at meetings of the Association to invite the attendance of distinguished men of science from all parts of the world; but the Council considered that on the present occasion it would be well to offer a special welcome to the American Association (of which also several eminent Canadian men of science are members); they have accordingly issued an invitation to the Standing Committee and Fellows of that Association to attend the meeting at Montreal on the footing of Honorary Members.

The Council were informed some time since that the General Treasurer would be prevented from attending the meeting at Montreal. They decided accordingly on the present occasion (as the usual assistant to the General Treasurer could not be present) to appoint a Deputy Treasurer and a Financial Officer; the latter to undertake the duties discharged by the assistant, together with some of those which usually fall upon the Treasurer. To the former office they have nominated Admiral Sir Erasmus Ommanney, C.B., F.R.S.; to the latter, Mr. Harry Brown, Assistant Secretary of University College, London.

Four resolutions were referred by the General Committee to the Council for consideration, and action if desirable:—

(1) That the Council be empowered, if they think fit, to form a separate section of Anthropology, and to give to the section of Biology the title 'Section D.—Biology (Zoology, Botany, and Physiology).'

The Council, after consideration, resolved to form a separate section of Anthropology, with the title 'Section H.—Anthropology,' but considered that it was better to continue to designate the section of Biology by the simpler title 'Section D.—Biology.'

(2) That application be made to the Admiralty to institute a Physical and Biological Survey of Milford Haven and the adjacent coast of Pembrokeshire, on the plan followed by the American Fisheries Commission.

The Council, after appointing a Committee to consider the necessary details, duly made application, and have been informed by the Lords of H.M. Treasury that they regretted to be unable to institute such a survey, as the Admiralty had no vessels available for this service.

(3) That the Council of the British Association be requested to consider the report of the Committee of Section A respecting the suppression of four of the seven principal observatories of the Meteorological Council, and to forward a copy of the same to the Meteorological Council.

The Council, after consideration of the above report, communicated with the Meteorological Council as directed. A reply was duly received, and in view of the statements therein made, and of supplementary information that arrangements had been made whereby three out of the four observatories relinquished by the Meteorological Council would be continued, though on a somewhat different footing, it was considered needless to proceed further in the matter.

(4) That the Council of the British Association be requested to communicate at the earliest opportunity with the Executive Committee of the International Fisheries Exhibition, in order to urge upon that body the appropriation of a sufficient sum out of the surplus funds remaining in their hands at the close of the Exhibition, to found a laboratory on the British Coast for the study of Marine Zoology; and to point out, as a reason for such appropriation, the great value to science, and to the prosperity of the fisheries industries, of such an institution.

A communication was duly made to the Executive Committee of the International Fisheries Exhibition, but there does not seem any prospect of such an appropriation of the surplus funds.

The Council have been informed that, through an inadvertence, the resolution of the Sectional Committee recommending the reappointment of the Committee on Screw Gauges was not transmitted to the Secretary in time to be considered by the Committee of Recommendations, and so did not receive the sanction of the General Committee. The Council, having regard to the importance of the work carried on by that Committee, have requested them, through their Secretary, to continue their labours and make a report as if duly appointed. The Council ask that this action of theirs be sanctioned, and that the above-named report be received and printed among the reports of the committees duly appointed.

The report of the Committee on Local Scientific Societies, mentioned in the report of the Council presented at the Southport meeting, has been printed in the volume for 1883; and the Council, believing that the suggestions made therein will be for the advantage of the Association, have considered the alterations which their adoption would make necessary in the rules. It is proposed to reserve the consideration of this question by the General Committee for the meeting to be held in London in November. The following are the alterations which will be necessary :—

No. I —In *Rules*, General Committee, Class B.—Temporary Members. To replace the first clause (The President . . . . representing him) by the following: 'Delegates nominated by the Corresponding Societies under the conditions hereinafter explained.'

No. II.—To insert in *Rules*, between the sections headed respectively *Committee of Recommendations* and *Local Committee*, the following sections :—

Corresponding Societies.

'(1.) Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

'(2.) Applications may be made by any Society to be placed on the List of Corresponding Societies. Application must be addressed to the Secretary on or before the first of June preceding the annual meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

'(3.) A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

'(4.) Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule, properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

'(5.) There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognizance of one or other of the various Sections of the Association.

'(6.) A Corresponding Society shall have the right to nominate any one of its members, who is also a member of the Association, as its delegate to the annual meeting of the Association, who shall be for the time a member of the General Committee.

'*Conference of Delegates of Corresponding Societies.*

'(7.) The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

'The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each annual meeting of the Association, and shall be empowered to invite any member or associate to take part in the meetings.

'The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

'It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.'

The vacancies in the Council to be declared at the General Committee meeting in November will be Lord Rayleigh, who has assumed the Presidency, together with the following who retire in the ordinary course:

Mr. F. Darwin, Mr. Hastings, Dr. Huggins, and Dr. Burdon Sanderson; and the Council will recommend for re-election on that occasion the other ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

*Abney, Captain W. de W.
Adams, Professor W. G.
*Ball, Professor R. S.
Bateman, J. F. La Trobe, Esq.
Bramwell, Sir F. J.
Dawkins, Professor W. Boyd.
De La Rue, Dr. Warren.
Dewar, Professor J.
Evans, Captain Sir F. J.
Flower, Professor W. H.
Gladstone, Dr. J. H.
Glaisher, J. W. L., Esq.
Godwin-Austen, Lieut.-Col. H. H.
Hawkshaw, J. Clarke, Esq.
Henrici, Professor O.
Hughes, Professor T. McK.
Jeffreys, Dr. J. Gwyn.
*Moseley, Professor H. N.
*Ommanney, Admiral Sir E.
Pengelly, W., Esq.
Perkin, Dr. W. H.
Prestwich, Professor.
Sclater-Booth, The Right Hon. George.
Sorby, Dr. H. C.
*Temple, Sir R.

In accordance with the decision arrived at by them at Southport, the General Committee will meet on Tuesday, 11th November, at 3 o'clock in the afternoon, in the Theatre of the Royal Institution, Albemarle Street, London, W., for the transaction of the following business, viz.:—

To elect the President, Officers, and Council for 1884–5.

To fix the date of meeting for 1885.

To appoint the place of meeting for 1886.

To consider the alteration of rules necessary to give effect to the recommendations of the Committee on Local Scientific Societies.

Supplementary Report presented to the General Committee at the Meeting held at the Royal Institution, London, November 11, 1884.

During the Meeting of the British Association at Montreal, a proposal was made to commemorate the first visit of the British Association to the Dominion of Canada, and the reception at Montreal, by founding a Gold Medal in the McGill University, as a permanent memorial of the Meeting.

There are at present five Gold Medals in the Faculty of Arts of the McGill University. Two of the five are for Science subjects, but for the special Faculty of Applied Science there is only one Silver Medal.

Although the final decision as to the details of the award would be left to the authorities of the University, it was suggested that the Medal should be given annually to the Graduating Class in the Faculty of Applied Science, any surplus income to be expended in prizes in that Faculty.

In support of this proposal private subscriptions from Members and Associates at Montreal were paid or promised to the amount of nearly 500*l.*, and it is believed that many Members of the Association who were unable to attend the Meeting, or who had left Montreal before the close thereof, will be glad to contribute to the fund.

The Council are of opinion that this commemoration of a Meeting which was held under such exceptional circumstances, and which proved so eminent a success, should not be wholly left to individual Members to carry out, but should also bear the impress of being the act of the Association; they would therefore suggest to the General Committee that their sanction be given to the Council to obtain, at the expense of the Association, a die suitable to the occasion, and that the General Treasurer of the Association take the necessary steps to receive the fund from the Treasurer of the Committee which was formed at Montreal, and transmit it in a suitable manner to the authorities of McGill University.

Recommendations adopted by the General Committee at the Montreal Meeting in August and September 1884.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That Professor Balfour Stewart (Secretary), Mr. Knox Laughton, Mr. G. J. Symons, Mr. R. H. Scott, and Mr. Johnstone Stoney be reappointed a Committee, with power to add to their number, for the purpose of co-operating with Mr. E. J. Lowe in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis, and that the unexpended sum of 25*l.* be again placed at their disposal for the purpose.

That Mr. Robert H. Scott, Mr. J. Norman Lockyer, Professor G. G. Stokes, Professor Balfour Stewart, and Mr. G. J. Symons be reappointed a Committee for the purpose of co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861; that Mr. R. H. Scott be the Secretary, and that the still unexpended sum of 50*l.* be again placed at their disposal for the purpose.

That Mr. James N. Shoolbred and Sir W. Thomson be reappointed a Committee for the purpose of reducing and tabulating the Tidal Observations in the English Channel made with the Dover Tide-gauge, and of connecting them with observations made on the French coast; that Mr. Shoolbred be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor Cayley, Professor G. G. Stokes, Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher be reappointed a Committee for the purpose of calculating certain tables in the Theory of Numbers, connected with the divisors of a number; that Mr. J. W. L. Glaisher be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Professor Crum Brown, Mr. Milne-Holme, Mr. John Murray, and Mr. Buchan be reappointed a Committee for the purpose of co-operating with the Scottish Meteorological Society, in making meteorological observations on Ben Nevis; that Professor Crum Brown be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Schuster, Professor Balfour Stewart, Professor Stokes, Mr. G. Johnstone Stoney, Professor Sir H. E. Roscoe, Captain Abney, and Mr. G. J. Symons be reappointed a Committee for the purpose of considering the best methods of recording the direct intensity of Solar Radiation; that Professor Schuster be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Mr. John Murray, Professor Schuster, Sir William Thomson, Professor Sir H. E. Roscoe, Professor A. S. Herschel, Captain W. de W. Abney, Professor Bonney, Mr. R. H. Scott, and Dr. J. H. Gladstone be reappointed a Committee for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities; that Mr. Murray be the Secretary, and that the sum of 70*l.* be placed at their disposal for the purpose.

That Professors Tilden and Ramsay, and Mr. W. W. J. Nicol be a Committee for the purpose of investigating the subject of Vapour Pressures and Refractive Indices of Salt Solutions; that Mr. W. W. J. Nicol be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Professors Williamson, Dewar, Frankland, Roscoe, Crum Brown, Odling, and Armstrong, Messrs. A. G. Vernon Harcourt, J. Millar Thomson, H. B. Dixon, and V. H. Veley, and Drs. F. Japp and H. Forster Morley be reappointed a Committee for the purpose of drawing up a statement of the varieties of Chemical Names which have come into use, for indicating the causes which have led to their adoption, and for considering what can be done to bring about some convergence of the views on Chemical Nomenclature obtaining among English and foreign chemists; that Mr. H. B. Dixon be the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

That Professors Ramsay, Tilden, Marshall, and W. L. Goodwin be a Committee for the purpose of investigating certain Physical Constants of Solution, especially the expansion of saline solutions; that Professor W. L. Goodwin be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Mr. H. Bauerman, Mr. F. W. Rudler, and Mr. H. J. Johnston-Lavis be a Committee for the purpose of investigating the Volcanic Phenomena of Vesuvius; that Mr. H. J. Johnston-Lavis be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Professor A. H. Green, Professor L. C. Miall, Mr. J. Brigg, and Mr. J. W. Davis be reappointed a Committee for the purpose of reporting upon the Raygill Fissure, Lothersdale; that Mr. J. W. Davis be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Mr. T. Gray, and Professor J. Milne be reappointed a Committee for the purpose of investigating the Earthquake Phenomena of Japan; that Professor J. Milne be the Secretary, and that the sum of 75*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Dr. H. Woodward, and Professor T. R. Jones be reappointed a Committee for the purpose of reporting on the Fossil Phyllopoda of the Palæozoic Rocks; that Professor T. R. Jones be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Mr. W. T. Blanford and Mr. J. S. Gardner be a Committee for the purpose of reporting upon the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom; that Mr. Gardner be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Dr. J. Evans, Professor W. J. Sollas, and Messrs. W. Carruthers, F. Drew, R. B. Newton, F. W. Rudler, W. Topley, E. Wethered, and W. Whitaker be reappointed a Committee for the purpose of carrying on the Geological Record; that Mr. W. Whitaker be the Secretary, and that the sum of 50*l*. be placed at their disposal for the purpose.

That Messrs. R. B. Grantham, C. E. De Rance, J. B. Redman, W. Topley, W. Whitaker, J. W. Woodall, Major-General Sir A. Clarke, Admiral Sir E. Ommanney, Sir J. N. Douglass, Captain Sir F. J. O. Evans, Captain J. Parsons, Captain W. J. L. Wharton, Professor J. Prestwich, and Messrs. E. Easton, J. S. Valentine, and L. F. Vernon Harcourt be reappointed a Committee for the purpose of inquiring into the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other Material in that Action; that Messrs. C. E. De Rance and W. Topley be the Secretaries, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professor E. Hull, Dr. H. W. Crosskey, Captain Douglas Galton, Professor J. Prestwich, and Messrs. James Glaisher, E. B. Marten, G. H. Morton, James Parker, W. Pengelly, James Plant, I. Roberts, Fox Strangways, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, W. Whitaker, and C. E. De Rance be reappointed a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various towns and districts from these formations; that Mr. De Rance be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professor Ray Lankester, Mr. P. L. Sclater, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, Professor A. C. Haddon, Professor Moseley, and Mr. Percy Sladen be reappointed a Committee for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples; that Mr. Percy Sladen be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Mr. E. C. Rye be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Mr. J. Cordeaux, Mr. J. A. Harvie Brown, Professor Newton, Mr. R. M. Barrington, Mr. A. G. More, Mr. J. Hardy, and Mr. W. Eagle Clarke be reappointed a Committee for the purpose of obtaining (with the consent of the Master and Elder Brethren of the Trinity House and of the Commissioners of Northern Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting upon the same at the meeting of 1885; that Mr. Cordeaux be the Secretary, and that the sum of 30*l*. be placed at their disposal for the purpose.

That Sir J. Hooker, Dr. Günther, Mr. Howard Saunders, and Mr. Sclater be reappointed a Committee for the purpose of exploring Kilima-njaro and the adjoining mountains of Equatorial Africa; that Mr. Sclater be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

That Dr. H. C. Sorby and Mr. G. R. Vine be a Committee for the purpose of reporting on Recent Polyzoa; that Mr. Vine be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Mr. John Murray, Professor Cossar Ewart, Professor Alleyne Nicholson, Professor Mackintosh, Professor Young, Professor Struthers, and Professor McKendrick be a Committee for the purpose of promoting the establishment of a Marine Biological Station at Granton, Scotland; that Mr. John Murray be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Professor Huxley, Mr. Sclater, Mr. Howard Saunders, Mr. Thiselton Dyer, and Professor Moseley be a Committee for the purpose of promoting the establishment of Marine Biological Stations on the coast of the United Kingdom; that Professor Moseley be the Secretary, and that the sum of 150*l.* be placed at their disposal for the purpose.

That General Sir J. H. Lefroy, Lieut.-Colonel Godwin-Austen, Mr. W. T. Blanford, Mr. Sclater, Mr. Carruthers, Mr. Thiselton Dyer, Professor Struthers, Mr. G. W. Bloxam, Mr. H. W. Bates, Lord Alfred Churchill, Mr. F. Galton, and Professor Moseley, with power to add to their number, be a Committee for the purpose of furthering the Exploration of New Guinea, by making a grant to Mr. Forbes for the purposes of his expedition; that Mr. H. W. Bates be the Secretary, and that the sum of 200*l.* be placed at their disposal for the purpose.

That General Sir J. H. Lefroy, the Rev. Canon Carver, Mr. F. Galton, Mr. P. L. Sclater, Professor Moseley, Dr. E. B. Tylor, Professor Boyd Dawkins, Mr. G. W. Bloxam, and Mr. H. W. Bates be a Committee for the purpose of furthering the scientific Examination of the country in the vicinity of Mount Roraima in Guiana, by making a grant to Mr. Everard F. im Thurn for the purposes of his expedition; that Mr. H. W. Bates be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Sir Frederick Bramwell, Professor A. W. Williamson, Professor Sir William Thomson, Mr. St. John Vincent Day, Sir F. Abel, Captain Douglas Galton, Mr. E. H. Carbutt, Mr. Macrory, Mr. H. Trueman Wood, Mr. W. H. Barlow, Mr. A. T. Atchison, Mr. R. E. Webster, Mr. A. Carpmael, Sir John Lubbock, Mr. Theodore Aston, and Mr. James Brunlees be reappointed a Committee for the purpose of watching and reporting to the Council on Patent Legislation; that Sir Frederick Bramwell be the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

That Dr. E. B. Tylor, Dr. G. M. Dawson, General Sir J. H. Lefroy, Dr. Daniel Wilson, Mr. Horatio Hale, Mr. R. G. Haliburton, and Mr. George W. Bloxam be a Committee for the purpose of investigating and publishing reports on the physical characters, languages, industrial and social condition of the North-western tribes of the Dominion of Canada; that Mr. Bloxam be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. J. Park Harrison, General Pitt-Rivers, Professor Flower, Professor Thane, Dr. Beddoe, Mr. Brabrook, Dr. Muirhead, Mr. F. W. Rudler, and Dr. Garson be reappointed a Committee for the purpose of defining the Physical Characteristics of the Races and Principal Crosses in the British Isles, and obtaining illustrative Photographs with a view to their publication; that Dr. Garson be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

Not involving Grants of Money.

That Professor G. Carey Foster, Sir William Thomson, Professor Ayrton, Professor J. Perry, Professor W. G. Adams, Lord Rayleigh, Professor Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. A. Muirhead, Mr. W. H. Preece, Mr. Herbert Taylor, Professor Everett, Professor Schuster, Dr. J. A. Fleming, Professor G. F. Fitzgerald, Mr. R. T. Glazebrook, Professor Chrystal, Mr. H. Tomlinson, and Professor W. Garnett be reappointed a Committee for the purpose of constructing and issuing practical Standards for use in Electrical Measurements; and that Mr. Glazebrook be the Secretary.

That Professor G. Forbes, Captain Abney, Dr. J. Hopkinson, Professor W. G. Adams, Professor G. C. Foster, Lord Rayleigh, Mr. Preece, Professor Schuster, Professor Dewar, Mr. A. Vernon Harcourt, and Professor Ayrton be a Committee for the purpose of reporting on Standards of Light; and that Professor G. Forbes be the Secretary.

That Professor Sir William Thomson, Mr. W. H. Barlow, Professor A. W. Williamson, Mr. W. H. Preece, and Mr. J. M. Thomson be a Committee for the purpose of promoting arrangements for facilitating the use of Weights and Measures in accordance with the permissive clauses of the Weights and Measures Act, 1878; and that Mr. J. M. Thomson be the Secretary.

That Professors A. Johnson, Macgregor, J. B. Cherriman, and H. J. Bovey and Mr. C. Carpmael be a Committee for the purpose of promoting Tidal Observations in Canada; and that Professor Johnson be the Secretary.

That Professor Sylvester, Professor Cayley, and Professor Salmon be reappointed a Committee for the purpose of calculating Tables of the Fundamental Invariants of Algebraic Forms; and that Professor Cayley be the Secretary.

That Professor G. H. Darwin and Professor J. C. Adams be reappointed a Committee for the Harmonic Analysis of Tidal Observations; and that Professor Darwin be the Secretary.

That Professors Balfour Stewart and Sir W. Thomson, Sir J. H. Lefroy, Sir Frederick Evans, Professor G. H. Darwin, Professor G. Chrystal, Professor S. J. Perry, Mr. C. H. Carpmael, and Professor Schuster be a Committee for the purpose of considering the best means of Comparing and Reducing Magnetic Observations; and that Professor Balfour Stewart be the Secretary.

That Professors Everett and Sir W. Thomson, Mr. G. J. Symons, Sir A. C. Ramsay, Dr. A. Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, and Mr. A. Strahan be reappointed a Committee for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water; and that Professor Everett be the Secretary.

That Professors W. A. Tilden and H. E. Armstrong be reappointed a Committee for the purpose of investigating Isomeric Naphthalene Derivatives; and that Professor H. E. Armstrong be the Secretary.

That Professors Dewar and A. W. Williamson, Dr. Marshall Watts, Captain Abney, Dr. Stoney, and Professors W. N. Hartley, McLeod, Carey Foster, A. K. Huntington, Emerson Reynolds, Reinold, Liveing, Lord Rayleigh, and W. Chandler Roberts be reappointed a Committee for the purpose of reporting upon the present state of our knowledge of Spectrum Analysis; and that Professor W. Chandler Roberts be the Secretary.

That Professor Sir H. E. Roscoe, Mr. Lockyer, Professors Dewar, Liveing, Schuster, W. N. Hartley, and Wolcott Gibbs, Captain Abney, and Dr. Marshall Watts be reappointed a Committee for the purpose of preparing a new series of Wave-length Tables of the Spectra of the Elements; and that Dr. Marshall Watts be the Secretary.

That Professor J. Prestwich, Professor T. McK. Hughes, and Mr. W. Topley be reappointed a Committee for the purpose of assisting in the preparation of an International Geological Map of Europe; and that Mr. W. Topley be the Secretary.

That Professors J. Prestwich, W. Boyd Dawkins, T. McK. Hughes, and T. G. Bonney, Dr. H. W. Crosskey, Dr. Deane, and Messrs. C. E. De Rance, H. G. Fordham, J. E. Lee, D. Mackintosh, W. Pengelly, J. Plant, and R. H. Tiddeman be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; and that Dr. H. W. Crosskey be the Secretary.

That Sir L. Playfair, Professor Moseley, Admiral Sir E. Ommanney, Mr. P. L. Sclater, and Mr. A. Sedgwick be a Committee for the purpose of preparing a report on the aid given by the Dominion Government and the Government of the United States to the encouragement of Fisheries and to the investigation of the various forms of marine life on the coasts and rivers of North America; and that Mr. Sedgwick be the Secretary.

That the Rev. Canon Tristram, the Rev. F. Lawrence, and Mr. James Glaisher be reappointed a Committee for the purpose of promoting the Survey of Palestine; and that Mr. James Glaisher be the Secretary.

That the Committee, consisting of Dr. Gladstone (Secretary), Mr. Wm. Shaen, Mr. Stephen Bourne, Miss Lydia Becker, Sir John Lubbock, Dr. H. W. Crosskey, Sir Richard Temple, Sir Henry E. Roscoe, Mr. James Heywood, and Professor Story Maskelyne be reappointed a Committee on Science Teaching in Elementary Schools.

That Mr. Mollison be requested to report on the present state of our knowledge of the Mathematical Theory of Thermal Conduction.

That Mr. R. T. Glazebrook be requested to draw up a Report on recent progress in Physical Optics.

That Mr. J. J. Thomson be requested to draw up a Report on Electrical Theories.

That Mr. W. Topley be requested to continue his Report upon National Geological Surveys.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

Professor Schuster's paper, opening the discussion on the Connection of Sunspots with Terrestrial Phenomena.

Professor O. J. Lodge's paper, opening the discussion on the seat of the Electromotive Force in the Voltaic Cell.

Professor Bonney's paper 'On the Archæan Rocks of Great Britain.'

Dr. Gwyn Jeffreys' paper, entitled 'The Concordance of the Mollusca inhabiting both sides of the North Atlantic.'

Professor Asa Gray's paper, entitled 'Remarks on the Characteristic Features of North American Vegetation.'

Professor Thurston's paper 'On the Theory of the Steam-engine.'

Sir James Douglass's paper 'On Improvements in Coast Signals,' with such diagrams as may be found indispensable.

Mr. J. M. Wilson's paper 'On American Permanent Way,' with the necessary diagrams.

Resolutions referred to the Council for Consideration, and Action if desirable.

That the Council of the Association be requested to communicate with the Government of the Dominion of Canada in order (1) to call the attention of the Government to the absence of trustworthy information concerning the tides of the Gulf of St. Lawrence and the adjoining Atlantic coast, and to the dangers which thence arise to the navigation; (2) to urge upon the Government the importance of obtaining accurate and systematic tidal observations, and of tabulating and reducing the results by the scientific methods elaborated by Committees of the Association; and (3) to suggest the immediate establishment of a sufficient series of observing stations on the coast of the Dominion.

That the Council be requested to examine the feasibility of instituting a scheme for promoting an International Scientific Congress, to meet at intervals in different countries, and to report thereon to the General Committee at the next meeting of the Association.

That the attention of the Council be drawn to the advisability of communicating with the Admiralty for the purpose of urging on them the importance of the Employment of the Harmonic Analysis in the Reduction of Admiralty Tidal Observations.

That the Council memorialise the Canadian Government as to the urgent necessity of encouraging investigation and publication of reports with respect to the physical characters, languages, social, industrial, and artistic condition of the native tribes of the Dominion.

That, in the event of that part of the Report of the Council concerning Corresponding Societies being accepted by the General Committee at their next meeting, the Council be empowered to form the Committee therein mentioned (see Report, *Corresponding Societies*, Section 3).

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Montreal Meeting in September 1884. The Names of the Members who are entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Stewart, Professor Balfour.—Meteorological Observations near Chepstow	25	0	0
*Scott, Mr. R. H.—Synoptic Charts of the Indian Ocean	50	0	0
*Shoolbred, Mr. J. N.—Reduction of Tidal Observations	10	0	0
*Cayley, Professor—Calculation of Mathematical Tables	100	0	0
*Brown, Professor Crum.—Meteorological Observations on Ben Nevis	50	0	0
*Schuster, Professor.—Solar Radiation.	20	0	0
*Murray, Mr. John.—Meteoric Dust.	70	0	0

Chemistry.

	£	s.	d.
Tilden, Professor.—Vapour Pressures and Refractive Indices of Salt Solutions	25	0	0
*Williamson, Professor.—Chemical Nomenclature	5	0	0
Ramsay, Professor.—Physical Constants of Solutions	20	0	0

Geology.

	£	s.	d.
Bauerman, Mr. H.—Volcanic Phenomena of Vesuvius	25	0	0
*Green, Professor A. H.—Raygill Fissure	15	0	0
*Etheridge, Mr. R.—Earthquake Phenomena of Japan	75	0	0
*Etheridge, Mr. R.—Fossil Phyllopoda of the Palæozoic Rocks	25	0	0
Blanford, Mr. W. T.—Fossil Plants of British Tertiary and Secondary Beds.	50	0	0
*Evans, Dr. J.—Geological Record	50	0	0
*Grantham, R. B.—Erosion of Sea-Coasts	10	0	0
*Hull, Professor E.—Circulation of Underground Waters	10	0	0
Carried forward	£635	0	0

* Reappointed.

	£	s.	d.
Brought forward	635	0	0
Biology.			
*Lankester, Professor Ray.—Table at the Zoological Station at Naples	100	0	0
*Stainton, Mr. H. T.—Record of Zoological Literature	100	0	0
*Cordeaux, Mr. J.—Migration of Birds	30	0	0
*Hooker, Sir J.—Exploration of Kilima-njaro and the adjoining Mountains of Equatorial Africa	25	0	0
Sorby, Dr. H. C.—Recent Polyzoa	10	0	0
Murray, Mr. J.—Marine Biological Station at Granton	100	0	0
Huxley, Professor.—Biological Stations on Coast of United Kingdom	150	0	0
Geography.			
Lefroy, General Sir H.—Exploration of New Guinea	200	0	0
Lefroy, General Sir H.—Exploration of Mount Roraima	100	0	0
Mechanics.			
*Bramwell, Sir F. J.—Patent Legislation	5	0	0
Anthropology.			
Tylor, Dr. E. B.—Investigation of Characteristics, physical and otherwise, of North-Western Tribes of Canada	50	0	0
*Harrison, Mr. J. Park.—Physical Characteristics of Races in the British Isles	10	0	0
	£1515	0	0

* Reappointed.

The Annual Meeting in 1885.

The Meeting at Aberdeen will commence on Wednesday, September 9.

Place of Meeting in 1886.

The Annual Meeting of the Association will be held at Birmingham.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 £ 75 0 0; 1855 £500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool ...	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance...	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Don ...	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance ...	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium ...	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcon Quatries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid...............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland......	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record...............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall..................	100	0	0
Ohm's Law........................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid...............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record...............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record...............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station...............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record...............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid...............	1	18	0
Geological Record...............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c................	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record...............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure........................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids...........	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors................	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
Electrical Standards	25	0	0
Anthropological Notes and Queries	9	0	0
Specific Refractions	7	3	1
	£476	3	1

1882.

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
Exploration of Caves of South of Ireland	10	0	0
Fossil Plants of Halifax	15	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Record of Zoological Literature	100	0	0
British Polyzoa	10	0	0
Naples Zoological Station	80	0	0
Natural History of Timor-laut	100	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Natural History of Socotra	100	0	0
Circulation of Underground Waters	15	0	0
Migration of Birds	15	0	0
Earthquake Phenomena of Japan	25	0	0

	£	s.	d.
Geological Map of Europe ...	25	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Anthropometric Committee...	50	0	0
Photographing Ultra-Violet Spark Spectra	25	0	0
Exploration of Raygill Fissure	20	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Geological Record	100	0	0
Standards for Electrical Measurements	100	0	0
Exploration of Central Africa	100	0	0
Albuminoid Substances of Serum	10	0	0
	£1126	1	11

1883.

	£	s.	d.
Natural History of Timor-laut	50	0	0
British Fossil Polyzoa	10	0	0
Circulation of Underground Waters	15	0	0
Zoological Literature Record	100	0	0
Exploration of Mount Kilima-njaro	500	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Fossil Plants of Halifax	20	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Isomeric Naphthalene Derivatives	15	0	0
Zoological Station at Naples	80	0	0
Investigation of Loughton Camp	10	0	0
Earthquake Phenomena of Japan	50	0	0
Meteorological Observations on Ben Nevis	50	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Migration of Birds	20	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Scottish Zoological Station ...	25	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Zoological Literature Record	100	0	0
Fossil Polyzoa	10	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Anthropometric Committee...	10	0	0
Fossil Plants of Halifax	15	0	0
International Geological Map	20	0	0
Erratic Blocks of England ...	10	0	0
Natural History of Timor-laut	50	0	0
Coagulation of Blood	100	0	0
Naples Zoological Station ...	80	0	0
Bibliography of Groups of Invertebrata	50	0	0
Earthquake Phenomena of Japan	75	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Meteorological Observatory at Chepstow	25	0	0
Migration of Birds	20	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Circulation of Underground Waters	5	0	0
Ultra-Violet Spark Spectra ...	8	4	0
Tidal Observations	10	0	0
Meteorological Observations on Ben Nevis	50	0	0
	£1173	4	0

General Meetings.

On Wednesday, August 27, at 8 P.M., in the Queen's Hall, Professor Cayley, M.A., D.C.L., LL.D., F.R.S. (represented by Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.), resigned the office of President to Professor Lord Rayleigh, M.A., D.C.L., F.R.S., F.R.A.S., F.R.G.S., who took the Chair, and delivered an Address, for which see page 1.

On Thursday, August 28, at 8 P.M., a Soirée took place in the McGill University.

On Friday, August 29, at 8.30 P.M., in the Queen's Hall, Professor Oliver J. Lodge, D.Sc., delivered a Discourse on 'Dust.'

On Monday, September 1, at 8.30 P.M., in the Queen's Hall, the Rev. W. H. Dallinger, LL.D., F.R.S., delivered a Discourse on 'The Modern Microscope in Researches on the Least and Lowest Forms of Life.'

On Tuesday, September 2, at 8 P.M., a Soirée took place in the Skating Rink.

On Wednesday, September 3, at 2.30 P.M., the concluding General Meeting took place in the Queen's Hall, when the Proceedings of the General Committee and the Grants of Money for Scientific purposes were explained to the Members.

The Meeting was then adjourned to Aberdeen. [The Meeting is appointed to commence on Wednesday, September 9, 1885.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

THE RIGHT HON. LORD RAYLEIGH,

M.A., D.C.L., F.R.S., F.R.A.S., F.R.G.S., *Professor of Experimental Physics in the University of Cambridge*,

PRESIDENT.

It is no ordinary meeting of the British Association which I have now the honour of addressing. For more than fifty years the Association has held its autumn gathering in various towns of the United Kingdom, and within those limits there is, I suppose, no place of importance which we have not visited. And now, not satisfied with past successes, we are seeking new worlds to conquer. When it was first proposed to visit Canada, there were some who viewed the project with hesitation. For my own part, I never quite understood the grounds of their apprehension. Perhaps they feared the thin edge of the wedge. When once the principle was admitted, there was no knowing to what it might lead. So rapid is the development of the British Empire, that the time might come when a visit to such out-of-the-way places as London or Manchester could no longer be claimed as a right, but only asked for as a concession to the susceptibilities of the English. But seriously, whatever objections may have at first been felt were soon outweighed by the consideration of the magnificent opportunities which your hospitality affords of extending the sphere of our influence and of becoming acquainted with a part of the Queen's dominion which, associated with splendid memories of the past, is advancing daily by leaps and bounds to a position of importance such as not long ago was scarcely dreamed of. For myself, I am not a stranger to your shores. I remember well the impression made upon me, seventeen years ago, by the wild rapids of the St. Lawrence, and the gloomy grandeur of the Saguenay. If anything impressed me more, it was the kindness with which I was received by yourselves, and which I doubt not will be again extended not merely to myself but to all the English members of the Association. I am confident that those who have made up their minds to cross the ocean will not repent their decision, and that, apart altogether from scientific interests, great advantage may be expected from this visit. We Englishmen ought to know more than we do of matters relating to the Colonies, and anything which tends to bring the various parts of the Empire into closer contact can hardly be overvalued. It is pleasant to think that this Association is the means of furthering an object which should be dear to the hearts of all of us; and I venture to say that a large proportion of the visitors to this country will be astonished by what they see, and will carry home an impression which time will not readily efface.

To be connected with this meeting is, to me, a great honour, but also a great responsibility. In one respect, especially, I feel that the Association might have done well to choose another President. My own tastes have led me to study mathematics and physics rather than geology and biology, to which naturally more attention turns in a new country, presenting as it does a fresh field for investigation. A chronicle of achievements in these departments by workers from among yourselves would have been suitable to the occasion, but could not come from me. If you would have preferred a different subject for this address, I hope, at least, that you will not hold me entirely responsible.

At annual gatherings like ours the pleasure with which friends meet friends again is sadly marred by the absence of those who can never more take their part in our proceedings. Last year my predecessor in this office had to lament the untimely loss of Spottiswoode and Henry Smith, dear friends of many of us, and prominent members of our Association. And now, again, a well-known form is missing. For many years Sir W. Siemens has been a regular attendant at our meetings, and to few indeed have they been more indebted for success. Whatever the occasion, in his Presidential Address of two years ago, or in communications to the Physical and Mechanical Sections, he had always new and interesting ideas, put forward in language which a child could understand, so great a master was he of the art of lucid statement in his adopted tongue. Practice with Science was his motto. Deeply engaged in industry, and conversant, all his life, with engineering operations, his opinion was never that of a mere theorist. On the other hand, he abhorred rule of thumb, striving always to master the scientific principles which underlie rational design and invention.

It is not necessary that I should review in detail the work of Siemens. The part which he took, during recent years, in the development of the dynamo machine must be known to many of you. We owe to him the practical adoption of the method, first suggested by Wheatstone, of throwing into a shunt the coils of the field magnets, by which a greatly improved steadiness of action is obtained. The same characteristics are observable throughout—a definite object in view and a well-directed perseverance in overcoming the difficulties by which the path is usually obstructed.

These are, indeed, the conditions of successful invention. The world knows little of such things, and regards the new machine or the new method as the immediate outcome of a happy idea. Probably, if the truth were known, we should see that, in nine cases out of ten, success depends as much upon good judgment and perseverance as upon fertility of imagination. The labours of our great inventors are not unappreciated, but I doubt whether we adequately realise the enormous obligations under which we lie. It is no exaggeration to say that the life of such a man as Siemens is spent in the public service; the advantages which he reaps for himself being as nothing in comparison with those which he confers upon the community at large.

As an example of this it will be sufficient to mention one of the most valuable achievements of his active life—his introduction, in conjunction with his brother, of the Regenerative Gas Furnace, by which an immense economy of fuel (estimated at millions of tons annually) has been effected in the manufacture of steel and glass. The nature of this economy is easily explained. Whatever may be the work to be done by the burning of fuel, a certain *temperature* is necessary. For example, no amount of heat in the form of boiling water would be of any avail for the fusion of steel. When the products of combustion are cooled down to the point in question, the heat which they still contain is useless as regards the purpose in view. The importance of this consideration depends entirely upon the working temperature. If the object be the evaporation of water or the warming of a house, almost all the heat may be extracted from the fuel without special arrangements. But it is otherwise when the temperature required is not much below that of combustion itself, for then the escaping gases carry away with them the larger part of the whole heat developed. It was to meet this difficulty that the regenerative furnace was devised. The products of combustion, before dismissal into the chimney, are caused to pass through piles of loosely stacked fire-brick, to which they give up their heat. After a time the fire-brick, upon which the gases first impinge, becomes nearly as hot as the furnace itself. By suitable valves the burnt gases are then diverted through another stack of brickwork, which they heat up in like manner, while the heat stored up in the first stack is utilised to warm the unburnt gas and air on their way to the furnace. In this way almost all the heat developed at a high temperature during the combustion is made available for the work in hand.

As it is now several years since your presidential chair has been occupied by a professed physicist, it may naturally be expected that I should attempt some record of recent progress in that branch of science, if indeed such a term be applicable. For it is one of the difficulties of the task that subjects as distinct as Mechanics, Electricity, Heat, Optics and Acoustics, to say nothing of Astronomy and Meteorology, are included under Physics.

Any one of these may well occupy the life-long attention of a man of science, and to be thoroughly conversant with all of them is more than can be expected of any one individual, and is probably incompatible with the devotion of much time and energy to the actual advancement of knowledge. Not that I would complain of the association sanctioned by common parlance. A sound knowledge of at least the principles of general physics is necessary to the cultivation of any department. The predominance of the sense of sight as the medium of communication with the outer world, brings with it dependence upon the science of optics; and there is hardly a branch of science in which the effects of *temperature* have not (often without much success) to be reckoned with. Besides, the neglected borderland between two branches of knowledge is often that which best repays cultivation, or, to use a metaphor of Maxwell's, the greatest benefits may be derived from a cross fertilisation of the sciences. The wealth of material is an evil only from the point of view of one of whom too much may be expected. Another difficulty incident to the task, which must be faced but cannot be overcome, is that of estimating rightly the value, and even the correctness, of recent work. It is not always that which seems at first the most important that proves in the end to be so. The history of science teems with examples of discoveries which attracted little notice at the time, but afterwards have taken root downwards and borne much fruit upwards.

One of the most striking advances of recent years is in the production and application of electricity upon a large scale—a subject to which I have already had occasion to allude in connection with the work of Sir W. Siemens. The dynamo machine is indeed founded upon discoveries of Faraday now more than half a century old; but it has required the protracted labours of many inventors to bring it to its present high degree of efficiency. Looking back at the matter, it seems strange that progress should have been so slow. I do not refer to details of design, the elaboration of which must always, I suppose, require the experience of actual work to indicate what parts are structurally weaker than they should be, or are exposed to undue wear and tear. But with regard to the main features of the problem, it would almost seem as if the difficulty lay in want of faith. Long ago it was recognised that electricity derived from chemical action is (on a large scale) too expensive a source of mechanical power, notwithstanding the fact that (as proved by Joule in 1846) the conversion of electrical into mechanical work can be effected with great economy. From this it is an evident consequence that electricity may advantageously be obtained from mechanical power; and one cannot help thinking that if the fact had been borne steadily in mind, the development of the dynamo might have been much more rapid. But discoveries and inventions are apt to appear obvious when regarded from the standpoint of accomplished fact; and I draw attention to the matter only to point the moral that we do well to push the attack persistently when we can be sure beforehand that the obstacles to be overcome are only difficulties of contrivance, and that we are not vainly fighting unawares against a law of Nature.

The present development of electricity on a large scale depends, however, almost as much upon the incandescent lamp as upon the dynamo. The success of these lamps demands a very perfect vacuum—not more than about one-millionth of the normal quantity of air should remain,—and it is interesting to recall that, twenty years ago, such vacua were rare even in the laboratory of the physicist. It is pretty safe to say that these wonderful results would never have been accomplished had practical applications alone been in view. The way was prepared by an army of scientific men whose main object was the advancement of knowledge, and who could scarcely have imagined that the processes which they elaborated would soon be in use on a commercial scale and entrusted to the hands of ordinary workmen.

When I speak in hopeful language of practical electricity, I do not forget the disappointment within the last year or two of many over-sanguine expectations. The enthusiasm of the inventor and promoter are necessary to progress, and it seems to be almost a law of nature that it should overpass the bounds marked out by reason and experience. What is most to be regretted is the advantage taken by speculators of the often uninstructed interest felt by the public in novel schemes by which its imagination is fired. But looking forward to the future of electric lighting, we have good ground for encouragement. Already the lighting of large passenger ships is an assured success, and one which will be highly appreciated by those travellers who have experienced the tedium of long winter evenings unrelieved by adequate illumination. Here, no doubt, the conditions are in many respects especially favourable. As regards space, life on board ship is highly concentrated; while unity of management and the presence on the spot of skilled engineers obviate some of the difficulties that are met with under other circumstances. At present we have no experience of a house-to-house system of illumination on a great scale and in competition with cheap gas; but preparations are already far advanced for trial on an adequate scale in London. In large institutions, such as theatres and factories, we all know that electricity is in successful and daily extending operation.

When the necessary power can be obtained from the fall of water, instead of from the combustion of coal, the conditions of the problem are far more favourable. Possibly the severity of your winters may prove an obstacle, but it is impossible to regard your splendid river without the thought arising that the day may come when the vast powers now running to waste shall be bent into your service. Such a project demands of course the most careful consideration, but it is one worthy of an intelligent and enterprising community.

The requirements of practice react in the most healthy manner upon scientific electricity. Just as in former days the science received a stimulus from the application to telegraphy, under which everything relating to measurement on a small scale acquired an importance and development for which we might otherwise have had long to wait, so now the requirements of electric lighting are giving rise to a new development of the art of measurement upon a large scale, which cannot fail to prove of scientific as well as practical importance. Mere change of scale may not at first appear a very important matter, but it is surprising how much modification it entails in the instruments, and in the processes of measurement. For instance, the resistance coils on which the electrician relies in dealing with currents whose maximum is a fraction of an ampere, fail altogether when it becomes a question of hundreds, not to say thousands, of amperes.

The powerful currents, which are now at command, constitute almost a new weapon in the hands of the physicist. Effects, which in old days were rare and difficult of observation, may now be produced at will on the most conspicuous scale. Consider for a moment Faraday's great discovery of the 'Magnetisation of Light,' which Tyndall likens to the Weisshorn among mountains, as high, beautiful, and alone. This judgment (in which I fully concur) relates to the scientific aspect of the discovery, for to the eye of sense nothing could have been more insignificant. It is even possible that it might have eluded altogether the penetration of Faraday, had he not been provided with a special quality of very heavy glass. At the present day these effects may be produced upon a scale that would have delighted their discoverer, a rotation of the plane of polarization through 180° being perfectly feasible. With the aid of modern appliances, Kundt and Röntgen in Germany, and H. Becquerel in France, have detected the rotation in gases and vapours, where, on account of its extreme smallness, it had previously escaped notice.

Again, the question of the magnetic saturation of iron has now an importance entirely beyond what it possessed at the time of Joule's early observations. Then it required special arrangements purposely contrived to bring it into prominence. Now in every dynamo machine, the iron of the field-magnets approaches a state of saturation, and the very elements of an explanation of the action require us to take the fact into account. It is indeed probable that a better knowledge of this subject might lead to improvements in the design of these machines.

Notwithstanding the important work of Rowland and Stoletow, the whole theory of the behaviour of soft iron under varying magnetic conditions is still somewhat obscure. Much may be hoped from the induction balance of Hughes, by which the marvellous powers of the telephone are applied to the discrimination of the properties of metals, as regards magnetism and electric conductivity.

The introduction of powerful alternate-current machines by Siemens, Gordon, Ferranti, and others, is likely also to have a salutary effect in educating those so-called practical electricians whose ideas do not easily rise above ohms and volts. It has long been known that when the changes are sufficiently rapid, the phenomena are governed much more by induction, or electric inertia, than by mere resistance. On this principle much may be explained that would otherwise seem paradoxical. To take a comparatively simple case, conceive an electro-magnet wound with two contiguous wires, upon which acts a given rapidly periodic electro-motive force. If one wire only be used, a certain amount of heat is developed in the circuit. Suppose now that the second wire is brought into operation in parallel—a proceeding equivalent to doubling the section of the original wire. An electrician accustomed only to constant currents would be sure to think that the heating effect would be doubled by the change, as much heat being developed in each wire separately as was at first in the single wire. But such a conclusion would be entirely erroneous. The total current, being governed practically by the self-induction of the circuit, would not be augmented by the accession of the second wire, and the total heating effect, so far from being doubled, would, in virtue of the superior conductivity, be halved.

During the last few years much interest has been felt in the reduction to an absolute standard of measurements of electro-motive force, current, resistance, etc., and to this end many laborious investigations have been undertaken. The subject is one that has engaged a good deal of my own attention, and I should naturally have felt inclined to dilate upon it, but that I feel it to be too abstruse and special to be dealt with in detail upon an occasion like the present. As regards resistance, I will merely remind you that the recent determinations have shown a so greatly improved agreement, that the Conference of Electricians assembled at Paris, in May, have felt themselves justified in defining the ohm for practical use as the resistance of a column of mercury of 0° C., one square millimetre in section, and 106 centimetres in length—a definition differing by a little more than one per cent. from that arrived at twenty years ago by a committee of this Association.

A standard of resistance once determined upon can be embodied in a 'resistance coil,' and copied without much trouble, and with great accuracy. But in order to complete the electrical system, a second standard of some kind is necessary, and this is not so easily embodied in a permanent form. It might conveniently consist of a standard galvanic cell, capable of being prepared in a definite manner, whose electro-motive force is once for all determined. Unfortunately, most of the batteries in ordinary use are for one reason or another unsuitable for this purpose, but the cell introduced by Mr. Latimer Clark, in which the metals are zinc in contact with saturated zinc sulphate and pure mercury in contact with mercurous sulphate, appears to give satisfactory results. According to my measurements, the electro-motive force of this cell is 1·435 theoretical volts.

We may also conveniently express the second absolute electrical measurement necessary to the completion of the system by taking advantage of Faraday's law, that the quantity of metal decomposed in an electrolytic cell is proportional to the whole quantity of electricity that passes. The best metal for the purpose is silver, deposited from a solution of the nitrate or of the chlorate. The results recently obtained by Professor Kohlrausch and by myself are in very good agreement, and the conclusion that one ampere flowing for one hour decomposes 4·025 grains of silver, can hardly be in error by more than a thousandth part. This number being known, the silver voltameter gives a ready and very accurate method of measuring currents of intensity varying from $\frac{1}{10}$ ampere to four or five amperes.

The beautiful and mysterious phenomena attending the discharge of electricity in nearly vacuous spaces have been investigated and in some degree explained by De La Rue, Crookes, Schöster, Moulton, and the lamented Spottiswoode, as well as by various able foreign experimenters. In a recent research Crookes has sought the origin of a bright citron-coloured band in the phosphorescent spectrum of certain earths, and after encountering difficulties and anomalies of a most bewildering kind, has succeeded in proving that it is due to yttrium, an element much more widely distributed than had been supposed. A conclusion like this is stated in a few words, but those only who have undergone similar experience are likely to appreciate the skill and perseverance of which it is the final reward.

A remarkable observation by Hall of Baltimore, from which it appeared that the flow of electricity in a conducting sheet was disturbed by magnetic force, has been the subject of much discussion. Mr. Shelford Bidwell has brought forward experiments tending to prove that the effect is of a secondary character, due in the first instance to the mechanical force operating upon the conductor of an electric current when situated in a powerful magnetic field. Mr. Bidwell's view agrees in the main with Mr. Hall's division of the metals into two groups according to the direction of the effect.

Without doubt the most important achievement of the older generation of scientific men has been the establishment and application of the great laws of Thermo-dynamics, or, as it is often called, the Mechanical Theory of Heat. The first law, which asserts that heat and mechanical work can be transformed one into the other at a certain fixed rate, is now well understood by every student of physics, and the number expressing the mechanical equivalent of heat resulting from the experiments of Joule, has been confirmed by the researches of others, and especially of Rowland. But the second law, which practically is even more important than the first, is only now beginning to receive the full appreciation due to it. One reason of this may be found in a not unnatural confusion of ideas. Words do not always lend themselves readily to the demands that are made upon them by a growing science, and I think that the almost unavoidable use of the word equivalent in the statement of the first law is partly responsible for the little attention that is given to the second. For the second law so far contradicts the usual statement of the first, as to assert that equivalents of heat and work are not of equal value. While work can always be converted into heat, heat can only be converted into work under certain limitations. For every practical purpose the work is worth the most, and when we speak of equivalents, we use the word in the same sort of special sense as that in which chemists speak of equivalents of gold and iron. The second law teaches us that the real value of heat, as a source of mechanical power, depends upon the temperature of the body in which it resides ; the hotter the body in relation to its surroundings, the more available the heat.

In order to see the relations which obtain between the first and the second law of Thermo-dynamics, it is only necessary for us to glance at the theory of the steam-engine. Not many years ago calculations were plentiful, demonstrating the inefficiency of the steam-engine on the basis of a comparison of the work actually got out of the engine with the mechanical equivalent of the heat supplied to the boiler. Such calculations took into account only the first law of Thermo-dynamics, which deals with the equivalents of heat and work, and have very little bearing upon the practical question of efficiency, which requires us to have regard also to the second law. According to that law the fraction of the total energy which can be converted into work depends upon the relative temperatures of the boiler and condenser ; and it is, therefore, manifest that, as the temperature of the boiler cannot be raised indefinitely, it is impossible to utilise all the energy which, according to the first law of Thermo-dynamics, is resident in the coal. On a sounder view of the matter, the efficiency of the steam-engine is found to be so high, that there is no great margin remaining for improvement. The higher initial temperature possible in the gas-engine opens out much wider possibilities, and many good judges look forward to a time when the steam-engine will have to give way to its younger rival.

To return to the theoretical question, we may say with Sir W. Thomson, that though energy cannot be destroyed, it ever tends to be dissipated, or to pass from more available to less available forms. No one who has grasped this principle can fail to recognise its immense importance in the system of the Universe. Every change—chemical, thermal, or mechanical—which takes place, or can take place, in Nature, does so at the cost of a certain amount of available energy. If, therefore, we wish to inquire whether or not a proposed transformation can take place, the question to be considered is whether its occurrence would involve dissipation of energy. If not, the transformation is (under the circumstances of the case) absolutely excluded. Some years ago, in a lecture at the Royal Institution, I endeavoured to draw the attention of chemists to the importance of the principle of dissipation in relation to their science, pointing out the error of the usual assumption that a general criterion is to be found in the development of heat. For example, the solution of a salt in water is, if I may be allowed the phrase, a downhill transformation. It involves dissipation of energy, and can therefore go forward; but in many cases it is associated with the absorption rather than with the development of heat. I am glad to take advantage of the present opportunity in order to repeat my recommendation, with an emphasis justified by actual achievement. The foundations laid by Thomson now bear an edifice of no mean proportions, thanks to the labours of several physicists, among whom must be especially mentioned Willard Gibbs and Helmholtz. The former has elaborated a theory of the equilibrium of heterogeneous substances, wide in its principles, and we cannot doubt far-reaching in its consequences. In a series of masterly papers Helmholtz has developed the conception of *free energy* with very important applications to the theory of the galvanic cell. He points out that the mere tendency to solution bears in some cases no small proportion to the affinities more usually reckoned chemical, and contributes largely to the total electro-motive force. Also in our own country Dr. Alder Wright has published some valuable experiments relating to the subject.

From the further study of electrolysis we may expect to gain improved views as to the nature of the chemical reactions, and of the forces concerned in bringing them about. I am not qualified—I wish I were—to speak to you on recent progress in general chemistry. Perhaps my feelings towards a first love may blind me, but I cannot help thinking that the next great advance, of which we have already some foreshadowing, will come on this side. And if I might without presumption venture a word of recommendation, it would be in favour of a more minute study of the simpler chemical phenomena.

Under the head of scientific mechanics it is principally in relation to fluid motion that advances may be looked for. In speaking upon this subject I must limit myself almost entirely to experimental work. Theoretical hydro-dynamics, however important and interesting to the mathematician, are eminently unsuited to oral exposition. All I can do to attenuate an injustice, to which theorists are pretty well accustomed, is to refer you to the admirable reports of Mr. W. M. Hicks, published under the auspices of this Association.

The important and highly practical work of the late Mr. Froude in relation to the propulsion of ships is doubtless known to most of you. Recognising the fallacy of views then widely held as to the nature of the resistance to be overcome, he showed to demonstration that, in the case of fair-shaped bodies, we have to deal almost entirely with resistance dependent upon skin friction, and at high speeds upon the generation of surface waves by which energy is carried off. At speeds which are moderate in relation to the size of the ship, the resistance is practically dependent upon skin friction only. Although Professor Stokes and other mathematicians had previously published calculations pointing to the same conclusion, there can be no doubt that the view generally entertained was very different. At the first meeting of the Association which I ever attended, as an intelligent listener, at Bath in 1864, I well remember the surprise which greeted a statement by Rankine, that he regarded skin friction as the only legitimate resistance to the progress of a well-designed ship. Mr. Froude's experiments have set the question at rest in a manner satisfactory to those who had little confidence in theoretical prevision.

In speaking of an explanation as satisfactory in which skin friction is accepted as the cause of resistance, I must guard myself against being supposed to mean that the nature of skin friction is itself well understood. Although its magnitude varies with the smoothness of the surface, we have no reason to think that it would disappear at any degree of smoothness consistent with an ultimate molecular structure. That it is connected with fluid viscosity is evident enough, but the *modus operandi* is still obscure.

Some important work bearing upon the subject has recently been published by Professor O. Reynolds, who has investigated the flow of water in tubes as dependent upon the velocity of motion and upon the size of the bore. The laws of motion in capillary tubes, discovered experimentally by Poiseuille, are in complete harmony with theory. The resistance varies as the velocity, and depends in a direct manner upon the constant of viscosity. But when we come to the larger pipes and higher velocities with which engineers usually have to deal, the theory which presupposes a regularly stratified motion evidently ceases to be applicable, and the problem becomes essentially identical with that of skin friction in relation to ship propulsion. Professor Reynolds has traced with much success the passage from the one state of things to the other, and has proved the applicability under these complicated conditions of the general laws of dynamical similarity as adapted to viscous fluids by Professor Stokes. In spite of the difficulties which beset both the theoretical and experimental treatment, we may hope to attain before long to a better understanding of a subject which is certainly second to none in scientific as well as practical interest.

As also closely connected with the mechanics of viscous fluids, I must not forget to mention an important series of experiments upon the friction of oiled surfaces, recently executed by Mr. Tower for the Institution of Mechanical Engineers. The results go far towards upsetting some ideas hitherto widely admitted. When the lubrication is adequate, the friction is found to be nearly independent of the load, and much smaller than is usually supposed, giving a coefficient as low as $\frac{1}{1000}$. When the layer of oil is well formed, the pressure between the solid surfaces is really borne by the fluid, and the work lost is spent in shearing, that is, in causing one stratum of the oil to glide over another. In order to maintain its position, the fluid must possess a certain degree of viscosity, proportionate to the pressure; and even when this condition is satisfied, it would appear to be necessary that the layer should be thicker on the ingoing than on the outgoing side. We may, I believe, expect from Professor Stokes a further elucidation of the processes involved. In the meantime, it is obvious that the results already obtained are of the utmost value, and fully justify the action of the Institution in devoting a part of its resources to experimental work. We may hope indeed that the example thus wisely set may be followed by other public bodies associated with various departments of industry.

I can do little more than refer to the interesting observations of Professor Darwin, Mr. Hunt, and M. Forel on Ripplemark. The processes concerned would seem to be of a rather intricate character, and largely dependent upon fluid viscosity. It may be noted indeed that most of the still obscure phenomena of hydro-dynamics require for their elucidation a better comprehension of the laws of viscous motion. The subject is one which offers peculiar difficulties. In some problems in which I have lately been interested, a circulating motion presents itself of the kind which the mathematician excludes from the first when he is treating of fluids destitute altogether of viscosity. The intensity of this motion proves, however, to be independent of the coefficient of viscosity, so that it cannot be correctly dismissed from consideration in consequence of a supposition that the viscosity is infinitely small. The apparent breach of continuity can be explained, but it shows how much care is needful in dealing with the subject, and how easy it is to fall into error.

The nature of gaseous viscosity, as due to the diffusion of momentum, has been made clear by the theoretical and experimental researches of Maxwell. A flat disc moving in its own plane between two parallel solid surfaces is impeded by the necessity of shearing the intervening layers of gas, and the magnitude of the hindrance is proportional to the velocity of the motion and to the viscosity of the gas, so that under similar circumstances this effect may be taken as a measure, or rather definition, of the viscosity. From the dynamical theory of gases, to the development of which he contributed so much, Maxwell drew the startling conclusion that the viscosity of a gas should be independent of its density,—that within wide limits the resistance to the moving disc should be scarcely diminished by pumping out the gas, so as to form a partial vacuum. Experiment fully confirmed this theoretical anticipation, —one of the most remarkable to be found in the whole history of science— and proved that the swinging disc was retarded by the gas, as much when the barometer stood at half an inch as when it stood at thirty inches. It was obvious, of course, that the law must have a limit, that at a certain point of exhaustion the gas must begin to lose its power; and

I remember discussing with Maxwell, soon after the publication of his experiments, the whereabouts of the point at which the gas would cease to produce its ordinary effect. His apparatus, however, was quite unsuited for high degrees of exhaustion, and the failure of the law was first observed by Kundt and Warburg, as pressures below 1 mm. of mercury. Subsequently the matter has been thoroughly examined by Crookes, who extended his observations to the highest degrees of exhaustion as measured by MacLeod's gauge. Perhaps the most remarkable results relate to hydrogen. From the atmospheric pressure of 760 mm. down to about $\frac{1}{2}$ mm. of mercury the viscosity is sensibly constant. From this point to the highest vacua, in which less than one-millionth of the original gas remains, the coefficient of viscosity drops down gradually to a small fraction of its original value. In these vacua Mr. Crookes regards the gas as having assumed a different, ultra-gaseous, condition; but we must remember that the phenomena have relation to the other circumstances of the case, especially the dimensions of the vessel, as well as to the condition of the gas.

Such an achievement as the prediction of Maxwell's law of viscosity has, of course, drawn increased attention to the dynamical theory of gases. The success which has attended the theory in the hands of Clausius, Maxwell, Boltzmann, and other mathematicians, not only in relation to viscosity, but over a large part of the entire field of our knowledge of gases, proves that some of its fundamental postulates are in harmony with the reality of Nature. At the same time, it presents serious difficulties; and we cannot but feel that while the electrical and optical properties of gases remain out of relation to the theory, no final judgment is possible. The growth of experimental knowledge may be trusted to clear up many doubtful points, and a younger generation of theorists will bring to bear improved mathematical weapons. In the meantime we may fairly congratulate ourselves on the possession of a guide which has already conducted us to a position which could hardly otherwise have been attained.

In Optics attention has naturally centred upon the spectrum. The mystery attaching to the invisible rays lying beyond the red has been fathomed to an extent that, a few years ago, would have seemed almost impossible. By the use of special photographic methods Abney has mapped out the peculiarities of this region with such success that our knowledge of it begins to be comparable with that of the parts visible to the eye. Equally important work has been done by Langley, using a refined invention of his own based upon the principle of Siemens' pyrometer. This instrument measures the actual energy of the radiation, and thus expresses the effects of various parts of the spectrum upon a common scale, independent of the properties of the eye and of sensitive photographic preparations. Interesting results have also been obtained by Becquerel, whose method is founded upon a curious action of the ultra-red rays in enfeebling the light emitted by phosphorescent substances. One of the most startling of Langley's conclusions relates to the influence of the atmosphere in modifying the quality of solar light. By the comparison of observations made through varying thicknesses of air, he shows that the atmospheric absorption tells most upon the light of high refrangibility; so that, to an eye situated outside the atmosphere, the sun would present a decidedly bluish tint. It would be interesting to compare the experimental numbers with the law of scattering of light by small particles given some years ago as the result of theory. The demonstration by Langley of the inadequacy of Cauchy's law of dispersion to represent the relation between refrangibility and wave-length in the lower part of the spectrum must have an important bearing upon optical theory.

The investigation of the relation of the visible and ultra-violet spectrum to various forms of matter has occupied the attention of a host of able workers, among whom none have been more successful than my colleagues at Cambridge, Professors Liveing and Dewar. The subject is too large both for the occasion and for the individual, and I must pass it by. But, as more closely related to Optics proper, I cannot resist recalling to your notice a beautiful application of the idea of Doppler to the discrimination of the origin of certain lines observed in the solar spectrum. If a vibrating body have a general motion of approach or recession, the waves emitted from it reach the observer with a frequency which in the first case exceeds, and in the second case falls short of, the real frequency of the vibrations themselves. The consequence is that, if a glowing gas be in motion in the line of sight, the spectral lines are thereby displaced from the position that they would occupy were the gas at rest—a principle which, in the hands of Huggins and others, has led to a determination of the motion of certain fixed stars relatively to the solar system. But the sun is itself in rotation, and thus the position of a solar spectral line is slightly different according as the light comes from the advancing or from the retreating limb. This displacement was, I believe, first observed by Thollon; but what I desire now to draw attention to is the application of it by Cornu to determine whether a line is of solar or atmospheric origin. For this purpose a small image of the sun is thrown upon the slit of the spectroscope, and caused to vibrate two or three times a second, in such a manner that the light entering the instrument comes alternately from the advancing and retreating limbs. Under these circumstances a line due to absorption within the sun appears to tremble, as the result of slight alternately opposite displacements. But if the seat of the absorption be in the atmosphere, it is a matter of indifference from what part of the sun the light originally proceeds, and the line maintains its position in spite of the oscillation of the image upon the slit of the spectroscope. In this way Cornu was able to make a discrimination which can only otherwise be effected by a difficult comparison of appearances under various solar altitudes.

The instrumental weapon of investigation, the spectroscope itself, has made important advances. On the theoretical side, we have for our guidance the law that the optical power in gratings is proportional to the total number of lines accurately ruled, without regard to the degree of closeness, and in prisms that it is proportional to the thickness of glass traversed. The magnificent gratings of Rowland are a new power in the hands of the spectroscopist, and as triumphs of mechanical art seem to be little short of perfection. In our own report for 1882, Mr. Mallock has described a machine, constructed by him, for ruling large diffraction gratings, similar in some respects to that of Rowland.

The great optical constant, the velocity of light, has been the subject of three distinct investigations by Cornu, Michelson, and Forbes. As may be supposed, the matter is of no ordinary difficulty, and it is therefore not surprising that the agreement should be less decided than could be wished. From their observations, which were made by a modification of Fizeau's method of the toothed wheel, Young and Forbes drew the conclusion that the velocity of light *in vacuo* varies from colour to colour, to such an extent that the velocity of blue light is nearly two per cent. greater than that of red light. Such a variation is quite opposed to existing theoretical notions, and could only be accepted on the strongest evidence. Mr. Michelson, whose method (that of Foucault) is well suited to bring into prominence a variation of velocity with wave length, informs me that he has recently repeated his experiments with special reference to the point in question, and has arrived at the conclusion that no variation exists comparable with that asserted by Young and Forbes. The actual velocity differs little from that found from his first series of experiments, and may be taken to be 299,800 kilometres per second.

It is remarkable how many of the playthings of our childhood give rise to questions of the deepest scientific interest. The top is, or may be understood, but a complete comprehension of the kite and of the soap-bubble would carry us far beyond our present stage of knowledge. In spite of the admirable investigations of Plateau, it still remains a mystery why soapy water stands almost alone among fluids as a material for bubbles. The beautiful development of colour was long ago ascribed to the interference of light, called into play by the gradual thinning of the film. In accordance with this view the tint is determined solely by the thickness of the film, and the refractive index of the fluid. Some of the phenomena are however so curious, as to have led excellent observers like Brewster to reject the theory of thin plates, and to assume the secretion of various kinds of colouring matter. If the rim of a wine-glass be dipped in soapy water, and then held in a vertical position, horizontal bands soon begin to show at the top of the film, and extend themselves gradually, downwards. According to Brewster these bands are not formed by the 'subsidence and gradual thinning of the film,' because they maintain their horizontal position when the glass is turned round its axis. The experiment is both easy and interesting; but the conclusion drawn from it cannot be accepted. The fact is that the various parts of the film cannot quickly alter their thickness, and hence when the glass is rotated they re-arrange themselves in order of superficial density, the thinner parts floating up over, or through, the thicker parts. Only thus can the tendency be satisfied for the centre of gravity to assume the lowest possible position.

When the thickness of a film falls below a small fraction of the length of a wave of light, the colour disappears and is replaced by an intense blackness. Professors Reinold and Rücker have recently made the remarkable observation that the whole of the black region, soon after its formation, is of uniform thickness, the passage from the black to the coloured portions being exceedingly abrupt. By two independent methods they have determined the thickness of the black film to lie between seven and fourteen millionths of a millimetre; so that the thinnest films correspond to about one-seventieth of a wave-length of light. The importance of these results in regard to molecular theory is too obvious to be insisted upon.

The beautiful inventions of the telephone and the phonograph, although in the main dependent upon principles long since established, have imparted a new interest to the study of Acoustics. The former, apart from its uses in every-day life, has become in the hands of its inventor, Graham Bell, and of Hughes, an instrument of first-class scientific importance. The theory of its action is still in some respects obscure, as is shown by the comparative failure of the many attempts to improve it. In connection with some explanations that have been offered, we do well to remember that molecular changes in solid masses are inaudible in themselves, and can only be manifested to our ears by the generation of a to and fro motion of the external surface extending over a sensible area. If the surface of a solid remains undisturbed, our ears can tell us nothing of what goes on in the interior.

In theoretical acoustics progress has been steadily maintained, and many phenomena, which were obscure twenty or thirty years ago, have since received adequate explanation. If some important practical questions remain unsolved, one reason is that they have not yet been definitely stated. Almost everything in connection with the ordinary use of our senses presents peculiar difficulties to scientific investigation. Some kinds of information with regard to their surroundings are of such paramount importance to successive generations of living beings, that they have learned to interpret indications which, from a physical point of view, are of the slenderest character. Every day we are in the habit of recognising, without much difficulty, the quarter from which a sound proceeds, but by what steps we attain that end has not yet been satisfactorily explained. It has been proved that when proper precautions are taken we are unable to distinguish whether a pure tone (as from a vibrating tuning fork held over a suitable resonator) comes to us from in front or from behind. This is what might have been expected from an *à priori* point of view; but what would not have been expected is that with almost any other sort of sound, from a clap of the hands to the clearest vowel sound, the discrimination is not only possible but easy and instinctive. In these cases it does not appear how the possession of two ears helps us, though there is some evidence that it does; and even when sounds come to us from the right or left, the explanation of the ready discrimination which is then possible with pure tones, is not so easy as might at first appear. We should be inclined to think that the sound was heard much more loudly with the ear that is turned towards than with the ear that is turned from it, and that in this way the direction was recognised. But if we try the experiment, we find that, at any rate with notes near the middle of the musical scale, the difference of loudness is by no means so very great. The wave-lengths of such notes are long enough in relation to the dimensions of the head to forbid the formation of anything like a sound shadow in which the averted ear might be sheltered.

In concluding this imperfect survey of recent progress in physics, I must warn you emphatically that much of great importance has been passed over altogether. I should have liked to speak to you of those far-reaching speculations, especially associated with the name of Maxwell, in which light is regarded as a disturbance in an electro-magnetic medium. Indeed, at one time, I had thought of taking the scientific work of Maxwell as the principal theme of this address. But, like most men of genius, Maxwell delighted in questions too obscure and difficult for hasty treatment, and thus much of his work could hardly be considered upon such an occasion as the present. His biography has recently been published, and should be read by all who are interested in science and in scientific men. His many-sided character, the quaintness of his humour, the penetration of his intellect, his simple but deep religious feeling, the affection between son and father, the devotion of husband to wife, all combine to form a rare and fascinating picture. To estimate rightly his influence upon the present state of science, we must regard not only the work that he executed himself, important as that was, but also the ideas and the spirit which he communicated to others. Speaking for myself as one who in a special sense entered into his labours, I should find it difficult to express adequately my feeling of obligation. The impress of his thoughts may be recognised in much of the best work of the present time. As a teacher and examiner he was well acquainted with the almost universal tendency of uninstructed minds to elevate phrases above things: to refer, for example, to the principle of the conservation of energy for an explanation of the persistent rotation of a fly-wheel, almost in the style of the doctor in 'Le Malade Imaginaire,' who explains the fact that opium sends you to sleep by its soporific virtue. Maxwell's endeavour was always to keep the facts in the foreground, and to his influence, in conjunction with that of Thomson and Helmholtz, is largely due that elimination of unnecessary hypothesis which is one of the distinguishing characteristics of the science of the present day.

In speaking unfavourably of superfluous hypothesis, let me not be misunderstood. Science is nothing without generalisations. Detached and ill-assorted facts are only raw material, and in the absence of a theoretical solvent, have but little nutritive value. At the present time and in some departments, the accumulation of material is so rapid that there is danger of indigestion. By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is usually spoken of as 'known,' and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory. In this matter we are greatly dependent upon annual reports and abstracts, issued principally in Germany, without which the search for the discoveries of a little-known author would be well-nigh hopeless. Much useful work has been done in this direction in connection with our Association. Such critical reports as those upon Hydro-dynamics, upon Tides, and upon Spectroscopy, guide the investigator to the points most requiring attention, and in discussing past achievements contribute in no small degree to future progress. But though good work has been done, much yet remains to do.

If, as is sometimes supposed, science consisted in nothing but the laborious accumulation of facts, it would soon come to a stand-still, crushed, as it were, under its own weight. The suggestion of a new idea, or the detection of a law, supersedes much that had previously been a burden upon the memory, and by introducing order and coherence facilitates the retention of the remainder in an available form. Those who are acquainted with the writings of the older electricians will understand my meaning when I instance the discovery of Ohm's law as a step by which the science was rendered easier to understand and to remember. Two processes are thus at work side by side, the reception of new material and the digestion and assimilation of the old; and as both are essential, we may spare ourselves the discussion of their relative importance. One remark, however, should be made. The work which deserves, but I am afraid does not always receive, the most credit is that in which discovery and explanation go hand in hand, in which not only are new facts presented, but their relation to old ones is pointed out.

In making oneself acquainted with what has been done in any subject, it is good policy to consult first the writers of highest general reputation. Although in scientific matters we should aim at independent judgment, and not rely too much upon authority, it remains true that a good deal must often be taken upon trust. Occasionally an observation is so simple and easily repeated, that it scarcely matters from whom it proceeds; but as a rule it can hardly carry full weight when put forward by a novice whose care and judgment there has been no opportunity of testing, and whose irresponsibility may tempt him to 'take shots,' as it is called. Those who have had experience in accurate work know how easy it would be to save time and trouble by omitting precautions and passing over discrepancies, and yet, even without dishonest intention, to convey the impression of conscientious attention to details. Although the most careful and experienced cannot hope to escape occasional mistakes, the effective value of this kind of work depends much upon the reputation of the individual responsible for it.

In estimating the present position and prospects of experimental science, there is good ground for encouragement. The multiplication of laboratories gives to the younger generation opportunities such as have never existed before, and which excite the envy of those who have had to learn in middle life much that now forms part of an undergraduate course. As to the management of such institutions there is room for a healthy difference of opinion. For many kinds of original work, especially in connection with accurate measurement, there is need of expensive apparatus; and it is often difficult to persuade a student to do his best with imperfect appliances when he knows that by other means a better result could be attained with greater facility. Nevertheless it seems to me important to discourage too great reliance upon the instrument maker. Much of the best original work has been done with the homeliest appliances; and the endeavour to turn to the best account the means that may be at hand develops ingenuity and resource more than the most elaborate determinations with ready-made instruments. There is danger otherwise that the experimental education of a plodding student should be too mechanical and artificial, so that he is puzzled by small changes of apparatus much as many school-boys are puzzled by a transposition of the letters in a diagram of Euclid.

From the general spread of a more scientific education, we are warranted in expecting important results. Just as there are some brilliant literary men with an inability, or at least a distaste practically amounting to inability, for scientific ideas, so there are a few with scientific tastes whose imaginations are never touched by merely literary studies. To save these from intellectual stagnation during several important years of their lives is something gained; but the thorough-going advocates of scientific education aim at much more. To them it appears strange, and almost monstrous, that the dead languages should hold the place they do in general education; and it can hardly be denied that their supremacy is the result of routine rather than of argument. I do not, myself, take up the extreme position. I doubt whether an exclusively scientific training would be satisfactory; and where there is plenty of time and a literary aptitude I can believe that Latin and Greek may make a good foundation. But it is useless to discuss the question upon the supposition that the majority of boys attain either to a knowledge of the languages or to an appreciation of the writings of the ancient authors. The contrary is notoriously the truth; and the defenders of the existing system usually take their stand upon the excellence of its discipline. From this point of view there is something to be said. The laziest boy must exert himself a little in puzzling out a sentence with grammar and dictionary, while instruction and supervision are easy to organise and not too costly. But when the case is stated plainly, few will agree that we can afford so entirely to disregard results. In after life the intellectual energies are usually engrossed with business, and no further opportunity is found for attacking the difficulties which block the gateways of knowledge. Mathematics, especially, if not learned young, are likely to remain unlearned. I will not further insist upon the educational importance of mathematics and science, because with respect to them I shall probably be supposed to be prejudiced. But of modern languages I am ignorant enough to give value to my advocacy. I believe that French and German, if properly taught, which I admit they rarely are at present, would go far to replace Latin and Greek from a disciplinary point of view, while the actual value of the acquisition would, in the majority of cases, be incomparably greater. In half the time usually devoted, without success, to the classical languages, most boys could acquire a really serviceable knowledge of French and German. History and the serious study of English literature, now shamefully neglected, would also find a place in such a scheme.

There is one objection often felt to a modernised education, as to which a word may not be without use. Many excellent people are afraid of science as tending towards materialism. That such apprehension should exist is not surprising, for unfortunately there are writers, speaking in the name of science, who have set themselves to foster it. It is true that among scientific men, as in other classes, crude views are to be met with as to the deeper things of Nature; but that the life-long beliefs of Newton, of Faraday, and of Maxwell are inconsistent with the scientific habit of mind, is surely a proposition which I need not pause to refute. It would be easy, however, to lay too much stress upon the opinions of even such distinguished workers as these. Men, who devote their lives to investigation, cultivate a love of truth for its own sake, and endeavour instinctively to clear up, and not, as is too often the object in business and politics, to obscure a difficult question. So far the opinion of a scientific worker may have a special value; but I do not think that he has a claim, superior to that of other educated men, to assume the attitude of a prophet. In his heart he knows that underneath the theories that he constructs there lie contradictions which he cannot reconcile. The higher mysteries of being, if penetrable at all by human intellect, require other weapons than those of calculation and experiment.

Without encroaching upon grounds appertaining to the theologian and the philosopher, the domain of natural science is surely broad enough to satisfy the wildest ambition of its devotees. In other departments of human life and interest, true progress is rather an article of faith than a rational belief; but in science a retrograde movement is, from the nature of the case, almost impossible. Increasing knowledge brings with it increasing power, and great as are the triumphs of the present century, we may well believe that they are but a foretaste of what discovery and invention have yet in store for mankind. Encouraged by the thought that our labours cannot be thrown away, let us redouble our efforts in the noble struggle. In the Old World and in the New, recruits must be enlisted to fill the place of those whose work is done. Happy should I be if, through this visit of the Association, or by any words of mine, a larger measure of the youthful activity of the West could be drawn into this service. The work may be hard, and the discipline severe; but the interest never fails, and great is the privilege of achievement.

REPORTS

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Report of the Committee, consisting of Sir WILLIAM THOMSON, Professor A. W. WILLIAMSON, Mr. W. H. PREECE, Mr. BARLOW, *and* Mr. J. M. THOMSON (*Secretary*), *appointed to consider and advise on the best means for facilitating the adoption of the Metric System of Weights and Measures in Great Britain.*

YOUR Committee have held several meetings during the past year.

They wish to take this opportunity of expressing their very deep regret at the loss which the Committee has sustained in the death of their colleague, Sir William Siemens, F.R.S., since the last meeting of the British Association. Sir William Siemens had taken a very prominent part in the formation of this Committee, and had himself undertaken personally much of the business of the Committee, and his colleagues further regret that his sudden and unexpected death has prevented them hearing from him more particulars of the results of the inquiries which he had undertaken to make.

Your Committee have been in correspondence with the Board of Trade on the subject of the introduction and wider employment of the metric system in Great Britain; but the answer received has not been so favourable to the general adoption of the system as they could have wished.

After due consideration, your Committee determined to memorialise Her Majesty's Government on the subject, and endeavour to induce the English Government to become members of the 'Bureau International des Poids et Mesures.'

Understanding that the Royal Society had already entered upon negotiations with the Government, and wishing to proceed upon the same grounds, your Committee put themselves in communication with the Society.

From the Royal Society your Committee learn that the former has been, and is still, in communication with the Secretary of the Treasury, and that the chief difficulties in the way of the Government joining the Bureau are (1) the expense, especially the arrears of payment, and (2) the question of being able to contribute to the Bureau without joining the Metric Convention, Her Majesty's Government—they are given to understand—regarding this latter step as committing this country to the metric system, which they are unwilling to do, as being opposed, in their judgment, to the public opinion of the country.

On receipt of this information from the Royal Society your Committee, taking into consideration, not only the late period of the present Session of Parliament, but also the short time that remains before the dissolution of the present Parliament, have determined that it will be more advantageous to defer approaching Government on the subject till a later period.

Your Committee still wish to hold the matter under further consideration, and they therefore ask that the Committee be reappointed without a grant of money.

NOTE.—Since the above Report was drafted the Government have agreed to join the 'Bureau International des Poids et Mesures'

Report of the Committee, consisting of Professor BALFOUR STEWART (*Secretary*), Professor STOKES, Mr. G. JOHNSTONE STONEY, Professor Sir H. E. ROSCOE, Professor SCHUSTER, Captain ABNEY, *and* Mr. G. J. SYMONS, *appointed for the purpose of considering the best methods of recording the direct intensity of Solar Radiation.*

THIS Committee, acting on a suggestion made by General Strachey, have chiefly devoted their attention to the subject of a self-recording actinometer.

The self-recording actinometer of Mr. Winstanley would not be suitable,[1] because it is influenced by radiation from all quarters. Other actinometers require manipulation on the part of the observer which would make it almost impossible to make them self-recording. It was suggested by Professor Balfour Stewart that a modification of his actinometer might be adapted to self-registration by taking for the quantity to be observed, not the rise of temperature of the enclosed thermometer after exposure for a given time, but the excess of its temperature when continuously exposed over the temperature of the envelope. After making some calculations as to the behaviour of such an instrument, Professor Stokes came to the following conclusions:

(1) The enclosure should be of such a nature as to change its temperature very slowly, and of such a material that the various portions of the interior should be at the same moment of the same uniform temperature. For this purpose an arrangement somewhat similar to that used in Prof. Stewart's actinometer is suggested; the outside to consist of polished metallic plates, then a layer of some non-conducting substance, such as felt, then a thick copper interior which need not be polished. Into this copper is to be inserted a thermometer which will give the temperature of the copper interior from moment to moment.

(2) In the middle of the enclosure is to be placed the thermometer, upon which the heat of the sun is made to fall by means of a hole in the enclosure, either with or without a lens. This thermometer should be so

[1] 'This is the case at present, but there would not be any great difficulty in modifying it so as to act as required. It is quite a matter worth consideration whether a differential air-thermometer would not be very suitable, one bulb silvered and the other blackened or of green glass, as I suggested to the Meteorological Council some years back. By this means only *one* reading would be necessary, whilst in the plan suggested two would have to be recorded, and the measurements would be more difficult.' (*Note by Captain Abney.*)

constructed as to be readily susceptible of solar influences. It is proposed to make it of green glass (a good absorber and radiator), and to give it a flattened surface in the direction perpendicular to the light from the hole.

Such an instrument should be so adjusted as to receive the sun's light continuously through the hole, and the objects of record would be the simultaneous heights of the two thermometers, the one giving the temperature of the enclosure, and the other of the central thermometer. There are two conceivable methods by which the necessary adjustment with regard to the sun's light might be secured, namely, (α) the enclosure might be subject to an equatorial motion so as to follow the sun, or (β) the enclosure might be kept at rest and the solar rays kept upon the hole by a heliostat. Captain Abney is of opinion that the latter arrangement is, mechanically, much preferable to the former.

As the direction of the earth's axis may be chosen as that into which the sun's light is to be reflected, a heliostat of a very simple construction will suffice; and as the angle of incidence on the mirror of such a heliostat changes only very slowly with the season, there is no difficulty in applying the small correction required for the change in the intensity of the reflected heat consequent on the change in the angle of incidence. It is assumed that the mirror of the heliostat is a speculum.

It has been remarked by General Strachey that some such instrument as this now suggested, even if not made self-recording, would have the advantage of giving an observation without the objectionable necessity of putting the light on for a given time and then shutting it off, operations only suitable for trained observers. We think that it would be desirable to construct an enclosure with its two thermometers such as herein recorded. In all probability the loan of a heliostat and of an actinometer might be obtained. By aid of the heliostat the sun's light might be kept continuously upon the hole of the enclosure. The two thermometers would be read, and the results compared with the simultaneous reading of an ordinary actinometer. By such means it is believed that the best method of constructing such an instrument and observing with it might be found.

We would therefore ask for a continuance of our Committee, with the sum of 30*l.* to be placed at our disposal for the purpose herein specified.

Report of the Committee, consisting of Professor G. CAREY FOSTER, Sir WILLIAM THOMSON, Professor AYRTON, Professor J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Professor JENKIN, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. A. MUIRHEAD, Mr. W. H. PREECE, Mr. HERBERT TAYLOR, Professor EVERETT, Professor SCHUSTER, Dr. J. A. FLEMING, Professor G. F. FITZGERALD, Mr. R. T. GLAZEBROOK (*Secretary*), Professor CHRYSTAL, Mr. H. TOMLINSON, *and* Professor W. GARNETT, *appointed for the purpose of constructing and issuing practical Standards for use in Electrical Measurements.*

THE Committee report that during the year the construction and testing of standards of electrical resistance has been proceeded with. The coils of 10, 100, 1,000, and 10,000 B.A. units, mentioned in the last Report, have been compared with the standard unit coils. An account of the comparison made by the Secretary and Mr. H. M. Elder, with a table of the values arrived at, is given in Appendix I. Further experiments on the temperature coefficients of these coils are in progress. During the year, twelve coils have been compared with the B. A. standards, and certificates of their values issued by the Secretary. A Table of the values found is given in Appendix II.

At the Southport meeting of the Association a grant was made to defray the expense of procuring standards of resistance in terms of the ohm. At a meeting of the Committee held in March, 1884, it was decided to defer the purchase of these till after the meeting of the Paris Congress, and a resolution was passed to the effect that 'In the event of the Paris Congress adopting any definite standard of resistance, standards be ordered for the Committee in accordance with that value.'

The Paris Congress adopted as a standard, to be called the 'legal ohm,' the resistance at 0°C. of a column of a mercury 106 centimetres long, and one square millimetre in section. The standard resistances at present in use being B.A. units, it became necessary to assume a relation between the B.A. unit and the legal ohm, in order to construct coils whose resistance should be one legal ohm. This relation has been determined by various observers with slightly different results, and a meeting of the Committee was held on June 28 to consider the question. At this meeting the following resolution, proposed by Professor W. G. Adams, seconded by Lord Rayleigh, was carried:—'That, for the purpose of issuing practical standards of electrical resistance, the number of B.A. units adopted as the resistance of a column of mercury 100 cm. in length, 1 sq. mm. in section, at 0°C., be ·9540.

Taking this number, then

1 legal ohm=1·0112 B.A. units.
1 B.A. unit=·9889 legal ohms.

Coils having respectively a resistance 1, 10, 100, 1,000 and 10,000 legal ohms have been ordered, two of each value, so that, by frequent comparison of one with the other, an accident to either may be checked. These standards are to have their correct values at temperatures near 15° C.

The two 1-ohm coils have been sent by the makers, and their testing is being proceeded with. When this is complete the Committee will be in a position to test and certify to the values of coils in terms of the legal ohm.

They propose that the certificate should run as follows:—

'This is to certify that the resistance coil X has been tested by the Electrical Standard Committee, and that its value at a temperature of 4° centigrade is P legal ohms.

'It has been assumed, for the purposes of this comparison, that 1 legal ohm is equal to 1·0112 B.A. units.'

The coils will be stamped with the monogram and a reference number.

A portion of the grant has been expended in some additions to the wire bridge belonging to the Committee, which have added greatly to its utility, while two thermometers for the testing room have been purchased.

The Committee would ask, in conclusion, that they may be reappointed, with the addition of the name of Mr. W. N. Shaw, in order to continue the work of issuing standards of resistance.

Appendix I.

On the values of the B.A. standards of resistance greater than 1 *B.A. unit.*

The coils of approximate value 10 B.A. units marked Elliott Bros., No. 66 and No. 67, or 20 and 21 respectively, were compared with the B.A. standards by the method described in the last report,[1] with the results given in the following table:

Mark of coil	Date	Value found in B.A.U.	Temperature
Elliott No. 66	July 5	10·0065	19°·1
No. 20	July 7	10·0043	18°·3
Elliott No. 67	July 5	10·0060	19°·1
No. 21	July 7	10·0043	18°·3
Elliott No. 68	July 24	100·038	16°·7
No. 22	August 11	100·115	19°·9
Elliott No. 69	July 24	100·024	16°·7
No. 23	August 11	100·097	19°·9
Elliott No. 70	July 26	999·79	15°·8
No. 24	August 11	1000·78	19°·9
Elliott No. 71	July 26	999·81	15°·8
No. 25	August 11	1000·79	19°·9
Elliott No. 72	—	—	—
No. 26	August 11	10006·2	19°·8
Elliott No. 73	—	—	—
No. 27	August 11	10006·9	19°·8

The coils were immersed in the water bath, the temperature of which remained constant during each observation, for some days before the measurements were made.

The values thus found were used for the determination of the coils of higher resistance, the methods of the last report[2] being employed in this case also. The insulation of the various parts of the apparatus was tested carefully. Each result given in the table is the mean of two or more determinations at the same temperature. The readings of the thermometer used were compared with those of a standard instrument.

[1] B. A. Report 1883, p. 43.
[2] B. A. Report 1883, p. 44.

Appendix II.

Table giving the values of the Coils tested for the Committee in 1883–4.

Mark of Coil	Certificate value	Temperature	Destination
Elliott Bros., No. 95	·99936	13°·9	
CU 5 51	1·00337	15°	Prof. Stuart.
CU 6 52	1·00237	15°·5	Prof. S. P. Thompson.
Warden, 456 53	·99920	15°	Mason College, Birmingham.
Elliott, 19 54	·99937	17°·7	Cavendish Laboratory.
Elliott, 41 55	·99950	13°·8	Messrs. Elliott Bros.
Elliott, 56 56	·99949	13°·8	"
Elliott, 113 57	1·00000	13°·8	Prof. Adams, King's College.
Simmons, 4 58	1·00101	16°·3	Messrs. Simmons.
Elliott, 92 59	1·00109	18°	Philadelphia Exhibition.
Elliott, 60	1·00067	18°·1	"
Elliott, 61	10·0163	19°·8	"

Report of the Committee, consisting of Mr. Robert H. Scott (*Secretary*), Mr. J. Norman Lockyer, Professor G. G. Stokes, Professor Balfour Stewart, *and* Mr. G. J. Symons, *appointed for the purpose of co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year* 1861. *Drawn up by* Mr. R. H. Scott.

As no application has been made for any portion of the grant placed at their disposal, the Committee ask that they may again be reappointed, with a continuance of the grant.

The present condition of the proposed publication may be learned from the following extract from a letter from Dr. Meldrum, dated Mauritius Observatory, July 9, 1884:—

'Our synoptic charts from January and March, 1861, have been lithographed by Messrs. Johnston, so far as the winds and weathers are concerned, and all that is wanted to complete them are the isobars. I regret that I have been unable to complete them for the meeting. The tracks of the cyclones for the Indian Ocean for each year since 1847 are ready.'

Second Report of the Committee, consisting of Professors G. H. DARWIN *and* J. C. ADAMS, *for the Harmonic Analysis of Tidal Observations. Drawn up by* Professor G. H. DARWIN.

DURING the past year Major Baird has been engaged in the transformation of the tidal constants for the several Indian ports, as deduced from the observations of previous years, to the form recommended in our first report (1883). He also intends to treat the European tidal results, published in previous Reports of the Association, in the same manner. Under his superintendence auxiliary tables have been prepared and printed in India for the use of the computers; a portion of these tables was given at the end of the Report of 1883. The current work at Poona is now being carried out in accordance with our suggestions. Forms have been prepared by Mr. Roberts for the reduction of the new compound tides MK, 2MK, MN (see Schedule H., Report of 1883); but I have not heard whether the range of any of these tides has been found to be sufficiently great to make it desirable that the reductions should be continued. The recommendations with regard to the tides M_1 and L have not been yet sufficiently tested, but the procedure is certainly theoretically correct.

An unexpected delay has occurred in the preparation of the new forms for the tides of long period, but they are to be complete by the beginning of November.

It has been found expedient to depart somewhat from the form recommended in Schedule R for the entry of the diurnal means from which these tides are reduced. The table is now divided into two parts; the rows marked 'change' are put together, and form the second half of the table. In the case of the tide MSf, to which Schedule R applies, the mode of the entry in the new forms will be thus. The values for days 0, 1, 2, 3, are entered from left to right in the first half; then, in the second half, entries 4, 5, 6, 7 are inserted from right to left, and 8, 9, 10, 11 from left to right; then we ascend to the first half again, and enter two rows, namely, 12, 13, 14 from right to left, and 15, 16, 17, 18 from left to right, and so on alternately. In both halves of the table the positive entries are put to the left and the negative to the right. The summations are carried out independently in the two halves, and the signs in the sums of the lower half are changed, before the final sums of both halves are formed.

In the preface to the Report of 1883 the intention was expressed of sending copies of the computation forms to certain public libraries, and a grant of money was made by the Association for the purchase of these copies. Complete copies have not, however, been as yet obtainable, on account of the delay in the preparation of the forms for the tides of long period.

Up to the present time the forms have been privately printed for the Indian Government, and as they have not been on sale, this method of harmonic analysis has been inaccessible to the public. To meet this want I have been making arrangements for producing an edition for sale. In the course of a month or two the copies will be on sale,[1] at a price not yet determined on. I have received much assistance towards the ex-

[1] By the Cambridge Scientific Instrument Company, St. Tibbs' Row, Cambridge.

penses of publication, and therefore the price will be considerably less than that which would pay for the printing. The printers for the India Office still had about fifteen pages in type, and permission was obtained through General Strachey to have copies struck off from these and from the sheets of the long period forms as they were ready. The remaining eighty pages of the work have been copied by photo-zincography at the office of the Ordnance Survey at Southampton. Mr. Roberts kindly corrected a few errata with the pen before sending the originals to be photographed. I have to thank the officers of the Royal Engineers in charge, and especially Major Bolland, R.E., for the attention which was bestowed on the matter.

It was through the exertions of General Strachey that permission was obtained to have this work done at Southampton; and in consequence of a correspondence between the India Office, the Board of Works, and the Treasury this part of the work has been done free of charge, on the condition of my supplying a certain number of copies to the Admiralty. I am also assisted in the publication by a grant from the fund administered by the Royal Society.

It is to be regretted that notwithstanding this requisition for computation forms it appears that the Admiralty is satisfied with the old method of tidal reduction, and has no intention of making any contribution to our tidal knowledge by instituting harmonic analysis of tidal records.

Dr. C. Börgen, of Wilhelmshaven, informs me, in a letter, that the tides of the North German Sea are now being reduced according to the harmonic method, presumably for the Imperial Admiralty, and he writes: 'It is intended to publish the results for the German coast in exactly the same manner as you propose for the English, so that they may be strictly comparable. The calculation for Heligoland, 1882, is begun and will be completed in about a month or so (from the end of June 1884).'

I learn from M. Bouquet de la Grye, of the Bureau des Longitudes, that he has been engaged for some time past in the reduction of a large mass of tidal observations according to an harmonic method devised by himself, and that the work approaches completion.

Mr. Neison, now in charge of the Natal Observatory, expresses his intention of reducing the tidal observations at Natal according to our methods, and I shall supply him with computation forms.

Mr. Gill, Astronomer Royal at the Cape, will also undertake the reduction of the tides of the Cape Colony, and will be supplied with forms.

There seems to be a possibility that some of the Australian Colonies may be induced to take up the matter.

Major Baird will probably undertake to draw up a manual of practical instructions for the erection of continuous tide-gauges, and the practical experience of one who has supervised so much work of the kind will prove of great value.

The fate of the tide-gauge erected by the Portuguese Government at Madeira affords a proof that it is not of much use to direct the establishment of a tide gauge, unless the work be placed in the hands of some one who has had experience in the matter. It is said that the tube which was sunk into the sea from the Loo Rock at Madeira was open at the bottom, and that the platinum wire attached to the float was broken at once by the pumping up and down of the water. I believe that nothing has been done to remedy this defect, and that the instrument has remained unused during several years.

On the whole we may congratulate ourselves on the amount of activity which is being displayed in the matter of tidal research, and we may hope that in a few years we shall be in possession of a large mass of tidal information, arranged in a form which will lend itself satisfactorily to theoretical examination.

As we already have a considerable amount of data with regard to India, extending over several years, I have requested Major Baird to supply me with the values of mean water-mark for a series of years, and I am in hopes that an examination of these results will give us the amount of the nineteen-yearly tide, if not with great precision, at least with some degree of accuracy. The result will be of much interest for the purpose of evaluating the degree of elastic yielding of the earth's figure.

A few errata have been detected in the Report of 1883, but only one of them has any importance, viz., that in Schedule [I], as noted below. The corrections to be made are as follows:—

1. First of (40), for R^2 read R.

2. First of (43) and second of (44), multiply the expressions on the right by $\frac{M}{M_0}$.

3. First of (56), multiply the numerator by k_2.

4. Schedule [I], entries K_2, K_1, third column, multiply the numerators 1·46407 by k. This important error arises from the mistakes (2) and (3).

5. After (67), in the next transformation, the $\frac{1}{2}$'s which occur before $(l_1+l_2)i$ and $(l_1-l_2)i$, are to be deleted; the subsequent analysis is correct.

Report of the Committee, consisting of Professor BALFOUR STEWART (*Secretary*), Mr. KNOX LAUGHTON, Mr. G. J. SYMONS, Mr. R. H. SCOTT, *and* Mr. JOHNSTONE STONEY, *appointed for the purpose of co-operating with* Mr. E. J. LOWE *in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis.*

MR. R. H. SCOTT and Professor Balfour Stewart have been in correspondence with Mr. Lowe, and the former has seen the site of the proposed observatory, which appears to him to be good. Professor Stewart purposes visiting the site at the end of July, and reporting the result of his visit to the other members of the Committee. Meanwhile it is proposed that the Committee be reappointed, with power to add to their number, but without any further sum being placed at their disposal.

Report of the Committee, consisting of Professor CRUM BROWN (*Secretary*) *and* Messrs. D. MILNE HOME, JOHN MURRAY, *and* ALEXANDER BUCHAN, *appointed for the purpose of co-operating with the Directors of the Ben Nevis Observatory in making Meteorological Observations on Ben Nevis.*

A GRANT of 50*l*. was made to the Committee by the British Association in 1883 to aid the Directors of the Ben Nevis Observatory in making meteorological observations on Ben Nevis during the summer months of 1883. The observations were in continuance of those made by Mr. Wragge in 1881 and 1882. As Mr. Wragge was unable to make the observations in 1883, owing to a contemplated visit to Australia early in the autumn, the observations were made by Messrs. Whyte and Rankin, who had been assistants to Mr. Wragge in 1881 and 1882. The observations began on June 1, and were continued to October 31, 1883, with scrupulous regularity and accuracy.

The observations included two series at The Lake (1,840 feet high), one on ascending and the other on descending the mountain, and five on the top, at 8, 8.30, 9, 9.30, and at 10 A.M.; and, with these, simultaneous observations near sea-level at Fort William, to which one series was added on starting for the mountain at 4 A.M., and another on returning at 2 P.M.

In the meantime the building of the permanent observatory was pushed forward with such success that the observatory was formally opened on October 17th. Shortly thereafter Mr. R. T. Omond, superintendent, and Messrs. Rankin and Duncan, the assistants, went into residence, and the regular observations began in the end of November. These consist of hourly eye-observations by night as well as by day. The Committee have much gratification in reporting that from November to the present date (July 25), the barometric observations have been made without the break of a single hour, and, since May 7, all the observations have been made without intermission. The omissions of the thermometric and other outside observations were mostly in winter and during the night, when the stormy state of the weather rendered it unsafe to venture out. Not unfrequently the observations were made by two of the observers, and sometimes all the three, roped together for safety. The Directors are making arrangements, by additions to the buildings and the introduction of new instruments, to secure, for the future, a more continuous record.

In connection with the Ben Nevis observations, Mr. Colin Livingstone makes eye-observations at Fort William at 8 and 9 A.M., 2, 6, 9, and 10 P.M., these being the hours at which observations are chiefly made in the British Islands. Mr. Livingstone is also furnished with a barograph and a thermograph, by which extremely valuable data have been contributed. Normals for temperature and atmospheric pressure at Ben Nevis Observatory have been calculated from the simultaneous observations made there and at the sea-level station at Fort William for five months for each of the years 1881, 1882, and 1883, from June to October, and seven months, from December 1883 to June 1884.

The following Table gives the normal monthly temperature and pressure at sea-level at Fort William, taken from Mr. Buchan's 'Papers on the Climate of the British Islands' ('Journal of Scottish Meteorological Society,' vol. vi. pp. 4–40), and the calculated normals for the Ben Nevis Observatory:—

Mean temperature	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fort William . .	38°·9	38°·9	41°·0	45°·5	49°·8	55°·7	57°·8	57°·0	52°·8	47°·5	41°·2	39°·8	47°·2
Ben Nevis Observatory. . . .	23·2	22·0	23·4	27·5	32·7	38·7	41·3	41·1	37·4	32·3	26·2	24·9	30·9
Mean Pressure—	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Fort William . .	29·747	29·814	29·800	29·878	29·934	29·914	29·884	29·85[illegible]	29·82[illegible]	29·78[illegible]	29·84[illegible]	29·793	29·838
Ben Nevis Observatory. . . .	25·141	25·194	25·196	25·296	25·330	25·410	25·400	25·373	25·314	25·241	25·239	25·189	25·281

These normals for pressure at the Ben Nevis Observatory have been arrived at from a table of corrections for the height (4,406 feet) which has been prepared directly from observations of the High and the Low Level Stations, the observations at the latter being reduced to sea-level. The approximate corrections have been calculated for each tenth of an inch of the sea-level pressure, and for each degree Fahr. of the mean temperature of the stratum of air from sea-level to the top of the mountain. The arithmetical mean of the temperatures at the base and the top has been assumed as the mean temperature of the intervening stratum.

The results of these observations will shortly be published, in detail, in the 'Journal of the Scottish Meteorological Society.' Thereafter a more complete examination of the observations at both stations will be resumed, and comparisons made of the two sets of observations, more especially as regards the relations of the varying results to the changes of weather which have preceded, accompanied, and followed them.

Report of the Committee, consisting of Mr. JAMES N. SHOOLBRED (*Secretary*) *and* Sir WILLIAM THOMSON, *appointed for the purpose of reducing and tabulating the Tidal Observations in the English Channel made with the Dover Tide-gauge, and of connecting them with Observations made on the French coast.*

THE Committee beg leave to report that the tidal curves of the self-registering tide-gauge at Dover for the years 1880, 1881, 1882, and 1883 have been kindly placed at their disposal by the Board of Trade, for reduction and tabulation; and that the Belgian Government has been good enough to present to the Committee copies of the tidal curves at Ostend during the same period of four years.

The reduction and tabulation of the high and low water registers of these two sets of tidal curves has progressed satisfactorily, and will be shortly completed.

It is hoped also that a like reduction will be soon commenced with other self-registering tidal curves during the same period at several other points, both on the English and the French coasts.

The Committee request to be allowed to transmit to the Board of Trade, and to the Belgian Government respectively, the thanks of the Association for their assistance and donations in furtherance of this inquiry.

The Committee request to be reappointed, with a grant of ten pounds to defray the expenses of reduction, &c.

Fourth Report of the Committee, consisting of Professor SCHUSTER (*Secretary*), Sir WILLIAM THOMSON, Professor Sir H. E. ROSCOE, Professor A. S HERSCHEL, Captain W. DE W. ABNEY, Mr. R. H. SCOTT, *and* Dr. J. H. GLADSTONE, *appointed for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities.*

DURING the past year a grant of 20*l.* has been spent in constructing a new instrument for collecting continuously any cosmic dust, volcanic dust, or other impurities mechanically suspended in the atmosphere. The essential part of the instrument consists in a series of filters of fine platinum wires through which the air is continuously drawn by an aspirator.

This instrument is being experimented with at the Marine Station for Scientific Research at Granton, and a complete description of the instrument and dust collected will be given in next year's Report. Large carboys furnished with glass filters, fourteen inches in diameter, have been arranged for collecting the dust carried down by rain on the top of Ben Nevis, Lord MacLaren's residence in Rossshire, Inch Mickry in the Firth of Forth, and at the Scottish Marine Station.

The dust from these different points and elevations will be carefully compared with that collected by the new instrument, by Messrs. Murray and Renard and by members of the Committee.

A full report will be furnished to the next meeting.

The Committee also consider it to be of great importance to collect dust on the island of Bermuda and on another coral island in the Pacific, say Longalubon, and hope to obtain a sufficient grant of money to enable them to carry out their intention.

Second Report of the Committee, consisting of Professors WILLIAMSON, DEWAR, FRANKLAND, ROSCOE, CRUM BROWN, ODLING, *and* ARMSTRONG, Messrs. A. G. VERNON HARCOURT, J. MILLAR THOMSON, H. B. DIXON (*Secretary*), *and* V. H. VELEY, *and* Drs. F. R. JAPP *and* H. FORSTER MORLEY, *reappointed for the purpose of drawing up a statement of the varieties of Chemical Names which have come into use, for indicating the causes which have led to their adoption, and for considering what can be done to bring about some convergence of the views on Chemical Nomenclature obtaining among English and foreign chemists.*

CHEMICAL NOMENCLATURE.

HISTORICAL NOTES.

UP to about the year 1780 no systematic attempts were made to give to chemical substances names in any way indicating their composition. The names used were derived for the most part in three ways: either they were relics of the nomenclature of the alchemists, who named the common metals after the known planets; or the substances bore the name of their discoverer; or lastly, chemists, adopting, as Dumas said, the language of the kitchen, gave names to substances on account of slight external resemblances with bodies in common use—*e.g.* oil of vitriol, butter of antimony, milk of lime, and cream of tartar. Lavoisier ascribes to Macquer the credit of being the first to classify substances under generic names, by introducing the terms vitriol and nitre, to indicate the classes of sulphates and nitrates respectively.

The term salt was applied in the writings of the alchemists to any substance which could be dissolved in water, and which affected the sense of taste. So bodies as different in nature as sal-ammoniac, sal-petræ, and sal-nitricum (HNO_3) came to be classed together. In the eighteenth century the three most distinctly marked classes of soluble substances—namely, those which are now commonly called acids, salts, and bases—were distinguished as salia acida, salia media, and salia alkalina. The salia media were also known as salia salsa or neutral salts, a name which survived long after the separation of the acids and alkalies from the salts.

The foundation of the present ideas as to salts is to be found in two papers presented to the French Academy in 1744 and 1754, by G. F. Rouelle. He excludes the alkalies and acids from the class of salts and defines a neutral salt as the product of the action of an acid on any body which can act as a base. This is the first definition of a salt based on its chemical properties.

The first complete attempt to devise a system of inorganic nomenclature was made in 1782, simultaneously and independently by Bergmann[1] and Guyton de Morveau.[2] The names proposed by the two are nearly identical, and resemble to some extent the names still in use. De Morveau lays down five principles to be observed in the choice of names for chemical substances :—

1. A phrase is not a name: the name 'l'alkali Prussien' is therefore

[1] Bergmann, *Observ. de Systemate Fossilium Naturali.*

[2] *Journal de Physique*, vol. xix. April, 1782; also as Cit. Guyton, *Ann. Chim.* vol. xxv. p. 205. [1798.]

to be preferred to the other name in vogue at that time—viz., 'liqueur alkaline saturée de la matière colorante du bleu de Prusse.'

2. The name should be as far as possible in real correspondence with the object. As corollaries to this rule he lays down that where a name is made up of an adjective and a substantive the more essential and unalterable constituent should bear the substantive form; also that the names of discoverers, since they stand in no essential connection with the bodies they discover, should find no place in the system.

3. If the constitution of a body is unknown, it is better to give it a name which conveys no meaning, than one which conveys a wrong one. Hence he prefers to call the body of unknown composition which we now know as potassium ferrocyanide, 'alkali Prussien,' rather than 'alkali phlogistiqué.'

4. In the choice of new names it is advisable to derive them from roots in the best-known dead languages.

5. Names must be adapted to the structure and nature of the different languages in which they are to be used.

De Morveau applies these principles to the nomenclature of 474 substances, belonging to the four classes, earths, alkalies, acids, and metals, and the products of their union. In the naming of salts he forms words for all the acids known to him, on the analogy of the terms vitriol and nitre introduced by Macquer, so that the salts $BaSo_4$, $CaCl_2$, acetate of iron, are called respectively vitriol barotique, muriate calcaire, and acète martial. He also tries to fix one name for carbonic acid gas, and calls it acide méphitique, and its salts méphites. The principal advance which we find in De Morveau is, then, that acids receive names with uniform terminations, and salts receive names indicating their being compositions from acid and base.

In 1787 Lavoisier and De Morveau,[1] with the assistance of Berthollet and Fourcroy, prepared and laid before the French Academy a scheme of chemical nomenclature based on the dualistic hypothesis, and their proposals form the basis of the nomenclature still in use. A system of nomenclature is necessarily bound up with a classification of known substances, and so we find that Morveau and Lavoisier give a table of all the substances to which they assign definite names arranged according to their relationships one with another. The elements retain their accustomed names, except that the names oxygen, hydrogen, and azote are introduced. The term oxide is introduced for the first time, and oxides are looked on as substances in a state intermediate between the element and its acid. Thus they call the two oxides of arsenic oxide d'arsénic (white arsenic) and acid arsénique; and the two known oxides of molybdenum, oxide de molybdène and acide molybdique. The correspondence of the terminations '-ate' and '-ic,' '-ite' and '-ous' in acids and salts is introduced for the first time. The nomenclature of salts thus came to be nearly identical with that now used. In this classification the French chemists do not distinguish by generic names between higher and lower basic oxides.

The views thus developed by Lavoisier and Morveau found acceptance all over Europe. Girrtanner translated the French names into German, and several English chemists, such as Dickson and Kirwan, Chevenix and Thomson,[2] adopted the system in its main outlines. Additions were made

[1] *Compt. Rend.*, translated by George Pearson, M.D. 1794; 2nd ed. 1799.
[2] *System of Chemistry*, ed. 1802.

to it from time to time, such as that of Thomson,[1] who distinguished the different metallic oxides as protoxides, deutoxides, &c.

Berzelius[2] made a more exact classification of salts, and added some new forms of names. He laid down the rule that the names of the simplest compounds should be formed by adding to the name of the one element the termination '-ide' or '-ure;' to that of the other, the termination '-eux' or '-ique,' with the further provision that the more electro-negative of the two constituents should have the substantive form. Instead of the terms protoxide, &c., he adds the terminations '-ous' and '-ic' to the name of the other constituent—*e.g.* ferrous oxide. Among the compounds of elements with oxygen he separated the compounds with electro-negative elements—the acids—from the other oxides, without thereby implying the existence of any fundamental difference between them. The halogen compounds of hydrogen he calls hydracids. In the investigation of salts he was the first who made clearer distinction between neutral, acid, and basic salts; instead of these terms he used the terms supersalts and subsalts.

From time to time systems of chemical nomenclature have been proposed which entirely discard the arbitrary names given even to the best known substances, and introduce artificial words, each of whose vowels or consonants means either a substance or a number. Thus Gmelin[3] proposes a system in which the different vowels and diphthongs represent the numbers from 1 to 9, and the elements are described by monosyllables with the vowel *a*, thus:—K = Pate, Mn = Ganne, &c. In combining the names of the elements the vowel is altered according to the number of atoms of the element to be denoted. Thus, if O = Ane, and Fe = Mart, then Fe_2O_3 = Mertin, and Fe_3O_4 = Mirton. Laurent attempted a system of the same sort but found it unworkable. For organic substances Newlands[4] has devised a series of names, some of which might be useful.

Laurent[5] enters into an elaborate comparison of the qualities of the compounds of hydrogen, zinc, gold, silver, and platinum, and shows that in respect of crystalline structure, behaviour on heating, and power of entering into chemical combinations the corresponding compounds of hydrogen and zinc—*i.e.* the hydrogen salts and the zinc salts—show a closer analogy with each other than the zinc salt does with those of the other metals. He concludes that if hydrogen were not gaseous and its oxide were not volatile, no one would hesitate to place it among the metals. He therefore looks on the acids as belonging to the same chemical type as their salts, as being, in fact, hydrogen salts. Laurent proceeds further to show that there is no essential distinction to be drawn between acids and salts and oxides. The differences between hydrogen and other metallic salts are as a rule not greater than the differences between the salts of two such metals as platinum and potassium, or two such bodies as a chloride and a carbonate. The reactions of the hydrogen salts are not always more energetic than those of the other metallic salts: thus, sulphate of hydrogen attacks metallic oxides just as the sulphates of gold and platinum do. The distinction which has been made between them is due to the non-metallic appearance of hydrogen, and the

[1] *System of Chemistry*, ed. 1804, 1807, 1810, &c.
[2] *Journal de Physique*, vol. lxxxiii. p. 253; also in *Lehrbuch der Chemie*.
[3] *Handbook*, vol. vii. p. 149.
[4] *Chem. News*, 1861.
[5] *Methode de Chemie.*

readiness with which it can be removed from a compound in the form of water. Laurent thus concludes that oxides, hydrogen salts, and other salts may with perfect propriety be classed together.

Acid and Basic Salts.

Rouelle was the first to call attention to the fact that a given acid and base can combine in different proportions. He prepared the salt now known as $KHSO_4$ from potassic sulphate (tartre vitriolé), and investigated its properties. He distinguished three different classes of salts. 1. He calls 'neutral salts with an excess or superabundance of acid,' salts which, besides the amount of acid which makes them quite neutral, have an additional quantity of acid *combined* with them, and he knows that this excess of acid has its point of saturation. Such salts, he says, are as a rule more soluble than the corresponding salts of his third class. 2. What we call neutral salts he calls 'sels neutres parfaits,' or 'sels salés.' 3. The third salts he calls 'neutral salts with the smallest possible quantity of acid.' At first sight these classes seem to correspond with what we now call acid, neutral, and basic salts, but Rouelle's examples show that this is not the case. The only acid salts which he seems to have known is the hydric potassic sulphate which he was the first to prepare, and he puts in the same class with it mercuric chloride and other persalts, while calomel is given as the typical instance of a salt with the smallest possible amount of acid. This confounding of hydrogen double salts with salts containing as large an amount of acid as the base can saturate continued up to the end of the century.

1787.—In course of time, however, more salts of the two abnormal classes were discovered. In the 'Morveau-Lavoisier' nomenclature, salts of the acid class were called acidulous salts, thus: $KHSO_4$=sulphate potassique acidule, while salts with an excess of the basic constituents were called alkaline, or supersaturated salts. Salts generally are called neutral salts. These terms were translated directly into English in Pearson's translation of 1794.

In an essay on 'Chemical Nomenclature,' published in 1796 by Stephen Dickson, he proposes to denote the predominance of acid and base respectively by prefixing the prepositions 'super-' or 'sub-' to the adjective the name of the acid.

Thus:—

$KHSO_4$=supervitriolated vegetable alkali.
Cu_2Cl_2=submuriated copper.

1809.—In Murray's 'System of Chemistry' we find that a distinction is at last made between the relation of K_2SO_4 to $KHSO_4$, and that of $HgCl_2$ to Hg_2Cl_2. He says that submuriate is not a good name for this last salt, as it contains enough acid to make it neutral. He does not, however, propose a systematic name for this substance, but calls it mild muriate of mercury. Similarly, he rejects the name of super-sulphate of iron, and distinguishes the two sulphates as red and green sulphates.

1810.—In the fourth edition of Thomson's treatise, we find yet another method of naming these salts. Thomson, following Lavoisier's theory of oxygen acids, considers that the difference between calomel and corrosive sublimate is that in the latter the mercury is in a more highly oxidised condition. He therefore calls $HgCl_2$ oxymuriate of mercury. This leads to a confusion with chlorate of mercury, then called by some chemists oxy-, by others hyperoxymuriate. Thomson also calls mercuric nitrate, oxynitrate, and says that on adding hot water to it an insoluble subnitrate and a soluble supernitrate are formed.

1811.—In Klaproth and Wolff's 'Dictionary of Chemistry' (French trans.), we find the names sulphate acide de potasse, sulphate de fer oxidulé ($=FeSO_4$); for the two potassium carbonates, the names carbonate saturé and nonsaturé.

1811.—Berzelius[1] uses entirely distinct means of denoting the two classes of salts with which we have been dealing. To mark the degree of oxidation of the base of a salt, he adds the termination -ous, or -ic, to the name of the metal—*e.g.* nitras mercurosus and nitras mercuricus., To denote the degree of acidity or basicity of a salt, he prefixes super- or sub-, to the name denoting the acid. From his language, it seems as though he had invented this method independently. In the cases where more than one acid or basic salt is found, he denotes the most acid salt by the adjective supremus, and the most basic by infimus, *e.g.*—

Superoxalas kalicus supremus.
Subnitras plumbicus infimus.

1829.—In his later works—*e.g.* in the French edition of his Treatise, 1829—he makes a difference in the nomenclature between haloid and amphid salts. In the case of acid haloids, he adds the word acid to the name of the salt, *e.g.*—

Fluorure potassique acide.

Basic salts of this class are named thus:—

Chlorure plombique bibasique.
" " tribasique, &c.

In the case of acid amphid salts, he drops the word acid, but prefixes to the name of the acid a suffix indicating the number of acid molecules, *e.g.*—

Bisulphate sodique.
Zweifach phosphorsaures natron.

Basic salts are named thus:—

Sous-sulphate trialuminique.

1827.—A somewhat similar system is adopted by Thenard.[2] He introduces into the name of each salt the full name (according to Thomson's system) of the oxide supposed to exist in it, thus:—

Sous-sulphate de deutoxide de mercure.

All these attempts at naming acid salts were founded on a false idea of their composition, inasmuch as it was not known that hydrogen is a constituent of bisulphate of potash. Thus in Turner's 'Chemistry' we find the formulæ:—

Sulphate of potassa, $KO+SO_3$.
Bisulphate " $KO+2SO_3$.

[1] *Journal de Physique*, vol. lxxii. p. 266.
[2] *Traité*, 5th ed. 1827.

Graham seems to have been the first to maintain that hydrogen existed in these salts otherwise than as water of crystallisation.

1847.—It was Gerhardt[1] who first clearly stated that the three substances, hydric sulphate, hydro-potassic sulphate, and potassic sulphate, stand to one another in the relations represented by the formulæ H_2SO_4, $KHSO_4$ K_2SO_4. He called salts of the type K_2SO_4, which correspond to acids formed by the direct combination of water with an 'anhydride,' *equisels;* while for acids and basic salts he used the old names, sur-sels and sous-sels.

TABLE I.

In this table of the nomenclature of the oxides of carbon, it is seen that the names carbonic oxide and carbonic acid, Kohlenoxyd and Kohlensaüre, oxide de carbon and acide carbonique, have been solely used by English, German, and French chemists for the two oxides of carbon from the time of their identification until twenty years ago. In Miller's 'Elements of Chemistry' we find the term carbonic acid used in the two first editions, in the later editions the term carbonic anhydride is introduced. In Fownes' Manual we find the term carbonic acid used from the fourth edition to the ninth; in the tenth and eleventh editions we find both the terms carbonic dioxide and carbonic oxide applied to the higher oxide, and the terms carbon monoxide and carbonous oxide applied to the lower; in the thirteenth edition we find the terms carbonic anhydride and carbon dioxide applied to the higher, and carbonic oxide and carbon monoxide applied to the lower. So that in different editions of the same manual we have the term carbonic oxide first applied to the lower, then to the higher, and again to the lower oxide. In Watts's Dictionary (1863) the lower oxide is called carbonic oxide, the higher carbonic anhydride; in the first Supplement (1872) the lower oxide is called *carbon monoxide* and *carbonous oxide*, the higher oxide *carbon dioxide* and *carbonic anhydride*.

In France and Germany the terms oxide de carbon and Kohlenoxyd, acide carbonique and Kohlensaüre, have continued to be used almost universally to the present day. Among English and American chemists of the present day there is a diversity of practice: carbonic oxide and carbon monoxide being most generally used for the lower oxide, and carbonic acid, carbonic anhydride, and carbon or carbonic dioxide for the higher.

TABLE II.

In the nomenclature of the oxides of nitrogen, we find the names *oxide azoteux* and *oxide azotique*, applied to the first and second oxides of nitrogen by the French Committee in 1787, have been employed by many chemists to the present day. In the first edition of Thomson's 'System of Chemistry' (1802) we find the terms nitrous and nitric oxide used; in a later edition (1817) he introduced the terms protoxide of azote and deutoxide of azote, calling the third oxide *hyponitrous acid*, and the fourth *nitrous acid*. In Brande's 'Manual' (1819) we have the term *nitrous acid* given to the third oxide, but most chemists adopted Thomson's nomenclature. In Berzelius (French edition, 1829) we find gas oxide nitreux, gas oxide nitrique and acide nitreux for the three lower oxides, and the term *acide nitroso nitrique* for the fourth. In Graham's 'Elements' (1842)

[1] *Journal de Pharmacie*, vol. xii. p. 57.

we find the terms *hyponitric acid* and *peroxide of nitrogen* applied to the fourth oxide, the other oxides being called nitrous and nitric oxides, nitrous and nitric acids.

In the earlier edition of Fownes' 'Manual,' the terms protoxide and binoxide of nitrogen are applied to the lower oxides, nitrous acid to the third, hyponitric and nitric acids to the fourth and fifth. In the tenth edition the terms *nitrogen monoxide* and *dioxide* are adopted for the two lower and *tetroxide* for the fourth oxide; the terms nitrous oxide and nitrogen trioxide are given to the third, and the terms nitric oxide and nitrogen pentoxide to the fifth. The terms nitrous and nitric oxides here applied to the fourth and fifth oxides had previously only been applied by chemists to the first and second.

TABLES III.–V.

The older chemists were agreed in designating the two oxides of sulphur the *sulphurous* and the *sulphuric* acids respectively. In Fownes' 'Manual,' ed. 1863, the alternative names *sulphur di-* and *trioxide* are first introduced, which, among the later writers, have gradually superseded the former names.

In a memoir in the 'Jahresbericht,' 1842, Berzelius recommends the introduction of the names *Di-*, *Tri-* and *Tetrathionic* acids. This nomenclature has superseded the older names hyposulphuric, monosulphyposulphuric, &c., acids, though some few of the later writers retain the term hyposulphuric acid.

The discovery of the true *hyposulphurous* acid by Schützenberger caused the acid, hitherto known by that name, to be designated *thiosulphuric* acid, as derived from sulphuric acid, by the replacement of one atom of oxygen by sulphur. Hydrosulphurous acid, the name originally proposed by Schützenberger for his acid, seems to be retained only by the French writers.

TABLES VI.–VII.

The oxides of chromium afford an instance of change of names owing to the discovery of another member of a series of compounds. Thus the green oxide of chromium was designated the *protoxide*, until the isolation of an oxide containing one atom of oxygen to one of the metal. The latter compound was then called the protoxide, while the name of the former was altered to *sesquioxide.*

The potassium and lead salts of chromic acid afford a good example of the want of unamimity of nomenclature among the older writers in those cases in which there are derived from one acid two salts, the one neutral, containing one equivalent of basic to one equivalent of acid oxide, the others containing an excess of either of the oxides. Thus the acid or red potassium chromate is called indifferently potassium *di* or *bi*chromate, but the former prefix is equally applied to the basic lead chromate. The later writers have avoided this confusion of prefixes by introducing the *di* or *bi* before the name of the acid or metal according as the salt contains excess of the acid or the basic oxide, respectively, thus :—

Potassium *di*chromate, but *di*plumbic chromate.

TABLES VIII.–X.

From the above tables it will be seen that many names have been used in more than one sense. Thus the terms phosphoric acid, phosphorous acid, and hypophosphorous acid were formerly exclusively employed to denote the oxides, but are now chiefly used to denote the hydrogen salts. Graham's researches were published in 1833, and previous to this date chemists made no distinction between anhydrous and hydrated phosphoric acid, but called one phosphoric acid, the other a solution of phosphoric acid; hence, when it was necessary to explain the differences between ortho- and pyro-phosphates, this was done by ascribing them to differences in the arrangement of atoms in the group P_2O_5. When, therefore, the older chemists speak of the different varieties of phosphoric acid, it is the anhydrous acid that they mean. For instance, Berzelius's α, β, and γ phosphoric acids are all three regarded by him as anhydrous. The term phosphoric oxide is applied to anhydrous phosphoric acid in the editions of Fownes edited by Watts; this term was formerly used to denote a supposed lower oxide of phosphorus, P_4O. (Gmelin, edited by Watts, 1849).

The term 'neutral phosphate of soda' has been applied both to trisodic phosphate and hydrodisodic phosphate. Diphosphate of soda has been applied to trisodic and hydrodisodic phosphates, and biphosphate to dihydrosodic phosphate, so that the three phosphates have had almost identical names.

The term 'acid phosphate of soda' has been applied to both hydrodisodic and dihydrosodic phosphates.

The term 'phosphorchlorid' has been applied to both chlorides of phosphorus. (Cf. Liebig and Poggendorff.)

It appears that when a numerical prefix is employed, the number ought to be understood as multiplying the word to which it is prefixed and not some other word. This rule has often been violated: thus trisodic phosphate has been called 'triphosphate of soda,' also 'diphosphate of soda' and 'sesquiphosphate of soda;' in all these cases the prefix is intended to indicate the number of molecules of soda to one molecule of phosphoric acid. So Turner calls hydrodisodic phosphate and dihydrosodic phosphate, 'triphosphate of soda and basic water' and 'acid triphosphate of soda and basic water' respectively.

It is to be observed, however, that in the older form of nomenclature ambiguity was avoided in the case of compounds containing double the usual amount of acid or of base by using the prefix:

bi- to multiply the acid.
di- to multiply the base.

Thus:

$Na_2O.2SiO_2$, bisilicate of soda.
$2Na_2O.SiO_2$, disilicate of soda.

The prefixes 'ter-' and 'tri-,' 'quater-' and 'tetra-' might have been employed in the same way, *e.g.* :—

$Na_2O.3SiO_2$, tersilicate of soda.
$3Na_2O.SiO_2$, trisilicate of soda.
$Ca_4H(PO_4)_3$, tetracalcic terphosphate.
$Ca_3(PO_4)_2$, calcic triphosphate.

But satisfactory evidence that they were so used has not been found.

(Continued on p. 73.)

Date	Author	Work	Lower Oxide		Higher Oxide	
			Formula	Name	Formula	Name
1755	Black	—	—	—	—	Fixed air
1772	Lavoisier	C. R. Paris Academy	—	—	—	Gas acide carbonique
1776	Berthollet	C. R. Paris Academy	—	—	—	Air fixe
1782	Morveau	Journal de Physique	—	—	—	Acide méphitique
1787	Lavoisier, Fourcroy, Berthollet, Morveau	C. R. Paris Academy	—	—	—	Acide carbonique
1810	Klaproth and Wolff	Dict. (Lagrange and Vogel)	—	L'oxyde de carbon	—	Acide carbonique
1802	Th. Thomson	System of Chem., 1st ed.	—	Carbonic oxide	—	Carbonic acid
1810	Th. Thomson	System of Chem., 4th ed.	—	Carbonic oxide	—	Carbonic acid
1817	Th. Thomson	System of Chem., 5th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1831	Th. Thomson	System of Chem., 7th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1819	W. T. Brande	Manual, 1st ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1836	W. T. Brande	Manual, 4th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1848	W. T. Brande	Manual, 6th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1863	Brande and Taylor	Manual, 6th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1823	W. Henry	Elements, 9th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1827	Thénard	Traité	CO	Oxide de carbon	CO_2	Acide carbonique
1828	Dumas	Traité	CO	Oxide de carbon	CO_2	Acide carbonique
1829	Berzelius	Trans. by Jourdan	CO	Gas oxide carbonique	CO_2	Acide carbonique
1853	Faraday	Lectures	—		CO_2	Carbonic acid
1834	Graham	Ed. R. S. Trans.	CO	Carbonic oxide	CO_2	Carbonic acid
1842	Graham	Elements	CO	Carbonic oxide	CO_2	Carbonic acid
1846	Graham	Elements	CO	Carbonic oxide	CO_2	Carbonic acid
1850	Graham	Elements	CO	Carbonic oxide	CO_2	Carbonic acid
1853	Gerhardt	Traité	CO	Oxyde de carbon	CO_2	Gas carbonique and acide carbonique
1854	Regnault	Chimie	CO	Oxyde de carbon	CO_2	Acide carbonique
1849	Liebig, Poggendorff, and Wöhler	Handwörterbuch (Kolbe)	CO	Kohlenoxyd	CO_2	Kohlensäure
1857	Buff and Kopp	—	CO	Kohlenoxyd	CO_2	Kohlensäure
1857	Bunsen	Gasometrisch. Method.	CO	Kohlenoxyd	CO_2	Kohlensäure
1877	Bunsen	Gasometrisch. Method. 2nd ed.	CO	Kohlenoxyd	CO_2	Kohlensäure
1861	Kekulé	Lehrbuch	CO	Kohlenoxyd	CO_2	Kohlensäure
1855	Otto	Anorg. Chem.	CO	Kohlenoxyd	CO_2	Kohlensäure
1863	Otto	Anorg. Chem.	CO	Kohlenoxyd	CO_2	Kohlensäure
1856	W. A. Miller	Elements, 1st ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1860	W. A. Miller	Elements, 2nd ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1864	W. A. Miller	Elements, 3rd ed.	CO	Carbonic oxide	CO_2	Carbonic anhydride
1868	W. A. Miller	Elements, 4th ed.	CO	Carbonic oxide	CO_2	Carbonic anhydride
1874	W. A. Miller	Elements, 5th (Macleod)	CO	Carbonic oxide	CO_2	Carbonic anhydride
1878	W. A. Miller	Elements, 6th (Macleod)	CO	Carbonic oxide	CO_2	—
1883	Bloxam	Chemistry	CO	Carbonic oxide	CO_2	Carbonic acid gas
1852	B. Jones and Hofmann	Fownes, 4th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1854	B. Jones and Hofmann	Fownes, 5th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1856	B. Jones and Hofmann	Fownes, 6th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1858	B. Jones and Hofmann	Fownes, 7th ed.	CO	Carbonic oxide	CO_2	Carbonic acid

TABLE I.—*continued.*

Date	Author	Work	Lower Oxide Formula	Lower Oxide Name	Higher Oxide Formula	Higher Oxide Name
1861	B. Jones and Hofmann	Fownes, 8th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1863	B. Jones and Hofmann	Fownes, 9th ed.	CO	Carbonic oxide	CO_2	Carbonic acid
1868	Bence Jones and Watts	Fownes, 10th ed.	CO	Carbon monoxide, or Carbonous oxide	CO_2	Carbon dioxide, or Carbonic oxide
1872	Watts	Fownes, 11th ed.	CO	Carbon monoxide, or Carbonous oxide	CO_2	Carbon dioxide, or Carbonic oxide
1877	Watts	Fownes, 12th ed.	CO	Carbon monoxide, or Carbonous oxide	CO_2	Carbon dioxide, or Carbonic oxide
1883	Watts	Fownes, 13th ed.	CO	Carbon monoxide, or Carbonic oxide	CO_2	Carbon dioxide, or Carbonic anhydride
1869	Odling	Outlines	CO	Carbonous oxide	CO_2	Carbon anhydride
	Odling	Carbon	CO	Carbonous oxide	CO_2	Carbonic gas
1870	Wurtz	Dict.	CO	Oxyde de carbon	CO_2	Acide carbonique
1874	Gorup-Besanez	Lehrbuch	CO	Kohlenoxyd gas	CO_2	Kohlensäure
1861	Percy	Metallurgy	CO	Carbonic oxide	CO_2	Carbonic acid
1871	Barff	Chemistry	CO	Carbonic oxide	CO_2	Carbonic acid
1868	Eliot and Storer	Manual	CO	Carbonic oxide	CO_2	Carbonic acid
1873	Williamson	Chem.	CO	Carbonic oxide	CO_2	Carbonic acid
1865	Naquet	Principes	CO	Carbonic oxide	CO_2	Carbonic anhydride
1870	Frankland	Lecture Notes	CO	Carbonic oxide	CO_2	Carbonic anhydride
1882	J. P. Cooke	Principles	CO	Carbonic monoxide	CO_2	Carbonic dioxide
1866	Roscoe	El. Lessons	CO	Carbonic oxide	CO_2	Carbonic dioxide
1869	Roscoe	El. Lessons	CO	Carbon monoxide	CO_2	Carbon dioxide
1874	Schorlemmer	Carbon Compds.	CO	Carbon monoxide	CO_2	Carbon dioxide
1872	Harcourt and Madan	Pract. Chem.	CO	Carbon protoxide	CO_2	Carbon dioxide
1877	Thorpe	Inorg. Chem.	CO	Carbon monoxide	CO_2	Carbon dioxide
1880	Armstrong	Org. Chem.	CO	Carbonic oxide	CO_2	Carbonic anhydride
1877	Remsen	Theoretical Chem.	CO	Carbonic oxide	CO_2	Carbonic anhydride
1878	Roscoe and Schorlemmer	Treatise	CO	Carbon monoxide	CO_2	Carbonic anhydride
1882	J. Thomsen	Thermochem.	CO	Kohlenoxyd	CO_2	Kohlensäure

TABLE II.—OXIDES OF NITROGEN.

Date	Author	Work	First Oxide		Second Oxide		Third Oxide		Fourth Oxide		Fifth Oxide	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name	Formula	Name
1787	Lavoisier, Fourcroy, Berthollet, De	Tables of Chemical Nomencla-	—	Oxide azoteux	—	Oxide azotique	—	—	—	—	—	—

1810	Klaproth and Wolff	Dict. (Lagrange and Vogel)	—	Nitrous oxide	—	Nitric oxide	—	—	—	—	—	—
1802	H. Thomson . . .	System of Chem., 1st ed.	—	Nitrous oxide	—	Nitric oxide	—	—	—	—	—	—
1817	H. Thomson . . .	System of Chem., 5th ed.	—	Protoxide of azote	—	Deutoxide of azote	—	Hyponitrous acid	—	Nitrous acid .	—	—
1837	H. Thomson . . .	System of Chem., 6th ed.	—	Protoxide of azote	—	Deutoxide of azote	—	Hyponitrous acid	—	Nitrous acid .	—	—
1819	Brande	Manual, 1st ed. .	—	Nitrous oxide	—	Nitric oxide	—	Nitrous acid .	—	—	—	—
1836	Brande	Manual, 4th ed. .	NO	Nitrous oxide	NO_2	Nitric oxide	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	NO_5	Nitric acid
1848	Brande	Manual, 6th ed. .	NO	Nitrous oxide	NO_2	Nitric oxide	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	NO_5	Nitric acid
1863	Brande and Taylor.	Manual	NO	Protoxide of azote, Nitrogen protoxide	NO_2	Deutroxide of nitrogen	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	NO_5	Nitric acid
1823	W. Henry	Elements, 9th ed.	NO	Nitrous oxide	NO_2	Nitrous gas	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	NO_5	Nitric acid
1827	Thénard	Traité de Chimie, 5th ed.	N_2O	Protoxide d'azote	NO_2	Deutoxide d'azote	N_2O_3	Acide hyponitreux	NO_2 or N_2O_4	Acide nitreux .	—	—
1827	Turner	El. of Chem., 1st ed.	—	Protoxide of nitrogen	—	Deutoxide of nitrogen	—	Hyponitrous acid	—	Nitrous acid .	—	—
1828	Dumas	Traité de Chimie	—	Protoxide d'azote	—	Deutoxide d'azote	—	Acide hyponitreux	—	Acide nitreux .	—	Acide nitrique
1829	Berzelius	Traité.	—	Gas oxide nitreux	—	Gas oxide nitrique	—	Acide nitreux	—	Acide nitrosonitrique	—	—
1842	Graham	Elements . . .	NO	Nitrogen protoxide, Nitrous oxide	NO_2	Nitrogen binoxide, Nitric oxide	NO_3	Nitrous acid .	NO_4	Hyponitric acid, Peroxide of nitrogen	—	Nitric acid
1842	Turner	El. of Chem., 7th ed.	NO	Protoxide of nitrogen	NO_2	Deutoxide of nitrogen	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	—	—
1847	Fownes	Manual of Chem., 1st ed.	NO	Protoxide of nitrogen	NO_2	Binoxide of nitrogen	NO_3	Nitrous acid .	NO_4	Hyponitric acid	—	—
1852	B. Jones & Hofmann	Manual of Chem., 4th ed.	NO	Protoxide of nitrogen	NO_2	Binoxide of nitrogen	NO_3	Nitrous acid .	NO_4	Hyponitric acid	—	Anhydrous nitric acid
1854	B. Jones & Hofmann	Manual of Chem., 5th ed.	NO	Protoxide of nitrogen	NO_2	Binoxide of nitrogen	NO_3	Nitrous acid .	NO_4	Hyponitric acid	NO_5	Anhydrous nitric acid
1868	B. Jones and Watts	Manual of Chem., 10th ed.[1]	N_2O	Nitrogen monoxide	N_2O_2 or NO	Nitrogen dioxide	N_2O_3	Nitrogen trioxide, Nitrous oxide	N_2O_4	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide, Nitric oxide
1849	Regnault	Cours de Chimie .	NO	Protoxide d'azote	NO_2	Deutoxide d'azote	NO_3	Acide azoteux .	NO_4	Acide hypoazotique	NO_5	Acid azotique
1856	Gmelin	Handbook (Watts)	NO	Nitrous oxide	NO_2	Nitric oxide	NO_3	Nitrous acid .	NO_4	Hyponitric acid	—	—
1855	Otto	Anorg. Chemie. .	NO	Nitrous oxide	NO_2	Nitric oxide	NO_3	Nitrous acid .	NO_4	Hyponitric acid	—	—
1854	Laurent	Méthode de Chimie	N_2O	Protoxide d'azote	NO_2	Bioxide d'azote	NO_3	Acide azoteux .	N_2O_4	Acide hypoazotique	N_2O_5	Acide nitrique anhydride
1853	Gerhardt	Traité.	NO	Protoxide d'azote	NO_2	Bioxide d'azote	NO_3	Acide azoteux .	N_2O_4	Acide hypoazotique	—	—
1853	Faraday	Non-metallic Elements	NO	Protoxide of nitrogen	NO_2	Binoxide of nitrogen	NO_3	Hyponitrous acid	NO_4	Nitrous acid .	—	—
1859	Faraday	Experimental Researches	NO	Protoxide of nitrogen	NO_2	Nitric oxide	—	Nitrous acid .	—	—	—	—

[1] Nomenclature unaltered in successive editions.

TABLE II.—*continued.*

Date	Author	Work	First Oxide		Second Oxide		Third Oxide		Fourth Oxide		Fifth Oxide	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name	Formula	Name
1856	Miller	Elements, 1st ed.	NO	Protoxide of nitrogen	NO_2	Deutoxide of nitrogen	NO_3	Nitrous acid	NO_4	Peroxide of nitrogen	NO_5	Anhydrous nitric acid
1864	Miller	Elements, 3rd ed.	N_2O	Nitrous oxide	NO	Nitric oxide	N_2O_3	Nitrous anhydride	N_2O_4	Peroxide of nitrogen	N_2O_5	Nitric anhydride
1868	Miller	Elements, 4th ed.	N_2O	Nitrous oxide	NO	Nitric oxide	N_2O_3	Nitrous anhydride	N_2O_4	Peroxide of nitrogen	N_2O_5	Nitric anhydride
1857	Buff and Kopp	Lehrbuch der Chemie	NO	Stickoxydul	NO_2	Stickoxyd	—	—	—	—	—	—
1859	Liebig, Poggendorff, and Wöhler	Handwörterbuch	NO or N_2O_2	Stickoxydul gas	NO_2 or N_2O_4	Stickoxyd	NO_3	Untersalpetri gesäure	NO_4	Untersalpeter Säure	N_2O_5	Salpetersäure-anhydrid
1857	Bunsen	Gasometrische Methoden.	—	Stickoxydul gas	—	Stickoxyd	—	—	—	—	—	—
1877	Bunsen	Gasometrisch Methoden.	—	Stickoxydul gas	—	Stickoxyd	—	—	—	—	—	—
1855	Kekulé	Lehrbuch	NO	Stickoxydul gas	NO_2	Stickoxyd	NO_3	Untersalpetri Säure	NO_4	Untersalpeter Säure	—	—
1861	Odling	Manual	N_2O	Nitrous oxide	N_2O_2 or $(NO)_2$	Nitric oxide	N_2O_3	Nitrous anhydride	N_2O_4	Pernitric oxide	N_2O_5	Nitric anhydride
1865	Naquet	Principes	N_2O	Oxyde azoteux	NO	Oxyde azotique	N_2O_3	Anhydride azoteux	NO_2 or N_2O_4	Hypoazotide	N_2O_5	Anhydride azotique
1865	Williamson	Chemistry	N_2O	Nitrous oxide	N_2O_2	Nitric oxide	N_2O_3	Nitrous anhydride	N_2O_4	Nitric peroxide	N_2O_5	Anhydrous nitric acid
1866	Frankland	Lecture Notes	N_2O	Nitrous oxide	N_2O_2	Nitric oxide	N_2O_3	Nitrous anhydride	N_2O_4	Nitric peroxide	N_2O_5	Nitric anhydride
1869	Harcourt & Madan	Practical Chem.	N_2O	Nitrogen protoxide	NO	Nitrogen dioxide	N_2O_3	Nitrogen dioxide	N_2O_4	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1866	Roscoe	Elementary Lessons	N_2O	Nitrous oxide, Nitrogen monoxide	NO	Nitric oxide, Nitrogen dioxide	N_2O_3	Nitrogen trioxide	NO_2	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1869	Wurtz	Dictionnaire	N_2O	Oxide azoteux	NO	Oxide azotique	N_2O_3	Anhydride azoteux	N_2O_4	Peroxide d'azote	N_2O_5	Anhydride azotique
1877	Roscoe and Schorlemmer	Treatise	N_2O	Nitrogen monoxide	NO	Nitrogen dioxide	N_2O_3	Nitrogen trioxide	NO_2	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1874	J. P. Cooke	The New Chem.	N_2O	Nitrous oxide	NO	Nitric oxide	N_2O_3	Nitrogen trioxide	NO_2	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1880	J. P. Cooke	Chem. Philosophy	N_2O	Nitrogen monoxide	NO	Nitrogen dioxide	N_2O_3	Nitrogen trioxide	NO_2	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1875	Bloxam	Chemistry	N_2O	Nitrous oxide	NO	Nitric oxide	N_2O_3	Nitrous acid	NO_2	Nitric peroxide	N_2O_5	Nitric acid
1876	Gorup-Besanez	Lehrbuch der Chemie	N_2O	Stickstoffoxydul	NO	Stickstoffoxyde	N_2O_3	Salpetrigesäure anhydride	NO_2	Stickstoffleoxide, Stickstoffledioxide	N_2O_5	Salpetersäure anhydride
1877	Thorpe	Inorganic Chem.	N_2O	Nitrogen monoxide	NO	Nitrogen dioxide	N_2O_3	Nitrogen trioxide	N_2O_4 or NO_2	Nitrogen tetroxide	N_2O_5	Nitrogen pentoxide
1879	Berthollet	Mécanique Chimique	$_2[NO]$	Protoxide d'azote	NO_2	Bioxide d'azote	$_2[NO_3]$	Acide azoteux	NO_4	Acide hypoazotique	$_2[NO_3]$	Acide azotique
1880	Armstrong	Organic Chem., & Papers in Journ. Chem. Soc.	N_2O	Nitrous oxide	NO	Nitric oxide	—	—	—	—	—	—

		...sche Untersuchungen	..	...dul	...	...oxyd	N_2O_3	Salpetergesäure	NO_2	Stickstoffbioxide	N_2O_5	...uride Salpetersäure anhydride
1883 1884	Divers	Papers in Journ. Chem. Soc.	N_2O	Nitrous oxide	NO	Nitric oxide	N_2O_3	Nitrogen trioxide	$[NO_2]$	Nitrogen bioxide	—	—
1863	Buff	Anorg. Chem.	N_2O	Stickoxydul	NO	Stickoxyd	N_2O_3	Salpetergesäure anhydride	NO_2	Stick-toff-bioxide	—	Salpetersäure anhydride

TABLE III.—NOMENCLATURE OF THE OXIDES OF SULPHUR.

Date	Author	Work	Lower Oxide		Higher Oxide	
			Formula	Name	Formula	Name
1787	Lavoisier, De Morveau, Berthollet, and De Fourcroy	Table of Chemical Nomenclature	—	Sulphurous acid	—	—
1810	Klaproth and Wolff	Dict. (Lagrange and Vogel)	—	—	—	—
1802	Th. Thomson	System of Chemistry, 4th ed.	—	Sulphurous acid	—	—
1820	Th. Thomson	System of Chemistry, 6th ed.	—	Sulphurous acid	—	—
1831	Th. Thomson	System of Chemistry, 7th ed.	—	Sulphurous acid	—	—
1819	W. T. Brande	Manual, 1st ed.	—	Sulphurous acid	—	Sulphuric acid
1836	W. T. Brande	Manual, 4th ed.	—	Sulphurous acid	SO_3	Sulphuric acid
1841	W. T. Brande	Manual, 5th ed.	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1863	Brande and Taylor	Manual	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1827	Henry	Elements, 9th ed.	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1828	Dumas	Traité	SO_2	Acide sulfureux	—	—
1827	Thénard	Traité	SO_2	Gas acide sulfureux	SO_3	Acide sulfurique secou anhydride
1830	Berzelius	Traité	—	Acide sulfureux	—	Acide sulfurique anhydride
1827	Turner	Elements of Chemistry, 1st ed.	—	Sulphurous acid gas	—	Anhydrous sulphuric acid
1842	Turner (Liebig & Gregory)	Elements of Chemistry, 7th ed.	SO_2	Sulphurous acid gas	SO_3	Anhydrous sulphuric acid
1842	Graham	Elements of Chemistry	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1847	Fownes	Manual of Chemistry, 1st ed.	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1863	Fownes (B. Jones and Hofmann)	Manual of Chemistry, 9th ed.	SO_2	Sulphurous oxide or Sulphur dioxide	SO_3	Sulphuric oxide or Sulphur trioxide
1868	Fownes (B. Jones & Watts)	Manual of Chemistry, 10th ed.	SO_2	Sulphurous oxide or Sulphur dioxide	SO_3	Sulphuric oxide or Sulphur trioxide
1849	Gmelin (Watts)	Handbook	SO_2	Sulphurous acid	SO_3	Anhydrous sulphuric acid
1852	Regnault	Cours	SO_2	Acide sulfureux	SO_3	Acide sulfurique
1856	Miller	Elements of Chemistry, 1st ed.	SO_2	Sulphurous acid	$[SO_3]_2$	Sulphuric anhydride
1868	—	Elements of Chemistry, 4th ed.	SO_2	Sulphurous anhydride	SO_3	Sulphuric anhydride
1857	Buff and Kopp	Lehrbuch	SO_2	Schwefeligesäure	—	—
1854	Laurent	Méthode de Chimie	—	Acide sulfureux	—	Acide sulfurique
1853	Faraday	Non-metallic Elements	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1861	Liebig, Poggendorff, and Wöhler	Handwörterbuch	SO_2	Schwefeligesäure	SO_3	Schwefelsäure

TABLE III.—*continued.*

Date	Author	Work	Lower Oxide		Higher Oxide	
			Formula	Name	Formula	Name
1861	Odling	Manual of Chemistry	SO_2	Sulphurous anhydride	SO_3	Sulphuric anhydride
1865	Williamson	Text Book	SO_2	Sulphurous acid	SO_3	Sulphuric acid
1866	Frankland	Lecture Notes	SO_2	Sulphurous anhydride	SO_3	Sulphuric anhydride
1865	Naquet	Principes	SO_2	Anhydride sulfureux	SO_3	Anhydride sulfurique
1869	Harcourt and Madan	Practical Chemistry	SO_2	Sulphur dioxide	SO_3	—
1869	Wurtz	Chem. Dict.	SO_2	Anhydride sulfureux	SO_3	Anhydride sulfurique
1865	Roscoe	Lessons in Elementary Chemistry	SO_2	Sulphuric dioxide	SO_3	Sulphuric trioxide
1877	Roscoe and Schorlemmer	Treatise	SO_2	Sulphur dioxide	SO_3	Sulphur trioxide
1874	J. P. Cooke	The New Chemistry	SO_2	Sulphurous oxide	SO_3	Sulphuric oxide
1882	J. P. Cooke	Chemical Philosophy	SO_2	Sulphur dioxide	SO_3	Sulphur trioxide
1875	Bloxam	Chemistry	SO_2	Sulphur dioxide	SO_3	Sulphuric anhydride
1876	Gorup-Besanez	Lehrbuch	SO_2	Schwefeldioxide	SO_3	Schwefeltrioxide
1879	Berthollet	Mécanique Chimique	SO_2	Acide sulfureux	SO_3	Acide sulfurique anhydride
1883	Thomsen	Thermochemischen Untersuchungen	SO_2	Anhydrid der Schwefeligesäure	SO_3	Anhydrid der Schwefelsäure
1881	Attfield	Pharm. Chem.	SO_2	Sulphurous acid gas	SO_3	Sulphuric anhydride
1877	Thorpe	Inorganic Chemistry	SO_2	Sulphur dioxide	SO_3	Sulphur trioxide

TABLE IV.—THE POLYTHIONIC ACIDS.

Date	Author	Work	First Acid		Second Acid		Third Acid		Fourth Acid	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name
1818	Welter and Gay-Lussac	Ann. Chim. Phys. (1) x. 312	—	Acide hyposulfurique	—	—	—	—	—	—
1820	Thomson	System of Chem., 6th ed.	—	Hyposulphuric acid	—	—	—	—	—	—
1831	Thomson	System of Chem., 7th ed.	—	Hyposulphuric acid	—	—	—	—	—	—
1836	Brande	Manual, 4th ed.	S_2O_5	Hyposulphuric acid	—	—	—	—	—	—
1848	Brande	Manual, 5th ed.	S_2O_5	Hyposulphuric acid	—	Trithionic acid	—	Tetrathionic acid	—	Pentathionic acid
1863	Brande & Taylor	Manual	S_2O_5	Dithionic acid	—	—	—	—	—	—
1826	Henry	Elements, 10th ed.	—	Hyposulphuric acid	—	—	—	—	—	—
1828	Dumas	Traité	—	Acide hyposulfurique	—	—	—	—	—	—
1827	Turner	El. of Chem., 1st ed.	S_2O_5	Hyposulphuric acid	S_3O_5	Sulphuretted hyposulphuric acid	S_4O_5	Persulphuretted hyposulphuric acid	—	—
18[illegible]	Turner (Liebig & [illegible]	El. of Chem., 7th ed.	S_2O_5	Hyposulphuric acid	[illegible]	[illegible]	[illegible]	[illegible]	—	—

1842	Berzelius	Jahresbericht	S_2O_5	Dithionsäure	S_3O_5	Trithionsäure	S_4O_5	Tetrathionsäure	—	—
1842	Langlois	Ann. Chim. Phys.	—	—	S_3O_5	—	—	—	—	—
1842 / 1848	Fordos and Gélis	Ann. Chim. Phys.	—	Acide hyposulfurique sulfuré	S_3O_5	Acide hyposulfurique sulfuré	—	Acide hyposulfurique disulfér	—	Acide hyposulfurique trisulfuré
1842	Graham	Elements of Chem.	S_2O_5	Hyposulphuric acid	S_3O_5	Monosulphyposulphuric acid	S_4O_5	Bisulphyposulphuric acid	S_5O_5	Trisulphyposulphuric acid
1847	Fownes	Manual of Chem., 1st ed.	S_2O_5	Hyposulphuric acid	S_3O_5	Sulphuretted hyposulphuric acid	S_4O_5	Disulphuretted hyposulphuric acid	—	—
1852	Fownes (B. Jones and Hofmann)	Manual of Chem., 4th ed.	S_2O_5	Hyposulphuric acid	S_3O_5	Sulphuretted hyposulphuric acid	S_4O_5	Disulphuretted hyposulphuric acid	S_5O_5	Trisulphuretted hyposulphuric acid
1868	Fownes (B. Jones and Watts)	Manual of Chem., 10th ed.	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithonic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1853	Gerhardt	Traité	—	—	—	—	—	—	—	—
1854	Regnault	Chimie	S_2O_5	Acide hyposulfurique	S_3O_5	Acide hyposulphurique monosulfuré	S_4O_5	Acide hyposulfurique bisulfuré	S_5O_5	Acide hyposulfurique trisulfuré
1851	Gmelin	Handbook (Watts)	S_2O_5	Hyposulphuric acid	S_3O_5	Trithionic acid	S_4O_5	Tetrathionic acid	S_5O_5	Pentathionic acid
1853	Faraday	—	S_2O_5	Hyposulphuric acid	—	—	—	—	—	—
1854	Laurent	Méthode de Chimie	—	—	—	—	—	—	—	—
1855	Otto	Anorg. Chemie	—	—	—	—	—	—	—	—
1856	Miller	Elements, 1st ed.	S_2O_5	Dithionic acid	S_3O_5	Trithionic acid	S_4O_5	Tetrathionic acid	S_5O_5	Pentathionic acid
1868	Miller	Elements, 4th ed.	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1878	Miller (Groves)	Elements, 6th ed.	$H_2S_2O_6$	Hyposulphuric acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1839	Liebig, Poggendorff & Wöhler	Handwörterbuch	S_2O_5	Unterschwefelsäure	S_3O_5	Trithionsäure	S_4O_5	Tetrathionsäure	S_5O_5	Pentathionsäure
1861	Odling	Manual	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1865	Naquet	Principes	H_2S_2O	Acide dithionique	$H_2S_3O_6$	Acide trithionique	$H_2S_4O_6$	Acide tétrathionique	$H_2S_5O_6$	Acide pentathionique
1865	Williamson	Chemistry	S_2O_5	Hyposulphuric acid	S_3O_5	Monosulphuretted hyposulphuric acid	S_4O_5	Disulphuretted hyposulphuric acid	S_5O_5	Trisulphuretted hyposulphuric acid
1866	Frankland	Lecture Notes	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic sulphodithionic acid	$H_2S_4O_6$	Tetrathionic, Disulphodithionic acid	$H_2S_5O_6$	Pentathionic, Trisulphodithionic acid
1866	Roscoe	Elementary Lessons	$H_2S_2O_6$	Hydric dithionate	$H_2S_3O_6$	Hydric trithionate	$H_2S_4O_6$	Hydric tetrathionate	$H_2S_5O_6$	Hydric pentathionate
1877	Roscoe and Schorlemmer	Treatise	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1868	Buff	Anorgan. Chem.	$H_2S_2O_6$	Dithionsäure	$H_1S_3O_6$	Trithionsäure	$H_2S_4O_6$	Tetrathionsäure	$H_2S_5O_6$	Pentathionsäure
1869	Wurtz	Dictionnaire	$H_2S_2O_6$	Acide dithionique	H_2S_3O	Acide trithionique	$H_2S_4O_6$	Acide tétrathionique	$H_2S_5O_6$	Acide pentathionique
1874	T. P. Cooke	The New Chemistry	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1875	Bloxam	Chemistry	$H_2S_2O_6$	Hyposulphuric acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1876	Gorup-Besanez	Lehrbuch der Chemie	$H_2S_2O_6$	Unterschiefelsäure	$H_2S_3O_6$	Trithionsäure	$H_2S_4O_6$	Tetrathionsäure	$H_2S_5O_6$	Pentathionsäure
1877	Korpe	Anorganic Chem.	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1879	Berthollet	Mécanique Chimique	HSO_3	Acide hyposulfurique	—	—	HS_4O_6	Acide tétrathionique	—	—
1881	Attfield	Pharm. Chem.	$H_2S_2O_6$	Dithionic acid	$H_2S_3O_6$	Trithionic acid	$H_2S_4O_6$	Tetrathionic acid	$H_2S_5O_6$	Pentathionic acid
1883	Thomsen (Julius)	Thermochemischen Untersuchungen	$H_2S_2O_6$	Dithionsäure	$H_1S_3O_6$	Trithionsäure	$H_2S_4O_6$	Tetrathionsäure	$H_2S_5O_6$	Pentathionsäure

Table V.—Other Acids of Sulphur not Included in Preceding Tables.

Date	Author	Work	Acid known as Hyposulphurous Acid: Formula	Name	Acid known as Thiosulphuric Acid: Formula	Name	Acid known as Pyrosulphuric Acid: Formula	Name
1800	Vauquelin	Ann. Chim. xxxii. 2?7	—	—	—	Acide sulfureux sulfuré	—	—
1820	Thomson	System of Chem., 6th ed.	—	—	—	Hyposulphurous acid	—	—
1831	Thomson	System of Chem., 7th ed.	—	—	—	Hyposulphurous acid	—	—
1819	Brande	Manual, 1st ed.	—	—	—	Hyposulphurous acid	—	—
1836	Brande	Manual, 4th ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1841	Brande	Manual, 5th ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1863	Brande and Taylor	Chemistry	—	—	S_2O_2	Hyposulphurous acid	—	—
1827	Henry	Elements, 9th ed.	—	—	—	Hyposulphurous acid	—	—
1828	Dumas	Traité	—	—	—	Acide hyposulfureux	—	—
1830	Berzelius	Traité	—	—	—	Acide hyposulfureux	—	—
1827	Thénard	Traité	—	—	—	Acide hyposulfureux	—	—
1827	Turner	El. of Chem., 1st ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1842	Turner, Liebig, and Gregory	El. of Chem., 7th ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1842	Graham	El. of Chem.	—	—	S_2O_2	Hyposulphurous acid	—	—
1847	Fownes	Man. of Chem., 1st ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1868	Fownes (B. Jones and Watts)	Man. of Chem., 10th ed.	—	—	$H_2S_2O_3$	Hyposulphurous acid	—	—
1872	Fownes (Watts)	Man. of Chem., 11th ed.	—		$H_2S_2O_3$	Thiosulphuric acid	—	—
1849	Gmelin (Watts)	Handbook		—	SO or S_2O_2	Hyposulphurous acid	—	—
1852	Regnault	Cours	—	—	S_2O_2	Acide hyposulfureux	—	—
1856	Miller	El. of Chem., 1st ed.	—	—	S_2O_2	Hyposulphurous acid	—	—
1868	Miller	El. of Chem., 4th ed.	—	—	$H_2S_2O_3$	Hyposulphurous acid	—	—
1874	Miller (McLeod)	El. of Chem., 5th ed.	H_2SO_2	Hyposulphurous acid	$H_2S_2O_3$	Thiosulphuric acid	$H_2S_2O_7$	Disulphuric acid
1880	Miller (Jones)	El. of Chem., 6th ed.	—	—	—	—	—	Triosulphuric acid
1854	Laurent	Méthode de Chimie	—	—	—	—	—	—
1803	Gerhardt	Traité	—	—	—	—	—	—
1853	Faraday	Lectures	—	—	S_2O	Hyposulphurous acid	—	—
1861	Liebig, Poggendorff, and Wöhler	Handwörterbuch	—	—	S_2O_2	Unterschwefeligesäure	—	—
1861	Odling	Manual of Chemistry	—	—	$H_2S_2O_3$	Thiosulphuric acid	—	—
1865	Williamson	Text-book	—	—	S_2O_3	Hyposulphurous acid	—	—
1865	Naquet	Principes	—	—	$H_2S_2O_3$	Acide sulfureux	$H_2S_2O_7$	Acide disulfurique
1866	Frankland	Lecture Notes	—	—	$H_2S_2O_3$	Hyposulphurous and sulphosulphuric acid	—	—
1866	Roscoe	Lessons in El. Chemistry	—	—	$H_4S_2O_4$	Hyposulphurous acid	—	—
1877	Roscoe & Schorlemmer	Treatise	H_2SO_2	Hyposulphurous acid	$H_2S_2O_3$	Thiosulphuric acid	$H_2S_2O_7$	Disulphuric acid
1868	Buff	Anorg. Chem.	—	—	$H_2S_2O_3$	Unterschwefelgesäure Dithionigesäure	—	Pyroschwefelsäure
1869	Harcourt and Madan	Practical Chem., 1st ed.	—	—	$H_2S_2O_3$	Hyposulphurous acid	—	—
1882	Harcourt and Madan	Practical Chem., 3rd ed.	—	—	$H_2S_2O_4$	—	—	—
1869	Wurtz	Dictionnaire	H_2SO_2	Acide hydrosulphureux	$H_2S_2O_3$	Acide hyposulfureux	$H_2S_2O_7$	Acide disulfurique
1874	Cooke, J. P.	The New Chemistry	H_2SO_2	Hyposulphurous acid	$H_2S_2O_3$	Thiosulphurous acid	$H_2S_2O_7$	Disulphuric acid
1875	Bloxam	Chemistry	H_2SO_2	Hydrosulphurous acid	$H_2S_2O_3$	Hyposulphurous acid	—	—
1877	Thorpe	Inorganic Chemistry	H_2SO_2	Hyposulphurous acid	$H_2S_2O_3$	Thiosulphuric acid	—	Nordhausen sulphuric acid

	. . . . . .	Thermochemische Untersuchungen	—	—	$H_2S_2O_3$	Unterschweflige-säure .	—	—
1874	Gorup-Besanez . . .	Lehrbuch	H_2SO_3	Hydromonothionige-säure	$H_2S_2O_3$	Unterschweflige-säure .	$H_2S_2O_7$	Pyroschwefelsäure

Table VI.—Oxides of Chromium.

Date	Author	Work	First Oxide		Second Oxide		Third Oxide		Fourth Oxide		Fifth Oxide	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name	Formula	Name
1802	Th. Thomson . .	System of Chem., 1st ed.	—	—	—	Green oxide of chromium	—	Brown oxide of chromium	—	Yellow oxide, Chromic acid	—	—
1817	Th. Thomson . .	System of Chem., 4th ed.	—	—	—	Protoxide of chromium	—	Deutoxide of chromium	—	Yellow oxide, Chromic acid	—	—
1831	Th. Thomson . .	System of Chem., 7th ed.	—	—	—	Protoxide of chromium	—	Deutoxide of chromium	—	Yellow oxide, Chromic acid	—	—
1819	W. T. Brande . .	Manual, 1st ed. . .	—	—	—	Protoxide of chromium	—	Deutoxide of chromium	—	Chromic acid or peroxide	—	—
1836	W. T. Brande . .	Manual, 4th ed. . .	—	—	$CrO1\frac{1}{2}$	Protoxide, sesquioxide of chromium	—	Deutoxide of chromium	CrO_3	Peroxide of chromium	—	—
1848	W. T. Brande . .	Manual, 6th ed. . .	CrO	Protoxide of chromium	Cr_2O_3	Sesquioxide of chromium	CrO_2	Binoxide of chromium	CrO_3	Peroxide of chromium	—	—
1823	Henry	Elements, 9th ed. .	—	—	Cr_2O_3	Protoxide of chromium	—	—	CrO_3	Chromic acid	—	—
1827	Thénard	Traité	—	—	—	Protoxide of chromium	—	Deutoxide of chromium	—	Chromic acid	—	—
1828	Dumas	Traité	—	—	—	Protoxide de chrome	CrO_2	Deutoxide de chrome	—	Acide chromique	—	—
1830	Berzelius . . .	Traité	—	—	—	Oxide chromique	—	Oxide surchromique	CrO_3	Acide chromique	—	—
1842	Turner (Liebig and Gregory)	Chemistry, 7th ed. .	—	—	—	Green protoxide	—	—	CrO_3	Chromic acid .	—	—
1842	Graham	El. of Chem., 1st ed.	—	—	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromic acid .	—	—
1846	Graham	El. of Chem., 2nd ed.	—	—	Cr_2O_2	Chromium sesquioxide	CrO_2	Oxide surchromique	CrO_3	Chromic acid .	—	—
1850	Graham	El. of Chem., 3rd ed.	—	—	Cr_2O_3	Chromium sesquioxide	CrO_2	Oxide surchromique	CrO_3	Chromic acid .	—	—
1858	Graham	El. of Chem., 4th ed.	CrO	Protoxide of chromium	Cr_2O_2	Chromic oxide .	Cr_2O_3, CrO_3	Monochromate of chromic oxide	CrO_3	Chromic acid .	—	—
1849	Liebig, Poggendorff, and Wöhler	Handwörterbuch .	CrO	Chromoxydul .	Cr_2O_2	Chromoxyd . .	—	—	CrO_3	Chromsäure . .	Cr_2O_7	Ueberchromsäure
1852	Regnault . . .	Chimie (trans. Betton)	CrO	Chromium protoxide	Cr_2O_2	Chromic oxide .	—	—	CrO_3	Chromic acid .	Cr_2O_7	—
1842	B. Jones and Hofmann	Fownes' Chem., 4th ed.	CrO	Chromium protoxide	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromic acid .	CrO_7	Perchromic acid
1851-63	B. Jones and Hofmann	Fownes' Chem., 5th-9th ed.	CrO	Chromium protoxide	Cr_2O_2	Chromium sesquioxide	—	—	CrO_3	Chromic acid .	OrO_7	Perchromic acid

TABLE VI.—*continued.*

Date	Author	Work	First Oxide		Second Oxide		Third Oxide		Fourth Oxide		Fifth Oxide	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name	Formula	Name
1868	B. Jones and Watts	Fownes' Chem., 10th ed.	CrO	Chromium monoxide	Cr_2O_2	Chromium sesquioxide	CrO_2	Chromium dioxide	CrO_3	Chromium trioxide	Cr_2O_7	Perchromic acid
1872-8?	Watts	Fownes' Chem., 11th-13th ed.	CrO	Chromium monoxide	Cr_2O_3	Chromium sesquioxide	CrO_2	Chromium dioxide	CrO_3	Chromium trioxide	Cr_2O_7	Perchromic acid
1850	Gmelin	Handbook	CrO	Protoxide of chromium, Chromous oxide	Cr_2O_3	Sesquioxide of chromium, Chromic oxide	CrO_2	Brown oxide of chromium, Chromate of chromic oxide	CrO_3	Chromic acid	Cr_2O_7	Perchromic acid
1856	Miller	El. of Chem., 1st ed.	CrO	Protoxide of chromium	Cr_2O_3	Sesquioxide of chromium	CrO_2	Intermediate oxide	CrO_3	Chromic acid	Cr_2O_7	Perchromic acid
1864	Miller	El. of Chem., 3rd ed.	CrO	Protoxide of chromium or Chromous oxide	Cr_2O_3	Sesquioxide of chromium, or Chromic oxide	CrO_2	Intermediate oxide	CrO_3	Chromic anhydride	Cr_2O_7	Perchromic acid
1868-74	Miller	El. of Chem., 4th and 5th ed.	CrO	Chromous oxide	Cr_2O_3	Chromic oxide	CrO_2	Intermediate oxide	CrO_3	Chromic anhydride	Cr_2O_7	Perchromic acid
1865	Williamson	Chemistry	CrO	Chromous oxide	Cr_2O_3	Chromic oxide	—	—	CrO_3	Chromic acid	—	—
1866	Frankland	Lecture Notes	CrO	Chromic oxide	Cr_2O_3	Chromic oxide	CrO_2	Chromic dioxide	CrO_3	Chromic anhydride	$H_2Cr_2O_8$	Perchromic acid
1866	Roscoe	Lessons in Chem., 1st ed.	CrO	Chromous oxide	Cr_2O_3	Chromic sesquioxide	—	—	CrO_3	Chrome trioxide	$H_2Cr_2O_8$	Perchromic acid
1869	Roscoe	Lessons in Chem., 5th ed.	CrO	Chromium monoxide	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromium trioxide	$H_2Cr_2O_8$	Perchromic acid
1879	Roscoe and Schorlemmer	Treatise	CrO	Chromium monoxide	Cr_2O_3	Chromic oxide	$3CrO_2$	Chromic chromate	CrO_3	Chromium trioxide	$HCrO_4$	Perchromic acid
1870	Odling	Outlines	CrO	Chromous oxide	Cr_2O_3	Chromic oxide	—	—	CrO_3	Chromium trioxide, Chromic anhydride	—	—
1870	Wurtz	Dictionnaire	CrO	Protoxide de chrome	Cr_2O_3	Sesquioxide de chrome	—	—	CrO_3	Acide chromique	Cr_2O_7	Acide perchromique anhydride
1872	Harcourt and Madan	Practical Chem.	—	—	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromium trioxide	—	—
1874	Gorup-Besanez	Lehrbuch	CrO	Chromoxydul	Cr_2O_3	Chromoxyd	—	—	CrO_3	Chromtrioxide	—	—
1875	Naquet	Principes	CrO	Protoxide de chrome	Cr_2O_3	Sesquioxide de chrome	CrO_2	Bioxide de chrome	CrO_3	Anhydride chromique	$HCrO_4$	Acide perchromique
1875	Bloxam	Chemistry, 3rd ed.	CrO	Chromium protoxide	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromic acid	$H_2Cr_2O_8$	Acide perchromique
1880	Bloxam	Chemistry, 4th ed.	CrO	Chromium protoxide	Cr_2O_3	Chromium sesquioxide	—	—	CrO_3	Chromic anhydride	$H_2Cr_2O_8$	Acide perchromique
1877	Thorpe	Chemistry (Metals)	CrO	Chromium monoxide	Cr_2O_3	Chromium sesquioxide	CrO_2	Chromium dioxide	CrO_3	Chromium trioxide	—	—
1882	Cooke, J. P.	Principles	CrO	Chromous oxide	Cr_2O_3	Chromic oxide	—	—	CrO_3	Chromic anhydride	—	—
1882	Thomsen (Julius)	Thermochemische Untersuchungen	—	—	Cr_2O_3	Chromoxyd	—	—	CrO_3	Chromsäure	—	—
1879	Berthollet	Mécanique Chimique	—	—	—	—	—	—	Cr_2O_3	Acide chromique	—	—

TABLE VII.—NOMENCLATURE OF SALTS (POTASSIUM AND LEAD) OF CHROMIC ACID.

Date	Author	Work	POTASSIUM SALTS				LEAD SALTS			
			First Salt		Second Salt		First Salt		Second Salt	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name
1817	Th. Thomson	System of Chemistry, 4th ed.	—	Chromate of potash	—	Bichromate of potash	—	Chromate of lead	—	Dichromate of lead
1831	Th. Thomson	System of Chemistry, 7th ed.	K_2CrO_4	Chromate of potash	$K_2Cr_2O_7$	Bichromate of potash	$PbCrO_4$	Chromate of lead	$PbO.PbCrO_4$	Dichromate of lead
1819	Brande	Manual, 1st ed.	—	Chromate of potassa	—	Bichromate of potassa	—	Chromate of lead	—	Dichromate of lead
1836	Brande	Manual, 4th ed.	$KO.CrO_3$	Chromate of potassa	$KO.2CrO_3$	Bichromate of potassa	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Di- or subchromate of lead
1848	Brande	Manual, 6th ed.	$KO.CrO_3$	Chromate of potassa	$KO.2CrO_3$	Bichromate of potassa	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Di- or subchromate of lead
1863	Brande and Taylor	Chemistry	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Di- or subchromate of lead
1823	Henry	Elements, 9th ed.	—	Chromate of potash	—	Bichromate of potash	—	—	—	—
1827	Thénard	Traité	$KO.CrO_3$	Chromate neutre de potasse	$KO.Cr_2O_6$	Chromate acide ou bichromate	$PbO.CrO_3$	Chromate de plomb	$2PbO.CrO_3$	Souschromate de plomb
1828	Dumas	Traité	—	Chromate de potasse	—	Bichromate de potasse	—	Chromate de plomb	—	—
1838	Berzelius	Traité	—	Chromate neutre potassique	—	Bichromate potassique	—	Chromate plombique	—	Chromate biplombique
1842	Turner (Liebig and Gregory)	Chemistry	$KO.CrO_3$	Chromate of potassa	$KO.2CrO_3$	Bichromate of potassa	$PbO.CrO_3$	Chromate of oxide of lead	$2PbO.CrO_3$	Dichromate of oxide of lead
1842	Graham	Elements	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1846	Graham	Elements	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1850	Graham	Elements	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1858	Graham	Elements	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1849	Liebig, Poggendorff, & Wöhler	Handwörterbuch	$KO.CrO_3$	Neutrales Chromsäures Kali	$KO.2CrO_3$	Doppelsäures Chromsäures Kali	$PbO.CrO_3$	Neutrales Chromsäures bleioxyd	$2PbO.CrO_3$	Basisches Chromsäures bleioxyd
1842	B. Jones and Hofmann	Fownes, 4th ed.	$KO.CrO_3$	Chromate of potassa	$KO.2CrO_3$	Bichromate of potassa	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1854–63	B. Jones and Hofmann	Fownes, 5th–9th ed.	$KO.CrO_3$	Chromate of potassa	$KO.2CrO_3$	Bichromate of potassa	$PbO.CrO_3$	Chromate of lead	$2PbO.CrO_3$	Subchromate of lead
1868	B. Jones & Watts	Fownes, 10th ed.	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium bichromate	$PbCrO_4$	Lead chromate	$PbO.PbCrO_4$	Basic lead chromate
1872–83	Watts	Fownes, 11th–13th ed.	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium bichromate	$PbCrO_4$	Lead chromate	$PbO.PbCrO_4$	Basic lead chromate

TABLE VII.—*continued.*

Date	Author	Work	POTASSIUM SALTS				LEAD SALTS			
			First Salt		Second Salt		First Salt		Second Salt	
			Formula	Name	Formula	Name	Formula	Name	Formula	Name
1850	Gmelin	Handbook . . .	$KO.CrO_3$	Chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	—	—	—
1856	Miller	Elements, 1st ed. .	$KO.CrO_3$	Neutral chromate of potash	$KO.2CrO_3$	Bichromate of potash	$PbO.CrO_3$	Lead chromate .	$PbO.PbCrO_4$	Dichromate of lead
1864	Miller	Elements, 3rd ed. .	K_2CrO_4	Normal or neutral chromate of potassium	$K_2Cr_2O_7$	Anhydrochromate of potassium	$PbCrO_4$	Lead chromate .	$PbO.PbCrO_4$	Basic chromate of lead
1868-74	Miller	Elements, 4th & 8th ed.	K_2CrO_4	Potassic chromate .	$K_2Cr_2O_7$	Potassic dichromate	$PbCrO_4$	Lead chromate .	$PbO.PbCrO_4$	Basic chromate of lead
1865	Williamson . . .	Chemistry . . .	K_2CrO_4	Potassic chromate .	$K_2Cr_2O_7$	Potassic dichromate	$PbCrO_4$	Plumbic chromate	$PbO.PbCrO_4$	Basic plumbic chromate
1866	Frankland . . .	Lecture Notes . .	K_2CrO_4	Dipotassic chromate	$K_2Cr_2O_7$	Dipotassic dichromate	$PbCrO_4$	Plumbic chromate	—	—
1866	Roscoe . . .	Lessons in Chemistry, 1st ed.	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium anhydro, or bichromate	$PbCrO_4$	Lead chromate .	—	—
1879	Roscoe and Schorlemmer	Treatise	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium dichromate	$PbCrO_4$	Lead chromate .	Pb_2CrO_5	Basic lead chromate
1870	Odling	Outlines	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium anhydro, or bichromate	$PbCrO_4$	Lead chromate .	$PbO.PbCrO_4$	Diplumbous oxychromate
1870	Wurtz	Dictionnaire . .	K_2CrO_4	Chromate neutre de potasse	$K_2Cr_2O_7$	Bichromate de potasse	$PbCrO_4$	Chromate neutre de plomb	$PbO.PbCrO_4$	Souschromate de plomb
1872	Harcourt & Madan	—	K_2CrO_4	Potassium chromate	$K_2Cr_2O_7$	Potassium dichromate	$PbCrO_4$	Lead chromate .	—	—
1871	Gorup-Besanez .	Lehrbuch . . .	K_2CrO_4	Chromsäures Kalium	$K_2Cr_2O_7$	Dichromsäures Kalium	$PbCrO_4$	Chromsäures Blei	$PbO.PbCrO_4$	Basisch Chromsäures Blei
1875	Naquet	Principes . . .	K_2CrO_4	Chromate neutre de potasse	$K_2Cr_2O_7$	Dichromate de potasse	$PbCrO_4$	Chromâte de plomb	—	—
1875	Bloxam	Chemistry, 3rd ed.	K_2CrO_4	Chromate of potash	$K_2Cr_2O_7$	Bichromate of potash	$PbCrO_4$	Chromate of lead	$PbO.PbCrO_4$	Basic chromate of lead
1877	Thorpe	Metals	K_2CrO_4	Neutral or normal potassium chromate	$K_2Cr_2O_7$	Potassium bichromate	$PbCrO_4$	Normal lead chromate	$PbO.PbCrO_4$	Diplumbic chromate
1882	Cooke, J. P. . .	Principles . . .	K_2CrO_4	Potassic chromate .	$K_2Cr_2O_7$	Potassic dichromate	$PbCrO_4$	Plumbic chromate	$PbO.PbCrO_4$	Diplumbic chromate
1882	Thomsen (Julius)	Thermochemischen Untersuchungen	—	—	$K_2Cr_2O_7$	Bichromsäures Kali	—	—	—	—

TABLE VIII.—CHLORIDES OF PHOSPHORUS, OXIDES OF PHOSPHORUS.

Date	Author	Work	CHLORIDES OF PHOSPHORUS				OXIDES OF PHOSPHORUS.			
			Name for Lower Chloride		Name for Higher Chloride		Name for Lower Oxide		Name for Higher Oxide	
			Formula		Formula		Formula		Formula	
1787	Morveau, Lavoisier, Berthollet, and Fourcroy	Table of Nomenclature	—	—	—	—	—	Acide phosphoreux	—	Acide phosphorique
1789	Lavoisier	Traité Elémentaire	—	—	—	—	—	Acide phosphoreux	—	Acide phosphorique
1810	Klaproth, Wolff, and Vogel	Dictionnaire . . .	—	—	—	—	—	Acide phosphoreux Phosphorichte Säure	—	Acide phosphorique
1806	W. Henry	Elements, 4th ed. .	—	—	—	—	—	Phosphorous acid .	—	Phosphoric acid
1810	W. Henry	Elements, 6th ed. .	—	A compound of muriatic and phosphorous acid	—	Murio-phosphoric acid	—	Phosphorous acid .	—	Phosphoric acid
1815	W. Henry	Elements, 7th ed. .	—	Phosphorane . . .	—	Phosphorana . . .	$PO1\frac{1}{2}$	Phosphorous acid .	PO_2	Phosphoric acid
1818	W. Henry	Elements, 8th ed. .	PCl	Chloride of phosphorus	PCl_2	Perchloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1823	W. Henry	Elements, 9th ed. .	PCl	Chloride or protochloride	PCl_2	Bi- or Per-chloride .	PO	Phosphorous acid .	PO_2	Phosphoric acid
1826	W. Henry	Elements, 10th ed. .	PCl	Chloride of phosphorus	PCl_2	Bichloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1802	Th. Thomson . .	System of Chem., 1st ed.	—	—	—	—	—	(Phosphorous acid, 'not known concrete')	—	Phosphoric acid
1807	Th. Thomson . .	System of Chem., 3rd ed.	—	—	—	—	—	Phosphorous acid .	—	Phosphoric acid
1810	Th. Thomson . .	System of Chem., 4th ed.	—	—	—	—	—	Phosphorous acid .	—	Phosphoric acid
1817	Th. Thomson . .	System of Chem., 5th ed.	PCl	Protochloride of phosphorus	PCl_2	Perchloride of phosphorus	PO_2	Phosphorous acid .	PO_4	Phosphoric acid
1820	Th. Thomson . .	System of Chem., 6th ed.	PCl	Protochloride of phosphorus	PCl_2	Perchloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1831	Th. Thomson . .	System of Chem., 7th ed.	$PCl1\frac{1}{2}$	Sesquichloride of phosphorus	$PCl2\frac{1}{2}$	Perchloride of phosphorus	$PO1\frac{1}{2}$	Phosphorous acid .	$PO2\frac{1}{2}$	Phosphoric acid
1825	Th. Thomson . .	Attempt, &c. . . .	PCl	Protochloride of phosphorus	PCl_2	Perchloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1819	W. T. Brande . .	Manual, 1st ed. . .	PCl	Chloride of phosphorus	PCl_2	Bichloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1821	W. T. Brande . .	Manual, 2nd ed. . .	PCl	Chloride of phosphorus	PCl_2	Perchloride of phosphorus	PO	Phosphorous acid .	PO_2	Phosphoric acid
1836	W. T. Brande . .	Manual, 4th ed. . .	$P+1\frac{1}{2}Cl$	Sesquichloride of phosphorus	$P+2\frac{1}{2}Cl$	Perchloride of phosphorus	$P+O1\frac{1}{2}$	Phosphorous acid .	$P+O2\frac{1}{2}$	Phosphoric acid
1841	W. T. Brande . .	Manual, 5th ed. . .	P_2Cl_3	Proto- or sesquichloride	P_2Cl_5	Perchloride of phosphorus	$P+1\frac{1}{2}O$	Phosphorous acid .	$P+2\frac{1}{2}O$	Phosphoric acid
1848	W. T. Brande . .	Manual, 6th ed. . .	PCl_3	Protochloride of phosphorus	PCl_5	Perchloride of phosphorus	PO_3	Phosphorous acid .	PO_5	Phosphoric acid

TABLE VIII.—*continued.*

Date	Author	Work	CHLORIDES OF PHOSPHORUS: Name for Lower Chloride — Formula	Name for Lower Chloride	Name for Higher Chloride — Formula	Name for Higher Chloride	OXIDES OF PHOSPHORUS: Name for Lower Oxide — Formula	Name for Lower Oxide	Name for Higher Oxide — Formula	Name for Higher Oxide
1863	Brande and Taylor	Manual.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid .	PO_5	Phosphoric acid
1825	Berzelius and Wöhler	Lehrbuch	—	Intermediärer Chlorphosphor	—	Chlorphosphor im maximum	—	Wasserfreie phosphorichte Säure	—	Wasserfreie phosphor-äure
1835	Berzelius and Wöhler	Lehrbuch, 4th Aufgabe	PCl^3	Phosphorsuperchlorür	PCl_5	Phosphorsuperchlorid	$\overset{\cdots}{\text{P}}$	Wasserfreie phosphorichte Säure	$\overset{\cdot\cdot\cdot\cdot\cdot}{\text{P}}$	Phosphorsäure
1821	L. J. Thenard . .	Traité, 3rd ed. . .	—	Protochlorure de phosphore	—	Deutochlorure de phosphore	- -	Acide phosphoreux	—	Acide phosphorique
1830	L. J. Thenard . .	Traité, 8th ed. . .	PCl_3	Protochlorure de phosphore	PCl_5	Deutochlorure de phosphore	P_2O_3	Acide phosphoreux	P_2O_5	Acide phosphorique
1834	L. J. Thenard . .	—	PCh^3	Protochlorure de phosphore	PCh^5	Deutochlorure de phosphore	Ph^2O^3	Acide phosphoreux	Ph^2O^5	Acide phosphorique
1828 1842	Gay-Lussac . . . Graham	Cours . . . . . . Elements	— PCl_3	Terchloride of phosphorus	— PCl_5	Perchloride of phosphorus	$PO1\frac{1}{2}$ PO_3	Acide phosphoreux Acide phosphoreux	$PO2\frac{1}{2}$ PO_5	Phosphoric acid Phosphoric acid
1836	E. Mitscherlich . .	Lehrbuch	—	Liquid chloride of phosphorus	—	Solid chloride of phosphorus	—	Wasserfreie Phosphorigsäure	—	Wasserfreie Phosphorsäure
1839	J. Persoz	Chimie Moléculaire	P_2Cl_6	Chloride phosphoreux	P_2Cl_{10}	Chloride phosphorique	$\overset{\cdots}{\text{P}}$	Acide phosphoreux anhydre	$\overset{\cdot\cdot\cdot\cdot\cdot}{\text{P}}$	Acide phosphorique
1839	Daniell	Chemical Philosophy	P_2Cl_3	Sesquichloride of phosphorus	P_2Cl_5	Perchloride of phosphorus	P_2O_3	Phosphorous acid .	P_2O_5	Phosphoric acid
1843	Daniell	Chemical Philosophy	P_2Cl_3	Sesquichloride of phosphorus	P_2Cl_5	Perchloride of phosphorus	$PO1\frac{1}{2}$	Phosphorous acid .	$PO2\frac{1}{2}$	Phosphoric acid
1843	Justus v. Liebig .	Handbuch d. Chemie u. Pharmacie	—	Phosphorchlorür . .	—	Phosphorchlorid . .	P_2O_3	Phosphorige Säure	P_2O_5	Phosphorsäure
1848	Charles Gerhardt .	Système Unitaire	—	—	—	—	P^2O^3	Anhydride phosphoreux	P^2O^5	Phosphatide normal ou Anhydride phosphorique
1854	F. Abel and Bloxam	Handbook	PCl_3	Terchloride of phosphorus	PCl^5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1854	Liebig and Poggendorff	Handwörterbuch d. Chemie	PCl_3	Phosphorchlorid . .	PCl^5	Phosphor Perchlorid	PO_3	Phosphorige Säure	PO_5	Phosphorsäure
1856	Wm. Allen Miller	Elements, 1st ed. .	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1860	Wm. Allen Miller	Elements, 2nd ed. .	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous anhydride	PO_5	Phosphoric acid
1864	Wm. Allen Miller	Elements, 3rd ed. .	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	$P_2\Theta_3$	Phosphorous anhydride	$P_2\Theta_5$	Phosphoric anhydride
1874	Wm. Allen Miller (Ed. M'Leod)	Elements, 5th ed. .	PCl_3	Trichloride of phosphorus	PCl_5	Pentachloride of phosphorus	P_2O_3	Phosphorous anhydride	P_2O_6	Phosphoric anhydride
1878	Wm. Allen Miller (Ed. Groves)	Elements, 6th ed. .	PCl_3	Trichloride of phosphorus	PCl_5	Pentachloride of phosphorus	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride

1868	H. L. Buff	—	—	—	PCl^5	Phosphorchlorid	P_2O_3	Phosphorigesäure-anhydrid	P_2O_5	Phosphorsäure-anhydrid
1859	V. Regnault	Cours de Chimie	$PhCl^3$	Chlorure phosphoreux	$PhCl^5$	Perchlorure de phosphore	PhO^3	Acide phosphoreux	PhO^5	Acide phosphorique
1860	Cahours	Traité	$PhCl^3$	Protochloride of phosphorus	$PhCl^5$	Perchloride of phosphorus	PhO^3	Acide phosphoreux anhydre	PhO^5	Acide phosphorique anhydre
1861	William Odling	Manual	Cl_3P	Trichloride of phosphorus	Cl_3PCl_2	Pentachloride of phosphorus	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride
1870	William Odling	Outlines	Cl_3P	Phosphorous chloride	Cl_5P	Phosphoric chloride	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride
1865	Naquet	Principes	PCl^3	Protochloride of phosphorus	PCl^5	Perchloride of phosphorus	$P^2\Theta^3$	Anhydride phosphoreux	$P^2\Theta^5$	Anhydride phosphorique
1867	Naquet	Principes	PCl^3	Protochloride of phosphorus	PCl^5	Perchloride of phosphorus	$P^2\Theta^3$	Anhydride phosphoreux	$P^2\Theta^3$	Anhydride phosphorique
1865	A. W. Williamson	Chemistry for Students	PCl^3	Phosphorous chloride	PCl_5	Phosphoric chloride	P^2O^3	Phosphorous acid	P^2O^5	Anhydrous phosphoric acid
1873	A. W. Williamson	Chemistry for Students, 3rd ed.	PCl_3	Phosphorous chloride	PCl_5	Phosphoric chloride	P_2O_3	Phosphorous acid	P_2O_4	Phosphoric acid
1866	E. Frankland	Lecture Notes	**PCl_3**	Phosphor*ous* trichloride	**PCl_5**	Phosphoric chloride	**P_2O_3**	Phosphorous anhydride	**P_2O_5**	Phosphoric anhydride
1870	E. Frankland	Lecture Notes	**PCl_3**	Phosphor*ous* trichloride	**PCl_5**	Phosphoric chloride	**P_2O_3**	Phosphorous anhydride	**P_2O_5**	Phosphoric anhydride
1876	E. Frankland	Lecture Notes	**PCl_3**	Phosphorous chloride	**PCl_5**	Phosphoric chloride	**P_2O_3**	Phosphorous anhydride	**P_2O_5**	Phosphoric anhydride
1866	Henry Watts	Dictionary	PCl^3	Trichloride of phosphorus, or Phosphorous chloride	PCl^5	Protochloride of phosphorus, or Phosphoric chloride	P^2O^3	Phosphorous oxide	P^2O^5	Phosphoric anhydride
1881	Henry Watts	Dictionary	PCl^3	Phosphorus trichloride	PCl^5	Phosphorus pentachloride	P^2O^3	Trioxide of phosphorus	P^2O^5	Pentoxide of phosphorus
1844	Geo. Fownes (Jones and Hofmann)	Manual, 1st ed.	PCl_3	Terchloride of phosphorus	PCl_5	Perchloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1848	Geo. Fownes (Jones and Hofmann)	Manual, 2nd ed.	PCl_3	Terchloride of phosphorus	PCl_5	Perchloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1850	Geo. Fownes (Jones and Hofmann)	Manual, 3rd ed.	PCl_3	Terchloride of phosphorus	PCl_5	Perchloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1852	Geo. Fownes (Jones and Hofmann)	Manual, 4th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1854	Geo. Fownes (Jones and Hofmann)	Manual, 5th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1856	Geo. Fownes (Jones and Hofmann)	Manual, 6th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1858	Geo. Fownes (Jones and Hofmann)	Manual, 7th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1861	Geo. Fownes (Jones and Hofmann)	Manual, 8th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1863	Geo. Fownes (Jones and Hofmann)	Manual, 9th ed.	PCl_3	Terchloride of phosphorus	PCl_5	Pentachloride of phosphorus	PO_3	Phosphorous acid	PO_5	Phosphoric acid
1868	Geo. Fownes (Jones and Watts)	Manual, 10th ed.	PCl_3	Phosphorus chloride or trichloride	PCl_5	Phosphoric chloride or pentachloride	P_2O_3	Phosphorous oxide	P_2O_5	Phosphoric oxide
1873	Geo. Fownes (Watts)	Manual, 11th ed.	PCl_3	Phosphorus chloride or trichloride	PCl_5	Phosphoric chloride or pentachloride	P_2O_3	Phosphorous oxide	P_2O_5	Phosphoric oxide

TABLE VIII.—*continued.*

Date	Author	Work	CHLORIDES OF PHOSPHORUS				OXIDES OF PHOSPHORUS			
			Lower Chloride		Higher Chloride		Lower Oxide		Higher Oxide	
			Formula		Formula		Formula		Formula	
1877	Geo. Fownes (Watts)	Manual, 12th ed.	PCl_3	Phosphorus chloride or trichloride	PCl_5	Phosphoric chloride or pentachloride	P_2O_3	Phosphorous oxide	P_2O_5	Phosphoric oxide
1883	Geo. Fownes (Watts)	Manual, 13th ed.	PCl_3	Phosphorus chloride or trichloride	PCl_5	Phosphoric chloride or pentachloride	P_2O_3	Phosphorous oxide	P_2O_5	Phosphoric oxide
1869	F. S. Barff	Scientific Chemistry	PCl_3	Phosphorous chloride	PCl_5	Phosphoric chloride	P_2O_3	Phosphorous acid	P_2O_5	Phosphoric acid
1869	Bernays	Student's Chemistry	PCl_3	Phosphorous chloride	PCl_5	Phosphoric chloride	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride
1870	J. P. Cooke	Principles	PCl_3	Phosphorous chloride	PCl_5	Phosphoric chloride	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride
1870	A. Geuther	Lehrbuch	PCl^3	Phosphorchlorür	PCl^5	Phosphorchlorid	P^2O^3	Phosphorigsäure-anhydrid	P^2O^5	Phosphorsäure-anhydrid
1873	Valentin	Analysis	—	—	—	—	—	—	—	—
1872	Harcourt & Madan	Analysis	—	—	—	—	—	Phosphorus trioxide	—	Phosphorus pentoxide
1867	Rammelsberg	Grundriss	PCl^3	Phosphortrichlorid	PCl^5	Phosphorpentachlorid	P^2O^3	Phosphorigsäure-anhydrid	P^2O^5	Phosphorsäure-anhydrid
1874	H. E. Roscoe	Elementary Chem.	PCl_3	Phosphorus trichloride	PCl_5	Phosphorus pentachloride	P_2O_3	Phosphorus trioxide	P_2O_5	Phosphorus pentoxide
1878	Roscoe and Schorlemmer	Treatise	PCl_3	Trichloride of phosphorus	PCl_5	Pentachloride of phosphorus	P_2O_3	Phosphorus trioxide	P_2O_5	Phosphorus pentoxide
1875	Fittig	Anorganische Chemie	PCl^3	Phosphorchlorür	PCl^5	Phosphorchlorid	P^2O^3	Phosphorigsäure-anhydrid	P^2O^5	Phosphorsäure-anhydrid
1875	Ad. Wurtz	Chimie Moderne	PCl^3	Trichlorure de phosphore	PCl^5	Pentachlorure de phosphore	Ph^2O^3	Anhydride phosphoreux	Ph^2O^5	Anhydride phosphorique
1876	Attfield	Chemistry	—	—	—	—	P_2O_3	Phosphorous anhydride	P_2O_5	Phosphoric anhydride
1877	H. Kolbe	Lehrbuch	PCl_3	Dreifach Chlorphosphor	PCl_5	Fünfach Chlorphosphor	P_2O_3	Phosphorigsäure-anhydrid	P_2O_5	Phosphorsäure-anhydrid
1877	Hofmann	Moderne Chemie	PCl_3	Phosphorchlorid	—	—	—	—	—	—
1877	T. E. Thorpe	Inorganic Chem.	PCl_3	Trichloride of phosphorus	PCl_5	Pentachloride of phosphorus	P_2O_3	Phosphorus trioxide	P_2O_5	Phosphorus pentoxide
1878	Michaelis	—	PCl_3	Phosphorchlorür	PCl_5	Phosphorchlorid	P_2O_3	Phosphortrioxyd	P_2O_5	Phosphorpentoxyd
1879	Berthelot	Mécanique Chimique	PCl_3	Chlorure phosphoreux	$PhCl_5$	Chlorure phosphorique	PhO^3	Acide phosphoreux anhydre	PhO^5	Acide phosphorique anhydre
1880	Tilden	Chemical Philosophy	PCl^3	Phosphorus trichloride	PCl_5	Pentachloride of phosphorus	P_2O_3	Phosphorus trioxide	P_2O_5	Pentoxide of phosphorus
1882	Jul. Thomsen	Thermochemische Untersuchungen	PCl^3	Phosphorchlorür	PCl^5	Phosphorchlorid	P^2O^3	Anhydrid der phosphorigen Säure	P^2O^5	Phosphorsäure-anhydrid

TABLE IX.—HYDROGEN SALTS OF PHOSPHORUS.

Date	Author	Work	Hydric Hypophosphate		Hydric Phosphite		Hydric Orthophosphate		Hydric Pyrophosphate		Hydric Metaphosphate	
			Formula		Formula		Formula		Formula		Formula	
1787	Morveau, Lavoisier	Table of Nomenclature	—	—	—	Acide phosphoreux en dissolution	—	Acide phosphorique en dissolution	—	—	—	—
1789	Lavoisier . . .	Traité Elémentaire	—	—	—	Acide phosphoreux en dissolution	—	Acide phosphorique en dissolution	—	—	—	—
1810	Klaproth, &c. . .	Dictionnaire . .	—	—	—	Acide phosphoreux	—	Acide phosphorique liquide	—	—	—	—
1806	W. Henry . . .	Elements, 4th ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1810	W. Henry . . .	Elements, 6th ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1815	W. Henry . . .	Elements, 7th ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1818	W. Henry . . .	Elements, 8th ed.	—	Solution of hypo- or per-phosphorous acid	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1823	W. Henry . . .	Elements, 9th ed.	—	Solution of hypophosphorous acid	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1826	W. Henry . . .	Elements, 10th ed.	—	Solution of hypophosphorous acid	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1802	Th. Thomson . .	System, 1st ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Phosphoric glass or dry phosphoric acid
1807	Th. Thomson . .	System, 3rd ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Phosphoric glass
1810	Th. Thomson . .	System, 4th ed.	—	—	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Phosphoric glass
1817	Th. Thomson . .	System, 5th ed.	PO	Solution of hypophosphorous acid	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Phosphoric glass
1820	Th. Thomson . .	System, 6th ed.	—	Solution of hypophosphorous acid	HO.PO	Hydrate of phosphorous acid	—	Solution of phosphoric acid	—	—	—	Phosphoric glass

TABLE IX.—*continued.*

Date	Author	Work	Hydric Hypophosphate		Hydric Phosphite		Hydric Orthophosphate		Hydric Pyrophosphate		Hydric Metaphosphate	
			Formula		Formula		Formula		Formula		Formula	
1831	Th. Thomson	System, 7th ed.	—	—	—	A compound of phosphorous acid and water	—	Solution of phosphoric acid	—	Solution of pyrophosphoric acid	—	Phosphoric glass
1825	Th. Thomson	Attempt, &c.	—	—	—	—	—	Solution of phosphoric acid	—	—	—	—
1819	W. T. Brande	Manual, 1st ed.	P_2O	Solution of hypophosphorous acid	—	—	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1821	W. T. Brande	Manual, 2nd ed.	P_2O	Solution of hypophosphorous acid	—	Hydrophosphorous acid	—	Solution of phosphoric acid	—	—	—	Glacial phosphoric acid
1836	W. T. Brande	Manual, 4th ed.	$2P+O$	Solution of hypophosphorous acid	—	Hydrophosphorous acid	—	Solution of phosphoric acid	—	Solution of pyrophosphoric acid	—	Solution of metaphosphoric acid
1841	W. T. Brande	Manual, 5th ed.	$2P+O$	Solution of hypophosphorous acid	—	Hydrophosphorous acid	—	Terhydrate or tribasic phosphate of water	—	Deutohydrate or bibasic phosphate of water	—	Protohydrate of phosphoric acid
1848	W. T. Brande	Manual, 6th ed.	PH_2O_3	Hydrated hypophosphorous acid	$PO_3 3HO$	Hydrated phosphorous acid	PO_5 $3HO$	Terhydrate of phosphoric acid	$PO_5 2HO$	Deutohydrate of phosphoric acid	$PO_5 HO$	Metaphosphoric acid or protohydrate of phosphoric acid
1863	Brande & Taylor	Manual, 6th ed.	$PO.2HO$	Hypophosphorous acid	$PO_3 3HO$	Hydrate of phosphorous acid	PO_5 $3HO$	Terhydrate of phosphoric acid	$PO_5 2HO$	Bihydrate of phosphoric acid	$PO_5 HO$	Protohydrate of phosphoric acid
1825	Berzelius	Lehrbuch	—	—	—	Wasserhaltige Phosphorichtesäure	—	Wasserhaltige Phosphorsäure	—	—	—	—
1835	Berzelius	Lehrbuch, 4th ed.	$\dot{P}$	Unterphosphorige Säure	P^2O^3	Wasserhaltige Phosphorichtesäure	$\dddot{P}$	*a*-Phosphorsäure (wasserhaltige)	$\dddot{P}$ (P_2O_5)	*b*-Phosphorsäure	P_2O_5	Wasserhaltige *c*-Phosphorsäure
1821	L. J. Thenard	Traité, 3rd ed.	—	Dissolution de l'acide hypophosphoreux	—	Dissolution de l'acide phosphoreux	—	Acide phosphorique en dissolution	—	—	—	—
1830	L. J. Thenard	Traité, 8th ed.	$4P+3O$	Dissolution de l'acide hypophosphoreux	—	Dissolution de l'acide phosphoreux	—	Acide phosphorique en dissolution	—	—	—	—
1834	L. J. Thenard	Traité, 8th ed.	Ph^4O^3	Dissolution de l'acide hypophosphoreux	—	Dissolution de l'acide phosphoreux	—	Acide phosphorique en dissolution	—	Dissolution de l'acide paraphosphorique	—	—

[illegible]	[illegible]	Elements	PO	Solution of hypophosphorous acid	$3HO+PO_3$	Hydrate of phosphorous acid	$3HO+PO_5$	Tribasic phosphate of water	$2HO+PO_5$	Bibasic phosphate of water	$HO+PO_5$	Monobasic phosphate of water
1836	E. Mitscherlich	Lehrbuch	—	Wasserhaltige unterphosphorichte Säure	—	Wasserhaltige Phosphorichtesäure	—	Wasserhaltige Phosphorsäure	—	Wasserhaltige Paraphosphorsäure	—	Wasserhaltige Metaphosphorsäure
1839	J. Persoz	Chimie Mol.	—	Dissolution de l'acide hypophosphoreux	—	Dissolution de l'acide phosphoreux	$P^2O^5+H^6O^3$	Acide phosphorique ordinaire	$P^2O^5+H^4O^2$	Acide pyrophosphorique	$P^2O^5+H^2O$	Acide métaphosphorique
1839	Daniell	Chem. Philosophy	P_2O	Solution of hypophosphorous acid	—	Solution of phosphorous acid	—	Solution of phosphoric acid	—	Solution of pyrophosphoric acid	P_2O_5+HO	Glacial phosphoric acid
1843	Daniell	Chem. Philosophy	P_2O	Solution of hypophosphorous acid	$PO_{1\frac{1}{2}}$	Solution of phosphorous acid	$PO_{2\frac{1}{2}}+1\frac{1}{2}HO$	Tritohydrate of phosphoric acid	$PO_{2\frac{1}{2}}+HO$	Deutohydrate of phosphoric acid	$2PO_{2\frac{1}{2}}+HO$	Protohydrate of phosphoric acid
1843	J. Liebig	Handbook	P_2O	Lösung von unterphosphorige Säure	P_2O_3 $3H_2O$	Wasserhaltige Phosphorigesäure	P_2O_5 $3H_2O$	Hydrat der gew. Phosphorsäure	P_2O_5 $2H_2O$	Hydrat der Pyrophosphorsäure	P_2O_5 H_2O	Hydrat der Metaphosphorsäure
1848	Gerhardt	Syst. Unitare	PH_2O_2H	Acide hypophosphoreux	—	Acide phosphoreux	PO^4H^3	Acide phosphorique	—	Acide pyrophosphorique	PO^3H	Acide métaphosphorique
1851	Abel and Bloxam	Handbook	$3HO.PO$	Hydrate of hypophosphorous acid	$PO_3 3HO$	Hydrate of phosphorous acid	$3HO.PO_5$	Tribasic phosphoric acid	$2HO.PO_5$	Pyrophosphoric acid	$HO.PO_5$	Monobasic phosphoric acid
1854	Liebig and Poggendorff	Dictionary	$2HO.PO$	Unterphosphorige Säure	$3HO.PO_3$	Phosphorigesäure hydrat	$3HO.PO_5$	Dreibasische Phosphorsäure-hydrat	$2HO.PO_5$	Zweibasische Phosphorsäurehydrat	$HO.PO_5$	Einbasische Phosphorsäure hydrat
1856	W. A. Miller	Elements, 1st ed.	$HO.PH_2O_3$	Hydrate of hypophosphorous acid	$2HO.PO_3HO$	Hydrate of phosphorous acid	$3HO.PO_5$	Tritohydrate of phosphoric acid	$2HO.PO_5$	Deutohydrate of phosphoric acid	$HO.PO_5$	Protohydrate of phosphoric acid
1860	W. A. Miller	Elements, 2nd ed.	$HO.PH_2O_3$	Hypophosphorous acid	$3HO.PO_3$	Phosphorous acid	$3HO.PO_5$	Tritohydrate of phosphoric acid	$2HO.PO_5$	Deutohydrate of phosphoric acid	$HO.PO_5$	Protohydrate of phosphoric acid
1864	W. A. Miller	Elements, 3rd ed.	HPH_2O_2	Hypophosphorous acid	H_2PHO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1874	W. A. Miller, Ed. McLeod	Elements, 5th ed.	HPH_2O_2	Hypophosphorous acid	H_2PHO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1878	W. A. Miller, Ed. Groves	Elements, 6th ed.	HPH_2O_2	Hypophosphorous acid	H_2PHO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1868	H. L. Buff	—	PH_2O_3	Unterphosphorige Säure	PO_3H_3	Phosphorige Säure	$PO(OH)_3$	Phosphorsäure	$P_2O_7H_4$	Pyrophosphorsäure	PO_3H	Metaphosphorsäure
1859	Regnault	Cours de Chimie	PhO	Acide hypophosphoreux	PhO^3 3HO	Acide phosphoreux hydraté	PhO^5 3HO	Acide phosphorique trihydraté	PhO^5 2HO	Acide phosphorique dihydraté	PhO^5HO	Acide phosphorique monohydraté
1860	Cahours	Traité	PhO. 3HO	Acide hypophosphoreux hydraté	PhO^3 3HO	Acide phosphoreux hydraté	PhO^5 3HO	Acide phosphorique	PhO^5 2HO	Acide pyrophosphorique	PhO^5HO	Acide métaphosphorique
1861	W. Odling	Manual	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1870	W. Odling	Outlines	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1865	Naquet	Principes	$PH^3\theta^2$	Acide hypophosphoreux	$PH^3\theta^3$	Acide phosphoreux	$PH^3\theta^4$	Acide phosphorique	$P^2H^4\theta^7$	Acide pyrophosphorique	$PH\theta^3$	Acide métaphosphorique

TABLE IX.—*continued.*

Date	Author	Work	Hydric Hypophosphate		Hydric Phosphite		Hydric Orthophosphate		Hydric Pyrophosphate		Hydric Metaphosphate	
			Formula		Formula		Formula		Formula		Formula	
1867	Naquet	Principes	$PH^3\Theta^2$	Acide hypophosphoreux	$PH^3\Theta^3$	Acide phosphoreux	$PH^3\Theta^4$	Acide phosphorique	$P^2H^4\Theta^7$	Acide pyrophosphorique	$PH\Theta^3$	Acide métaphosphorique
1865	Williamson	Chemistry	PO^2H^3	Hypophosphorous acid	—	—	PO^4H^3	Trihydric phosphate	$P^2O^7H^4$	Tetrahydric diphosphate	$(PO^3H)n$	Metaphosphoric acid
1873	Williamson	Chemistry, 3rd ed.	PO_2H_3	Hydric phosphite	PO_3H_3	Hydric phosphite	PO_4H_3	Hydric phosphate	$P_2O_7H_4$	Tetrahydric diphosphate	$(PO^3H)n$	Hydric metaphosphate
1866	Frankland	Lecture Notes	POH_2Ho	Hypophosphorous acid	$POHHo_2$	Phosphorous acid	$POHo_3$	Phosphoric acid	$P_2O_3Ho_4$	Pyrophosphoric acid	PO_2Ho	Metaphosphoric acid
1870	Frankland	Lecture Notes	POH_2Ho	Hypophosphorous acid	$POHHo_2$	Phosphorous acid	$POHo_3$	Phosphoric acid	$P_2O_3Ho_4$	Pyrophosphoric acid	PO_2Ho	Metaphosphoric acid
1876	Frankland	Lecture Notes	$POHHo$	Hypophosphorous acid	$POHHo_2$	Phosphorous acid	$POHo_3$	Phosphoric acid	$P_2O_3Ho_4$	Pyrophosphoric acid	PO_2Ho	Metaphosphoric acid
1866	Henry Watts	Dictionary	H^3PO^2	Hypophosphorous acid	H^3PO^3	Phosphorous acid	H^3PO^4	Phosphoric acid	$H^4P^2O^7$	Pyrophosphoric acid	HPO^3	Metaphosphoric acid
1881	Henry Watts	Dictionary	H^3PO^2	Hypophosphorous acid	H^3PO^3	Phosphorous acid	H^3PO^4	Phosphoric acid	$H^4P^2O^7$	Pyrophosphoric acid	HPO^3	Metaphosphoric acid
1844	George Fownes (Jones and Hoffmann)	Manual, 1st ed.	PO	Solution of hypophosphorous acid	$3HO+PO_3$	Hydrated phosphorous acid	—	Tribasic hydrate of phosphoric acid	—	Bibasic hydrate of phosphoric acid (or Pyrophosphoric acid)	—	Monobasic hydrate of phosphoric acid (or Metaphosphoric acid)
1848	George Fownes (Jones and Hoffmann)	Manual, 2nd ed.	PO	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1850	George Fownes (Jones and Hoffmann)	Manual, 3rd ed.	PO	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1352	Geoorge Fownes (Jones and Hoffmann)	Manual, 4th ed.	PO.	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1854	George Fownes (Jones and Hoffmann)	Manual, 5th ed.	PO.	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1856	George Fownes (Jones and Hoffmann)	Manual, 6th ed.	PO.	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1858	George Fownes (Jones and Hoffmann)	Manual, 7th ed.	PO.	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1861	George Fownes (Jones and Hoffmann)	Manual, 8th ed.	PO	Solution of hypophosphorous acid	$3HO.PO_3$	Hydrated phosphorous acid	$3HO.PO_5$	Tribasic hydrate of phosphoric acid	—	Bibasic hydrate of phosphoric acid	—	Monobasic hydrate of phosphoric acid

[illegible]	George Fownes (Jones and Hoffmann)	Manual, 9th ed.	—	Hydrate of hypophosphorous acid	—	Hydrated phosphorous acid	—	Hydrate of tribasic phosphoric acid	—	Hydrate of bibasic phosphoric acid	—	Hydrate of monobasic phosphoric acid
1868	(Jones & Watts)	Manual, 10th ed.	PO_2H_3	Hypophosphorous acid	PO_3H_3	Phosphorous acid	PO_4H_3	Orthophosphoric acid	$P_2O_7H_4$	Pyrophosphoric acid	PO_3H	Metaphosphoric acid
1873	(Watts)	Manual, 11th ed.	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1877	(Watts)	Manual, 12th ed.	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1883	(Watts)	Manual, 13th ed.	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1869	Barff	Chemistry . . .	H_3PO_2	Hydric hypophosphite	H_3PO_3	Hydric phosphite	H_3PO_4	Trihydric phosphate	$H_4P_2O_7$	Tetrahydric diphosphate	HPO_3	Hydric metaphosphate
1869	Bernays	Student's Chem.	HPO_2H_2	Hypophosphorous acid	H_2PHO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1870	J. P. Cooke . .	Principles . .	$HOPO$ H_2	Hypophosphorous acid	H_2O_2 $PO.H$	Phosphorous acid	H_3O_3PO	Orthophosphoric acid	H_4O_4 PO_2P	Pyrophosphoric acid	$HOPO_2$	Metaphosphoric acid
1870	A. Geuther . .	Lehrbuch . . .	PH^3O^2	Unterphosphorige Säure	PO^3H^3	Phosphorigsäure-hydrat	PO^4H^3	Trihydroxyphosphorsäure	$P^2O^7H^4$	Pyrophosphorsäure	PO^3H	Monohydroxyphosphorsäure
1873	Valentin . . .	Analysis . . .	POH_2 Ho	Hypophosphorous acid	POH Ho_2	Phosphorous acid	$POHo_3$	Phosphoric acid	P_2O_3 Ho_4	Pyrophosphoric acid	PO_2Ho	Metaphosphoric acid
1872	Harcourt & Madan	Analysis . . .	—	—		—		Hydrogen orthophosphate		Hydrogen pyrophosphate	—	Hydrogen metaphosphate
1867	Rammelsberg .	Grundriss . .	H^3PO^2	Unterphosphorige Säure	H^3PO^3	Phosphorige Säure	H^3PO^4	Phosphorsäure	$H^4P^2O^7$	Pyrophosphorsäure	HPO^3	Metaphosphorsäure
1874	H. E. Roscoe . .	Elementary Chemistry	HPH_2O_2	Hydrogen hypophosphite	H_3PO_3	Hydrogen phosphite	H_3PO_4	Trihydrogen phosphate	$H_4P_2O_7$	Tetrahydrogen phosphate	HPO_3	Monohydrogen phosphate
1878	Roscoe & Schorlemmer	Treatise . . .	$PH(OH)_2$	Hypophosphorous acid	$P(OH)_3$	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1875	Rud. Fittig . .	Anorganische Chemie	PO^2H^3	Unterphosphorige Säure	PO^3H^3	Phosphorige Säure	PO^4H^3	Phosphorsäure	$P^2O^7H^4$	Pyrophosphorsäure	PO^3H	Metaphosphorsäure
1875	Ad. Wurtz . . .	Chimie Moderne	PhH^3O^2	Acide hypophosphoreux	PhH^3O^3	Acide phosphoreux	PhH^3O^4	Acide (ortho) phosphorique	$Ph^2O^7H^4$	Acide pyrophosphorique	PhO^3H	Acide métaphosphorique
1876	Attfield	Chemistry . .	HPH_2O_2	Hypophosphorous acid	H_2PHO_3	Phosphorous acid	H_3PO_4	Phosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1877	Hermann Kolbe .	Lehrbuch . .	PH_3O_2	Unterphosphorige Säure	PO_3H_3	Phosphorige Säure	POO_3H_3	Dreibasische Phosphorsäure	$P_2O_7H_4$	Vierbasische Diphosphorsäure	PO_2OH	Einbasische Phosphorsäure
1877	A. W. Hofmann .	Moderne Chemie	H_3PO_2	Unterphosphorige Säure	H_3PO_3	Phosphorigesäure	H_3PO_4	Phosphorsäure	—	—	—	—
1877	T. E. Thorpe . .	Inorganic Chemistry	PH_3O_2	Hypophosphorous acid	PH_3O_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1878	Michaelis . . .	Lehrbuch . . .	PO_2H_3	Unterphosphorige Säure	PO_3H_3	Phosphorigesäure	PO_4H_3	Orthophosphorsäure	$P_2O_7H_4$	Pyrophosphorsäure	PO_3H	Metaphosphorsäure
1879	Berthelot . . .	Mécanique Chimique	$PhO,$ $3HO$	Acide hypophosphoreux	PhO^3 $3HO$	Acide phosphoreux	PhO^5 $3HO$	Acide phosphorique hydraté	PhO^5 $2HO$	Acide pyrophosphorique	PhO^5 HO	Acide métaphosphorique
1880	Tilden	Chemical Philosophy	H_3PO_2	Hypophosphorous acid	H_3PO_3	Phosphorous acid	H_3PO_4	Orthophosphoric acid	$H_4P_2O_7$	Pyrophosphoric acid	HPO_3	Metaphosphoric acid
1882	Julius Thomsen .	Thermochemische Untersuchungen	PO^2H^3	Unterphosphorige Säure	PO^3H^3	Phosphorige-säure	PO^4H^3	Orthophosphorsäure	$P^2O^7H^4$	Paraphosphorsäure	PO^3H	Metaphosphorsäure

Table X.—Phosphates of Soda.

Date	Author	Work	Trisodic Phosphate: Formula	Trisodic Phosphate	Hydrodisodic Phosphate: Formula	Hydrodisodic Phosphate	Dihydrosodic Phosphate: Formula	Dihydrosodic Phosphate
1787	De Morveau, Lavoisier, &c.	Table of Nomenclature	—	—	—	Phosphate de soude . .	—	—
1789	Lavoisier	Traité Elémentaire	—	—	—	Phosphate de soude . .	—	—
1810	Klaproth, Wolff, &c.	Dictionnaire . . .	—	—	—	Phosphate de soude . .	—	Phosphate acide de soude
1806	Wm. Henry . . .	Elements, 4th ed. .	—	—	—	Phosphate of soda . .	—	—
1810	Wm. Henry . . .	Elements, 6th ed. .	—	—	—	Phosphate of soda . .	—	—
1815	Wm. Henry . . .	Elements, 7th ed. .	—	—	—	Phosphate of soda . .	—	—
1818	Wm. Henry . . .	Elements, 8th ed. .	—	Subphosphate of soda .	—	Phosphate of soda . .	—	Biphosphate of soda
1823	Wm. Henry . . .	Elements, 9th ed. .	$NaO.PO_5$	Simple phosphate of soda	$NaO2PO_5$	Biphosphate of soda .	$NaO4PO_5$	Quadriphosphate of soda
1826	Wm. Henry . . .	Elements, 10th ed. .	$NaO.PO_5$	Simple phosphate of soda	$NaO2PO_5$	Biphosphate of soda (phosphate of soda)	$NaO4PO_5$	Quadriphosphate of soda
1802	Thomas Thomson .	System of Chem., 1st ed.	—	—	—	Phosphat of soda . .	—	Superphosphat of soda
1807	Thomas Thomson .	System of Chem., 3rd ed.	—	—	—	Phosphate of soda . .	—	Superphosphate of soda
1810	Thomas Thomson .	System of Chem., 4th ed.	—	—	—	Phosphate of soda . .	—	Superphosphate of soda
1817	Thomas Thomson .	System of Chem., 5th ed.	—	Subphosphate (of potash)	—	Phosphate of soda . .	—	Superphosphate of soda
1820	Thomas Thomson .	System of Chem., 6th ed.	—	Subphosphate (of potash)	—	Phosphate of soda . .	—	Biphosphate of soda
1831	Thomas Thomson .	System of Chem., 7th ed.	—	Subphosphate (of potash)	$NaOPO2\frac{1}{2}13HO$	Phosphate of soda . .	$NaO2PO2\frac{1}{2}4HO.$	Biphosphate of soda
1825	Thomas Thomson .	Attempt, &c. . .	—	—	$NaO.PO_5 12HO$	Phosphate of soda . .	$NaO2PO_5 3\frac{1}{2}HO.$	Biphosphate of soda
1819	Wm. Thos. Brande .	Manual, 1st ed. .	—	—	$NaO.PO_5$	Phosphate of soda . .	—	—
1821	Wm. Thos. Brande .	Manual, 2nd ed. .	—	—	$NaO.PO_5$	Phosphate of soda . .	$NaO2PO_5$	Biphosphate of soda
1836	Wm. Thos. Brande .	Manual, 4th ed. .	$(NaO)1\frac{1}{2}PO2\frac{1}{2}$	Subphosphate of soda .	$NaO.PO2\frac{1}{2}$	Phosphate of soda . .	$NaO2PO2\frac{1}{2}$	Biphosphate of soda
1841	Wm. Thos. Brande .	Manual, 5th ed. .	$(SoO)1\frac{1}{2}PO2\frac{1}{2}$ 12HO	Subphosphate of soda .	$SoO.PO2\frac{1}{2}$	Phosphate of soda . .	$SoO(PO2\frac{1}{2})_2 4HO$	Biphosphate of soda
1848	Wm. Thos. Brande .	Manual, 6th ed. .	$3NaO,cPO_5+24HO$	Subphosphate of soda .	$2NaO,HO,cPO_5+24HO$	Phosphate of soda . .	$NaO,2HO,cPO_5+2HO$	Phosphate of soda and water
1863	Brande & Taylor .	Manual	$3(NaO),HO_5$	Subphosphate of soda .	$2(NaO), HO,PO_5$	Phosphate of soda . .	$NaO,2(HO),PO_5$	Biphosphate of soda
1825	Berzelius, H. Wöhler	Lehrbuch	—	—	—	Phosphorsaures Natron	—	Zweifach phosphorsaures Natron
1835	Berzelius, H. Wöhler	Lehrbuch, 4th ed. .	$\dot{Na}^3\dddot{\overline{P}}$	Basisches phosphorsäures Natron	$\dot{Na}^2\dddot{\overline{P}}$	Neutrales c-phosphorsaures Natron	$(\dot{Na}\dot{H}^2)+\dddot{\overline{P}}$	Zweifach c-phosphorsaures Natron
1821	L. J. Thenard . .	Traité, 3rd ed. . .	—	Sousphosphate de soude	—	Phosphate neutre de soude	—	Phosphate acide de soude
1830	L. J. Thenard . .	Traité, 8th ed. . .	?	Sousphosphate de soude	$NaO_2P_2O_5 24H_2O$	Phosphate neutre de soude	—	Phosphate acide de soude
1834	L. J. Thenard . .	Traité, 6th ed. . .	$3NaO,PO^5$	Phosphate de soude sesquibasique	$2NaO,P^2O^5+25H_2O$	Phosphate neutre de soude	$NaO,P^2O^5+4H^2O$	Biphosphate de soude

1828	Gay-Lussac . . .	Cours	1½NaO.PO2½	Sesquiphosphate de soude	NaOPO2½	Phosphate de soude .	NaO2PO2½	Biphosphate de soude
1842	Graham	Elements	$3NaO.PO_5 + 24HO$	Subphosphate of soda .	$HO,2NaO.PO_5 + 24HO$	Phosphate of soda .	$2HO,NaoPO_5 - + 2HO$	Biphosphate of soda
1836	E. Mitscherlich . .	Lehrbuch	—	Basisch phosphorsäures Natron	—	Phosphorsaures Natron	—	Saures phosphorsaures Natron
1839	J. Persoz	Chimie Moléculaire	$P^2O^5+3Na^2O$	Phosphate sesquisodique	$P^2O^5+2Na^2O$	Phosphate neutre de soude	$P^2O^5+Na^2O$	Biphosphate de soude
1839	Daniell	Chem. Philosophy .	—	—	—	—	—	—
1843	Daniell	Chem. Philosophy .	$3NaO.P_2O_5$	Tribasic phosphate of soda	$2NaO.HO.P_2O_5$	Phosphate of soda	$NaO2HOP_2O_5$	Biphosphate of soda
1843	J. Liebig	Handbuch	$3NaO.P_2O_5$	Basisch phosphorsäures Natron	$2NaO,P_2O_5,H_2O + 24H_2O$	Phosphorsaures Natron	$NaO,P_2O_5, 2H_2O.$	Saures phosphorsaures Natron
1848	C. Gerhardt . . .	Système Unitaire .	PO_4Na_3	Phosphate de soude neutre	PO^4HNa^2	Surphosphate de soude	PO^4H^2Na	Phosphate de soude acide
1854	Abel and Bloxam .	Handbook. . . .	$3NaO.PO_5$	Triphosphate of soda	$2NaO.HO.PO_5$	Phosphate of soda . .	$NaO.2HO.PO^5$	Acide phosphate of soda
1854	Liebig and Poggendorff	Dictionary . . .	$3NaO.cPO_5$	Basisches phosphorsäures Natron	$2NaO.HOcPO_5$	Neutrales c-phosphorsaures Natron	$NaO.2HOcPO_5$	Saures c-phosphorsaures Natron
1856	W. A. Miller . . .	Elements, 1st ed. .	$3NaO,PO_5$	Neutral tribasic phosphate of soda	$2NaO,HO,PO_5$	Phosphate of soda .	NaO,HO,PO_5	Biphosphate of soda
1860	W. A. Miller . . .	Elements, 2nd ed. .	$3NaO,PO_5$	Neutral tribasic phosphate of soda	$2NaO,HO,PO_5$	Phosphate of soda .	NaO,HO,PO	Biphosphate of soda
1864	W. A. Miller . . .	Elements, 3rd ed. .	Na_3PO_4	Normal tribasic phosphate of soda	Na_2HPO_4,	Phosphate of soda .	NaH_2PO_4	Biphosphate of soda
1874	W. A. Miller and Ed. McLeod	Elements, 4th ed. .	$Na_3PO_4 12H_2O$	Trisodic phosphate .	$Na_2HPO_4, 12H_2O$	Hydric disodic phosphate	NaH_2PO_4,H_2O	Sodic dihydric phosphate
1878	W. A. Miller and Ed. Groves	Elements, 5th ed. .	$Na_3PO_4 12H_2O$	Trisodic phosphate .	$Na_2HPO_4, 12H_2O$	Hydric disodic phosphate	NaH_2PO_4,H_2O	Sodic dihydric phosphate
1868	H. L. Buff . . .	—	PO_4Na_3	Natrium phosphat .	$PO_4Na_2H + 12H_2O$	Halbsaures Natrium-phosphat	$PO_4NaH_2+H_2O$	Saures natrium Phosphat
1859	V. Regnault . . .	Cours de Chimie .	$3NaO.PhO^5$	—	$2NaO.HO.PhO_5$	—	$NaO2HOPhO^5$	—
1860	Cahours	Traité	$PhO^5,3NaO$	—	$PhO_5.(2NaO, HO)$	—	$PhO^5(NaO, 2HO)$	—
1861	Odling	Manual	Na_3PO_4	Trimetallic or normal phosphate of soda	Na_2HPO_4	Bimetallic or monacid phosphate of soda	NaH_2PO_4	Monometallic or biacid phosphate of soda
1870	Odling	Outlines	Na_3PO_4	Trisodium phosphate	Na_2HPO_4	Disodium phosphate .	NaH_2PO_4	Monosodium phosphate
1865	Naquet	Principes	—	Phosphate neutre de sodium	$P\Theta\left\{\begin{array}{l}\Theta H\\ONa\\ONa\end{array}\right.$	Phosphate acide de sodium	—	Phosphate acide de sodium
1867	Naquet	Principes	—	Phosphate neutre de sodium	$P\Theta\left\{\begin{array}{l}\Theta H\\ONa\\ONa\end{array}\right.$	Phosphate acide de sodium	—	Phosphate acide de sodium
1865	Williamson . . .	Chemistry, 1st ed.	—	Normal sodic phosphate	—	Hyd ro disodi phosphate	—	Dihydrodisodic phosphate
1873	Williamson . . .	Chemistry, 2nd ed.	Na_3PO_4	Sodic phosphate . .	HNa_2PO_4	Hydro disodic phosphate	H_2NaPO_4	Dihydrodisodic phosphate
1866	Frankland . . .	Lecture Notes, 1st ed.	$PONao_3$	Trisodic phosphate .	$POHoNao_2$	Hydric disodic phosphate	$POHo_2Nao$	Dihydric sodic phosphate
1870	Frankland . . .	Lecture Notes, 2nd ed.	$PONao_3$	Trisodic phosphate .	$POHoNao_2, 12OH_2$	Hydric disodic phosphate	$POHo_2Nao$	Dihydric sodic phosphate

TABLE X.—*continued.*

Date	Author	Work	Trisodic Phosphate		Hydrodisodic Phosphate		Dihydrosodic Phosphate	
			Formula		Formula		Formula	
1876	Frankland . . .	Lecture Notes . .	$PONao_3$	Trisodic phosphate .	$POHoNao_2, 12OH_2$	Hydric disodic phosphate	$POHo_2Nao$	Dihydric sodic phosphate
1866	Henry Watts . .	Dictionary . . .	Na^3PO^4	Trisodic orthophosphate	Na^2HPO^4	Disodic orthophosphate	NaH_2PO_4	Monosodic orthophosphate
1881	Henry Watts . .	Dictionary . . .	Na^3PO^4	Trisodic orthophosphate	Na^2HPO^4	Disodic orthophosphate	NaH_2PO_4	Monosodic orthophosphate
1844	Geo. Fownes (Jones and Hoffmann)	Manual, 1st ed. .	$3NaO,PO_5+24HO$	Subphosphate of soda	$2NaO,HO,PO_5+24HO$	Phosphate of soda . .	$NaO,2HO.PO_5+2HO$	Super- or biphosphate of soda
1848	Geo. Fownes (Jones and Hoffmann)	Manual, 2nd ed. .	$3NaO.PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO$	Super- or biphosphate of soda
1850	Geo. Fownes (Jones and Hoffmann)	Manual, 3rd ed. .	$3NaO,PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO$	Super- or biphosphate of soda
1852	Geo. Fownes (Jones and Hoffmann)	Manual, 4th ed. .	$3NaO.PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO$	Super- or biphosphate of soda
1854	Geo. Fownes (Jones and Hoffmann)	Manual, 5th ed. .	$3NaO.PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO,2HO.PO_5+2HO$	Super- or biphosphate of soda
1856	Geo. Fownes (Jones and Hoffmann)	Manual, 6th ed. .	$3NaO.PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO$	Super- or biphosphate of soda
1858	Geo. Fownes (Jones and Hoffmann)	Manual, 7th ed. .	$3NaO.PO_5+24HO$	Subphosphate of soda	$2NaOHOPO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO$	Super- or biphosphate of soda
1861	Geo. Fownes (Jones and Hoffmann)	Manual, 8th ed. .	$3NaO.PO_5+24H_2O$	Subphosphate of soda	$2NaO.HO.PO_5+24HO$	Phosphate of soda . .	$NaO2HOPO_5+2HO$	Super- or biphosphate of soda
1863	Geo. Fownes (Jones and Hoffmann)	Manual, 9th ed. .	$3NaO PO_5+24HO$	Subphosphate of soda	$2NaO HO.PO_5+24HO$	Phosphate of soda . .	$NaO.2HO.PO_5+2HO.$	Super- or biphosphate of soda
1868	Geo. Fownes (Jones and Watts)	Manual, 10th ed. .	$PO_4Na_3 12OH_2$	Trisodic orthophosphate	$PO_4Na_2H,12OH_2$	Disodiohydric phosphate	PO_4NaH_2,OH_2	Super- or biphosphate of soda
1873	Geo. Fownes (Watts)	Manual, 11th ed. .	$Na_3PO_4 12H_2O$	Trisodic orthophosphate	$Na_2HPO_4 12H_2O$	Disodiohydric phosphate	$NaH_2PO_4H_2O$	Monosodic orthophosphate
1877	Geo. Fownes (Watts)	Manual, 12th ed. .	$Na_3PO_4 12H_2O$	Trisodic phosphate .	$Na_2HPO_4 12H_2O$	Disodiohydric phosphate	$NaH_2PO_4H_2O$	Monosodic orthophosphate
1833	Geo. Fownes (Watts)	Manual, 13th ed. .	$Na_3PO_4 12H_2O$	Trisodic orthophosphate	$Na_2HPO_4 12H_2O$	Disodic orthophosphate	$NaH_2PO_4H_2O$	Monosodic orthophosphate
1869	Barff	Chemistry	Na_3PO_4	Trisodic phosphate .	Na_2HPO_4	Hydro-disodic phosphate	NaH_2PO_4	Dihydro sodic phosphate
1869	Bernays	Student's Chemistry	Na_3PO_4	Trisodium orthophosphate	Na_2HPO_4	Disodium hydrogen phosphate	NaH_2PO_4	—
1870	J. P. Cooke . . .	Principles	Na_3O_3PO	Neutral phosphate of soda	HNa_2O_3PO	Acid sodic phosphate .	H_2NaO_3PO	Acid sodic phosphate
1870	A. Geuther . . .	Lehrbuch	$PO^4Na^3+12OH^2$	Neutrales Natrium-phoshat	$PO^4HNa^2+12OH^2$	Saures natrium-Phosphat	$PO^4H^2Na+OH^2$	Saures natrium-Phosphat
1873	Valentin	Analysis	$PO.Nao_3$	Normal sodic phosphate	$POHoNao_2$	Normal monohydric sodic phosphate	$PO.Ho_2Nao$	Normal dihydric sodic phosphate
1872	Harcourt & Madan	Analysis	—	Sodium phosphate . .	—	Hydrogen and sodium phosphate	—	—
1867	Rammelsberg . .	Grundriss	Na^3PO^4	Normal phosphat des Natrons	HNa^2PO^4	Monophosphat des Natrons	H^2NaPO^4	Diphosphat des Natrons

1874	H. E. Roscoe	Elementary Chemistry	Na_3PO_4 $+12H_2O$	Trisodium phosphate	HNa_2PO_4 $+12H_2O$	Hydrogen disodium phosphate	$H_2NaPO_4+H_2O$	Dihydrogen sodium phosphate
1878	Roscoe & Schorlemmer	Chemistry	Na_3PO_4 $+12H_2O$	Trisodium phosphate	HNa_2PO_4 $+12H_2O$	Hydrogen disodium phosphate	$H_2NaPO_4+H_2O$	Dihydrogen sodium phosphate
1875	Fittig	Anorganische Chemie	$PO^4Na^3+12H^2O$	Neutrales phosphorsaures Natrium	PO^4HNa^2 $+12H^2O$	Einfach saures phosphorsaures Natron	$PO^4H^2Na+H^2O$	Zweifach saures phosphorsaures Natron
1875	Ad. Wurtz	Chimie Moderne	$PO^4Na^3+12H^2O$	Phosphate trisodique	PO^4HNa^2 $+12H^2O$	Phosphate disodique	PO^4NaH^2 $+2H^2O$	Phosphate monosodique
1876	Attfield	Chemistry	—	—	Na_2HPO_4	Phosphate of sodium	NaH_2PO_4	Acid phosphate of sodium
1877	Kolbe	Lehrbuch	POO_3Na_3	Neutrales phosphorsaures Natron	POO_3Na_2H	Einfach saures phosphorsaures Natron	POO_3NaH_2	Zweifach saures phosphorsaures Natron
1877	Hofmann	Moderne Chemie	—	—	—	—	—	—
1877	T. E. Thorpe	Inorganic Chemistry	Na_3PO_4	Trisodium orthophosphate	Na_2HPO_4	Disodium hydrogen phosphate	NaH_2PO_4	Monosodium dihydrogen phosphate
1878	Michaelis	Lehrbuch	Na_3PO_4	Neutrales phosphorsaures Natron	Na_2HPO_4	Einfach saures phosphorsaures Natron	NaH_2PO_4	Zweifach saures phosphorsaures Natron
1879	Berthelot	Mécanique Chimique	—	—	—	—	—	—
1880	Tilden	Chemical Philosophy	Na_3PO_4	—	Na_2HPO_4	—	NaH_2PO_4	—
1882	Jul. Thomsen	Thermochemische Untersuchungen	—	—	—	—	—	—

Table XI.—Chlorides of Copper.

Date	Author	Work	Names for Lower Chloride		Names for Higher Chloride	
			Formula		Formula	
1787	Lavoisier, Berthollet, Morveau, Fourcroy	Méthode de Nomenclature Chimique	—	—	—	Muriate de cuivre
1819	W. T. Brande	Chemistry, 1st ed.	$CuCl$	Chloride of copper	$CuCl_2$	Bichloride of copper
1848	W. T. Brande	Chemistry, 6th ed.	Cu_2Cl	Dichloride of copper	$CuCl$	Protochloride of copper
1863	Brande and Taylor	Chemistry	Cu_2Cl	Subchloride (or dichloride) of copper	$CuCl$	Chloride of copper
1802	Th. Thomson	System, 1st ed.	—	Muriate of copper	—	Oxymuriate
1810	Th. Thomson	System, 4th ed.	Cu_2Cl	Muriate of copper	$CuCl$	Oxymuriate of copper
1817	Th. Thomson	System, 6th ed.	$CuCl$	Protochloride of copper	$CuCl_2$	Perchloride of copper
1825	Th. Thomson	Attempt, &c.	Cu_2Cl	Protochloride of copper	$CuCl$	Deutochloride of copper
1831	Th. Thomson	System, 7th ed.	Cu_2Cl	Subchloride of copper	$CuCl$	Chloride of copper
1827	Thénard	Traité de Chimie, 5th ed.	$CuCl_2$	Protochlorure de cuivre	$CuCl_4$	Chlorure de cuivre
1828	Gay-Lussac	Cours de Chimie	—	Protochlorure de cuivre	—	Perchloride de cuivre
1842	Turner	Elements of Chem., 7th ed.	Cu_2Cl	Dichloride of copper	$CuCl$	Chloride of copper
1842	Graham	Elements	Cu_2Cl	Subchloride of copper	$CuCl$	Chloride of copper
1851	Gmelin (Watts)	Handbook	—	Dichloride or cuprous chloride	—	Protochloride or cupric chloride
1851	Regnault	Cours	Cu_2Cl	Chlorure de cuivre	$CuCl$	Protochlorure de cuivre
1856	W. A. Miller	Elements, 1st ed.	Cu_2Cl	Dichloride of copper	$CuCl$	Chloride of copper
1860	W. A. Miller	Elements, 2nd ed.	Cu_2Cl	Subchloride of copper	$CuCl$	Chloride of copper
1864	W. A. Miller	Elements, 3rd ed.	$CuCl$ or Cu_2Cl	Cupreous chloride	$CuCl_2$ or $CuCl$	Cupric chloride
1868	W. A. Miller	Elements, 4th ed.	Cu_2Cl_2	Cupreous chloride or subchloride	$CuCl_2$	Cupric chloride

TABLE XI.—*continued.*

Date	Author	Work	Names for Lower Chloride: Formula	Names for Lower Chloride	Names for Higher Chloride: Formula	Names for Higher Chloride
1874	W. A. Miller	Elements, 5th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1852	Fownes (B. Jones & Hofmann)	Manual, 4th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1854	Fownes (B. Jones & Hofmann)	Manual, 5th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1856	Fownes (B. Jones & Hofmann)	Manual, 6th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1858	Fownes (B. Jones & Hofmann)	Manual, 7th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1861	Fownes (B. Jones & Hofmann)	Manual, 8th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1863	Fownes (B. Jones & Hofmann)	Manual, 9th ed.	Cu_2Cl_2	Subchloride of copper	$CuCl$	Chloride of copper
1868	Fownes (B. Jones & Watts)	Manual, 10th ed.	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Cupric chloride
1873	Fownes (Watts)	Manual, 11th ed.	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Cupric chloride
1883	Fownes (Watts)	Manual, 13th ed.	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Cupric chloride
1865	Bernays	Notes	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Protochloride of copper
1865	Naquet	Principes	Cu_2Cl_2	Protochlorure de cuivre	$CuCl_2$	Bichlorure de cuivre
1859	Rose	Chem. Analyt.	Cu_2Cl_2	Protochlorure de cuivre	$CuCl_2$	Bichlorure de cuivre
1869	Harcourt and Madan	Pract. Chem.	Cu_2Cl_2	Protochloride of copper	$CuCl_2$	Perchloride of copper
1863	Fresenius	Analysis	Cu_2Cl_2	Subchloride of copper	$CuCl_2$	Chloride of copper
1872	Fresenius	Analysis	Cu_2Cl_2	Subchloride of copper	$CuCl_2$	Chloride of copper
1847	Laurent	Method	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1866	Frankland	Lecture Notes	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1870	Odling	Outlines	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1870	J. P. Cooke	Chem. Philosophy	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1873	Williamson	Chemistry	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1883	Bloxam	Chemistry, 5th ed.	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1881	Attfield	Pharm. Chem.	Cu_2Cl_2	Cupreous / Cuprous chloride	$CuCl_2$	Cupric chloride
1866	Roscoe	Lessons	$CuCl$	Cuprous chloride	$CuCl_2$	Cupric chloride
1878	Roscoe and Schorlemmer	Treatise	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Cupric chloride
1877	Thorpe	Inorg. Chem.	Cu_2Cl_2	Cuprous chloride	$CuCl_2$	Cupric culoride
1870	Wurtz	Dict. Chem. Med.	Cu_2Cl_2	Chlorure cuivreux and Sous-chlorure de cuivre	$CuCl_2$	Chlorure cuivrique
1849	Liebig / Poggendorff / Wöhler } Kolbe	Handwörterbuch	Cu_2Cl	Kupferchlorür	$CuCl$	Kupferchlorid
1855	Otto	Anorg. Chem., 3rd ed.	Cu_2Cl	Kupferchlorür	$CuCl$	Kupferchlorid
1847	Berzelius	Traité	$CuCl$	Chlorure cuivreux	$CuCl$	Chlorure cuivrique

The employment of such terms as 'Phosphorsuperchlorür,' 'intermediärer Chlorphosphor' for the trichloride, and the corresponding 'Phosphorsuperchlorid,' 'Chlorphosphorsepim maximum' for the pentachloride, is explained by the fact that a solution of phosphorus in the trichloride was formerly supposed to be a lower chloride of phosphorus, 'Phosphorchlorür,' 'Chlorphosphor im minimum.'

The following observations relate to the prevalence of certain names at different periods:—

1. *Anhydrous Phosphorous Acid* was formerly called phosphorous acid; it is now usually called phosphorous anhydride, and to a less extent phosphorus trioxide.

2. *Hydric Phosphite* was called (when obtained from trichloride of phosphorus and water) a compound of phosphorous acid and water. From 1840 till 1860 it was called hydrate of phosphorous acid or hydrated phosphorous acid. It is now called phosphorous acid. The term hydric phosphite has been very seldom used.

3. *Anhydrous Phosphoric Acid* was originally called phosphoric acid; it is now usually called phosphoric anhydride, and to a less extent phosphorus pentoxide. The term anhydrous phosphoric acid has been frequently employed.

4. *Hydric Phosphate* was called hydrate of phosphoric acid or hydrated phosphoric acid till 1860; it is now called phosphoric acid. The term hydric phosphate has been seldom used.

5. *Trichloride of Phosphorus.*—The terms protochloride of phosphorus and phosphorous chloride (or Phosphorclorür) were of equal prevalence till 1868, when the former expired. Trichloride of phosphorus is the name now chiefly used.

6. Similar remarks apply to *pentachloride of phosphorus*, except that the term perchloride of phosphorus has been more largely used than phosphoric chloride, although it expired in 1868.

TABLE XI.

In this table we find that the names 'chloride of copper,' 'dichloride of copper,' and 'protochloride of copper,' have all been applied to the lower chloride, and the names 'chloride of copper,' 'deutochloride,' 'bichloride,' and 'protochloride of copper,' have all been applied to the higher chloride. Th. Thomson introduced the names proto- and deutochloride for the 1st and 2nd chloride respectively, but later on he adopted the names subchloride and chloride. Brande, in the first edition of his 'Chemistry,' calls the two bodies chloride and bichloride of copper, but in his 6th edition we find the names dichloride and protochloride, signifying that the first has two atoms of copper and the second one. Some chemists have followed this rule, others the system of Thomson, so that while Brande, Watts, Regnault, and Bernays apply the name protochloride to the higher body, Thomson, Thenard, Gay-Lussac, Naquet, and Harcourt apply the same name to the lower body.

General Remarks on the Preliminary Report.

The usefulness of any system of nomenclature rests mainly on its permanence.

The tables in this Report, summarising the history of the nomenclature of certain typical chemical compounds, clearly indicate the conditions most essential for permanence. Names have been given to bodies expressing particular opinions on their ultimate constitution, whilst other names have been given expressing no theoretical views, but simply stating experimental facts which admit of no dispute. These tables bring prominently forward the fact that those names have endured which express no particular opinion on the ultimate constitution of the bodies to which they were applied. Where the names have expressed such opinions the advance of knowledge has necessitated change. Sixty years ago the names 'Bi-chloride of phosphorus' and 'Perchloride of phosphorus' were both applied to the higher chloride of phosphorus. The former name has not lasted because it expressed a particular view as to the number of atoms in the molecule, which view is no longer accepted. The other name has endured because it merely expressed the experimental fact that the compound contained more chlorine than the lower chloride. To secure permanence for the future this principle should be acted on. As a general rule those names are to be preferred which have shown the most vitality and have led to no ambiguity. *Where there are two compounds composed of the same elements the terminations* OUS *and* IC *should be employed.* These terminations have been used in the same sense by the great majority of chemists since Lavoisier. The terms 'cuprous chloride,' 'chlorure cuivreux,' 'Kupferchlorür' for the lower chloride of copper, and the terms 'cupric chloride,' 'chlorure cuivrique,' 'Kupferchlorid' for the higher chloride have been used by English, French, and German chemists consistently and without ambiguity.

The prefixes *proto*, *deuto*, &c., introduced into chemical nomenclature by Thomas Thomson, were not intended by him to indicate the number of atoms in a molecule, but to mark the first, second, or third compound of a series. Thus he styled the lower and higher chlorides of copper 'protochloride' and 'deutochloride' respectively; but other chemists have styled the higher chloride the *protochloride*, thereby indicating that the molecule contained one atom of copper, and the lower chloride the *dichloride*, thereby indicating that the molecule contained two atoms of copper. Where the prefixes *proto*, *deuto*, &c., are retained they should always be applied in the sense used by Thomson as indicating the first, second, &c., compound of a series.

A name once given to a particular body should not be taken from that body and applied to another without the gravest reasons for the transfer—reasons accepted by the majority of chemists. The name *carbonic oxide* has been regularly used to denote the lower oxide of carbon from the time of its discovery. Until quite recently, the name 'carbonic oxide' served without ambiguity to indicate a particular compound. This name has lately been applied by certain chemists to the higher oxide of carbon, and a new name has been given to the lower oxide. On account of this transfer the name has become ambiguous. A return to the common nomenclature would involve less change, and would, therefore, be preferable to the adoption of two new names to avoid this ambiguity.

Report of the Committee, consisting of Professor W. A. TILDEN *and* Professor H. E. ARMSTRONG (*Secretary*), *appointed for the purpose of investigating Isomeric Naphthalene Derivatives.*

THE Committee have to report that some steps have been taken towards commencing the work; but, owing to the unfortunate fire at the London Institution, whereby much of the material was destroyed, and the appointment of Dr. Armstrong to the Chair of Chemistry at the Central Technical Institute, the results are not yet in a state fit for publication.

[Two other Reports read in Section B, having been unavoidably delayed, will be found immediately before the Papers printed *in extenso.*]

Second Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*), *on the Fossil Phyllopoda of the Palæozoic Rocks.*

IN our former Report (1883) we offered a Synopsis of the known genera of the Fossil Phyllopods, and we have not found reason to modify the classification there proposed, as far as the univalve genera are concerned, except (1) that the term 'flat-shield' is incorrect for a group in which several forms are slightly convex or subconical; (2) that one (*Dipterocaris*) is bent along the back in a ridge-like manner; (3) possibly *Pinnocaris* is really bivalved, without a rostral piece, and not merely sutured along the back; (4) probably *Crescentilla* may be placed near *Pterocaris* and *Dipterocaris*. Last year we offered observations on some genera that have bent or folded carapaces (*Hymenocaris*), and on some that are bivalved (*Caryocaris* and *Lingulocaris*); but we have now to take up the flat-shielded or subconical forms, excepting the *Dithyrocarides*.

Examining all the species of which specimens or figures are within reach, we find the following genera and species; and we have briefly described or re-described them on one uniform plan, so that comparison may be the more easily made.

LIST OF THE SPECIES OF THE FOSSIL UNIVALVED PHYLLOPODA (EXCEPTING DITHYROCARIS).

I. *Shield not sutured along the back.*

1. *Posterior margin entire.*

1. DISCINOCARIS, H. Woodward, 1866.
    1. Browniana, H. W.
    2. dubia, F. A. Roemer.
    3. lata, H. W.
    4. triasica, Reuss.
    5. sp. nov.
    6. congener, Clarke.
    7. ? gigas, H. W.
2. SPATHIOCARIS, Clarke, 1882.
    1. Emersonii, Clarke.
    2. ungulina, Clarke.
3. PHOLADOCARIS, H. Woodward, 1882.
    1. Leeii, H. W.
    2. sp. nov.
4. LISGOCARIS, Clarke, 1882.
    1. Lutheri, Clarke.
5. ELLIPSOCARIS, H. Woodward, 1882.
    1. Dewalquei, H. W.
    2. sp. nov.

2. *Posterior margin truncate, indented, or slightly notched.*

6. CARDIOCARIS, H. Woodward, 1882.
    1. Roemeri, H. W.
    2. bipartita, H. W.
    3. Veneris, H. W.
    4. Koeneni, Clarke.

3. *Posterior margin deeply notched.*

7. DIPTEROCARIS, Clarke, 1883.
    1. pes-cervæ, Clarke.
    2. vetusta, d'Arch. & de V.
    3. procne, Clarke.
    4. pennæ-dædali, Clarke.
    5. Etheridgei, nobis.
8. PTEROCARIS, Barrande, 1872.
    1. bohemica, Barr.
9. CRESCENTILLA, Barrande, 1872.
    1. pugnax, Barr.

II. *Sutured along the back.*

1. *Nuchal suture angular.*

10. APTYCHOPSIS, Barrande, 1872.
    1. prima, Barr.
    1A. var. secunda, nov.
    2. Wilsoni, H. Woodward.
    3. Lapworthi, H. W.
    4. glabra, H. W.
    5. sp. nov.
    6. sp. nov.
    7. Salteri, H. W.
    8. sp. nov.

2. *Nuchal suture rounded.*

11. PELTOCARIS, Salter, 1863.
    1. aptychoides, Salter.
    2. ? anatina, Salter.
    3. sp. nov.
    4. sp. nov.
    5. ? Harknessi, Salter.

3. *Possibly truly bivalved, without a rostral piece.*

12. PINNOCARIS, R. Etheridge, Jun. 1878.
    1. Lapworthi, R. E., Jr.

Before we proceed with the comparative descriptions, we may remark that some specimens of these little fossil carapaces were noticed long ago by palæontologists, before their Crustacean characters were recognised. Their general likeness to the opercula of Ammonites[1] led some observers to suggest that these little fossils may have belonged to *Goniatites*, an 'Ammonitidal' cephalopod found occasionally in strata of the same formation (Devonian) as that in which certain of these Aptychus-like fossils occur.[2] Many of the species, however, occur in beds in which *Goniatites* are unknown. Only one specimen has as yet been found in close association with a Goniatite;[3] and nothing is yet known for certain of any real opercula of Goniatites. Herr Kayser found and noticed the occurrence of a '*Spathiocaris*' in the body-chamber of a *Goniatites intumescens* from the Devonian of Nassau. Small fossils are very commonly met with in a similar position in the body-chambers of *Goniatites* and other Cephalopods, as also in the cavities of various shells.

Of the Phyllopodous forms under consideration we have some, like *Discinocaris*, which could not, on account of their shape in general, and the presence of the frontal piece in particular, have belonged to any Cephalopod, much less to *Goniatites*, even if it possessed an operculum, which is by no means proved. Next we have a large series of forms which occur in beds wherein no Goniatites have been found. Lastly, as is the case with specimens from Nassau, the Eifel, Hartz, and Petschoraland, some occur in beds containing *Goniatites*, but their outlines do not, even in these instances, correspond exactly with the apertures of the shells of such Cephalopods.

As other Phyllopods, such as *Estheria*, are imbedded in Devonian rocks, it is not strange that these Phyllocarida should be there also.

Whilst, however, we are far from denying that some forms, now associated with undoubted shield-bearing *Phyllopoda*, may hereafter be shown to be Molluscan, we are certain that some have no relation to Mollusca; and with regard to such cases as those in which there is any possibility of doubt, the *onus probandi* must rest with those who are dissatisfied with and do not accept our views regarding their affinities.

We are the more strengthened in our opinion of the affinities of these palæozoic Crustacean shields, because their ornamentation agrees with that of known Phyllopod carapaces, both in the minute, ridge-like, con-

[1] Calcareous and bipartite, *Aptychus*; corneous and undivided, *Anaptychus*.

[2] See, for instance, Herr Dames' remarks in the *Neues Jahrb. für Min.* &c., 1884, vol. i. pp. 275–279.

[3] See Kayser, *Zeitsch. d. deutsch. geol. Ges.* xxxiv. 1882 pp. 818, 819; and von Koenen, *Neues Jahrb. für Min.* &c., 1884, vol. i. pp. 45, 46.

centric lines of growth, and, in some cases, in the delicate surface ornament between them.

Another objection to the supposed *Aptychus* nature of many of these circular and ovate shields arises from the fact that they were not originally flat discs or plates, as may be seen by examining a series from various localities.

Thus *Discinocaris Browniana* was in some degree convex, with a low conical apex; *Aspidocaris triasica* was evidently conical, as may be seen by the split state of the outer rim, caused by the flattening of the whole shield; others, as *Spathiocaris Emersonii* and *Lisgocaris Lutheri*, had elevated subconical carapaces. *Aptychopsis* not unfrequently exemplifies the same condition and similar breakage. A median mark, caused by the depression of the central portion in *Cardiocaris bipartita* and *C. Koeneni*, is also the result of flattening in a toughish subconical shield. Again, some of these carapaces were bent like a low ridge along the dorsum, as shown by Mr. J. M. Clarke's description and figure of *Dipterocaris procne*—all which conditions are compatible with the nature of Phyllopods.

Phyllopodous Shields figured by early observers (1832–1850).

1. 1832–48.—One of the above-mentioned little fossils has been recorded as '*Aptychus lævigatus* (Goldfuss)' in von Dechen's German translation of De la Beche's 'Manual of Geology,' 'Handbuch der Geognosie,' 1832, p. 529; and it was entered in Bronn's 'Index Palæontologicus,' 1848, vol. i. p. 90. As we know of no figure, we cannot offer an opinion as to its generic relationship.

2. 1842.—The '*Aptychus vetustus*' of d'Archiac and de Verneuil, 'Transactions Geol. Soc. London,' ser. 2, vol. vi. 1842, p. 343, pl. 26, f. 9, found in the Devonian beds of the Eifel (rare), is one of these little apparently bivalved but really tripartite carapaces, with a front notch, and an open split at the hinder part of the median suture. If this latter feature be an original condition, as it seems, the species is referable to *Dipterocaris.*

3. 1846.—In 1846 A. von Keyserling gave figures and descriptions of some small Aptychus-like fossils in the 'Wissenchaft. Beobacht. Petschora-Land, Geogn. Beobacht.' p. 286, pl. 13, f. 3–7. These he referred to as being probably the *Aptychi* of *Goniatites.* The figures show no median line of suture; and therefore, instead of looking like the more common *Aptychopsis*, they resemble the allied *Discinocaris*, with an undivided shield, and with a rounded or elliptical nuchal or cephalic notch. If this latter feature be real, we have a form here which comes near *Ellipsocaris.* One of his figures in particular (fig. 3) reminds us of this genus.[1]

4. 1850.—In the 'Palæontographica,' vol. iii. p. 28, pl. 4, fig. 18, F. A. Roemer described and figured his *Aptychus dubius*, from the Upper Devonian beds of the Hartz (Goniatite-limestone of the Kelwasserthal). M. Barrande in 1872 was inclined to refer it to *Aptychopsis* ('Syst. Sil. Bohême,' vol. i. Suppl. p. 456); Mr. J. M. Clarke thought it might be a *Spathiocaris*; but we regard it as a *Discinocaris.*

5. 1850.—In the same volume of the 'Palæontographica,' iii. p. 88, t. 13, f. 13, F. A. Römer also illustrated what he regarded as an *Aptychus*

[1] We are informed that unfortunately these Russian specimens cannot now be found at St. Petersburg.

of a Goniatite, from the Goniatiten-Kalk of Altenau, in the Hartz. In general appearance the figure approaches *Pholadocaris*.

Synoptical Plan of the Discinocarida.

Shield without a median dorsal suture. (Type, *Discinocaris.*)		*Species.*	*Shape or outline of Shield* (complete, and measured outside the notches).
1. Posterior margin entire and rounded. I. Cephalic notch (=nuchal suture) angular 1. Shield not ridged nor furrowed	notch broad i. DISCINOCARIS	*Browniana, dubia, lata*	circular.
		triasica . . .	oval.
		sp. nov. . . .	obovate.
		congener . . .	oblong.
	notch narrow ii. SPATHIOCARIS	*Emersonii* . .	oblong.
		——? small form .	obovate.
		angulina . . .	oval.
2. Shield having radiate furrows and ridges . . .	iii. PHOLADOCARIS .	*Leeii*	cuneiform.
		sp. nov. . . .	obovate.
II. Cephalic notch rounded. . .	iv. ELLIPSOCARIS .	*Dewalquei* . . .	oval.
		sp. nov. . . .	suboblong.
2. Posterior margin angular; shield with radiate ridges. Cephalic notch rounded . .	v. LISGOCARIS .	*Lutheri* . . .	subpentagonal.
3. Posterior margin indented; cephalic notch angular .	vi. CARDIOCARIS .	*Roemeri, bipartita* .	narrow obovate.
		Veneris, Koeneni .	broad obovate.
4. Posterior margin deeply notched; cephalic notch, angular. . . A. Concentrically striate, like *Discinocaris*, &c. . .	vii. DIPTEROCARIS .	*pes-cervæ, vetusta* .	obovate.
		procne . . .	subquadrate.
		pennæ-dædali . .	suboblong.
		Etheridgei . . .	oval.
B. Not concentrically striate. 1. Test with radiate ornament . .	viii. PTEROCARIS	*bohemica* . . .	obovate.
2. Test smooth; minute . . .	ix. CRESCENTILLA	*pugnax* . . .	oblate.

As in all other natural groups, it is difficult or impossible to arrive at a perfectly linear arrangement; the order, therefore, in this plan of the Discinocarids does not quite correspond with that in the foregoing list of genera and species, which is followed in the descriptions.

I. DISCINOCARIS, H. Woodward, 1866. 'Quart. Journ. Geol. Soc.' vol. xxii. p. 503; and 'Geol. Mag.' vol. iii. 1866, p. 72.

This Phyllopod has a round, oval, ovate, or oblong shield, slightly conical, without a median suture, but crossed anteriorly by an angular nuchal suture, often leaving a corresponding notch. Concentrically striate, like its congeners.

1. *Discinocaris Browniana*, H. Woodward, 1866. 'Quart. Journ. Geol. Soc.' vol. xxii. p. 504, pl. 25, figs. 4 and 7, and f. 5 side view, &c. 'Geol. Mag.' vol. iii. 1866, p. 72. 'Catal. W.-Scot. Fossils,' 1876, p. 7. 'Catal. Cambr. and Silur. Foss. Pract. Geol. Museum,' 1878, p. 28. 'Proceed. Belfast Nat. Field-Club,' 1877, Appendix, p. 122, &c., pl. 7, f. 25 *a* and 25 *c*.

This is a circular shield, 15 mm. in diameter. Slope of nuchal suture, 60°; diameter of disk-shaped carapace, 7 lines; width of nuchal portion nearly one-sixth of the entire circumference. A larger specimen folded together probably measured 14 lines in diameter, 'Quart. Journ. Geol. Soc.' vol. xxii. p. 504.

Found in the Anthracitic Shales of the Moffat district, at Dobbs Linn, Dumfriesshire, and Garpoolburn, Moffat; and in equivalent Silurian beds at Coalpit Bay, co. Down, Ireland.

2. *Discinocaris dubia* (F. A. Roemer), 1850. *Aptychus dubius*, F. A. Roemer ('Palæontographica,' vol. iii. part 1, p. 28, t. 4, f. 18). *Spathiocaris dubia*, J. M. Clarke, 'Neues Jahrb. für Min.' &c., 1884, vol. i. pp. 129 and 183.

Nearly circular when perfect, but somewhat narrowed posteriorly, thus becoming short-obovate. Notch rather shallow. Originally about 25 mm. long, 24 mm. at the widest; slope of nuchal suture, 30°. Concentric lines wide apart, as preserved, and otherwise obscure at the centre. This is referred by Mr. J. M. Clarke to his genus *Spathiocaris*.

Roemer's specimen was found in the Goniatite-limestone of the Kelwasserthal, in the Hartz.

3. *Discinocaris lata* (H. Woodward), 1882. *Cardiocaris lata*, H. Woodward, 'Geol. Mag.,' Dec. 2, vol. ix. p. 388, pl. 9, fig. 13. *Spathiocaris lata*, Clarke, 'Neues Jahrb. für Min.' &c., 1884, vol. i. p. 181, pl. 4, fig. 2.

Shield broadly obovate, nearly circular, with broad and deep cephalic notch; not indented behind. If complete, it would be about 22 mm. long, 18 mm. wide. Slope of notch-sides about 45°. As far as the fig. 13 shows, this may be a *Discinocaris*.

From Büdesheim, in the Upper Devonian of the Eifel.

In Mr. Clarke's paper this appears as having a round shield, slightly broader anteriorly than behind; with a wide notch reaching to the centre. Length (complete) about 19 mm. according to the figure, width 19 mm. Slope of notch uncertain, probably about 50°.

Not rare in the Upper Devonian, at Bicken, near Herborn, in Nassau.

4. *Discinocaris triasica* (Reuss), 1867. *Aspidocaris triasica*, Reuss, 'Sitzungsb. k. Akad. Wissensch. Wien,' math.-nat. Cl., vol. lv. 1867, pp. 1 *et seq.* pl. O, f. 1–5.

As Dr. Woodward has already intimated ('Geol. Mag.,' Dec. 2, vol. ix. p. 386), there is apparently no real difference between the late Dr. A. E. von Reuss's genus here mentioned, and *Discinocaris*, to which Reuss thought it to be closely allied. Reuss's specimens indicate, however, a different species. It was oval in outline, when perfect, and had a wide and deep notch, with its apex near the centre of the test. The dimensions of the fossils are somewhat increased by forcible depression of their original somewhat conical form: fig. 2, length about 36 mm., width about 29 mm.; fig. 3, length about 25 mm., width about 19 mm. The slope of the nuchal suture is 40° in the fossils, but Dr. Reuss was probably right in restoring it at 50° (fig. 4).

From the Raibl beds, near Hallstadt.

5. *Discinocaris* sp. nov.

In the Cambridge Museum we notice a Phyllopodous test, broadly sagittate, or sharp-shovel-shaped, in its present state, the cephalic portion being absent. Originally obovate, with a narrow pointed posterior margin, it has been truncated in front by a nuchal suture of slight angularity, which has left a broad shallow re-entrant angle, with its apex reaching back about one-third of the shield's original length, and its sides reaching the margin almost before they run into the curve of the front border. Original length about 24 mm., width 15 mm. Slope of nuchal suture 30°.

From the Coniston mudstone (Upper Silurian) of Skelgill Beck, near Ambleside, Westmoreland (at the lower foot-bridge). Collected by Mr. J. E. Marr, F.G.S.

6. *Discinocaris congener* (Clarke), 1884. *Spathiocaris* (*Cardiocaris?*) *congener*, Clarke, 'Neues Jahrb. für Min.' &c., 1884, vol. i. p. 183, pl. 4, f. 5.

This also seems to be a *Discinocaris*. Shield, when complete, elliptical-oblong; in the fossil state deeply notched at the anterior end, leaving on each side a narrow tapering projection. Mr. Clarke says that the fossil is 14 mm. long and 8 mm. broad. The slope of the notch seems to be about 65°.

From the Upper Devonian, at Bicken, near Herborn, Nassau.

7. *Discinocaris? gigas*, H. Woodward, 1872, 'Geol. Mag.,' vol. ix. p. 564; 'Report Brit. Assoc.' for 1872, 1873, p. 323.

A sub-triangular fragment of a Phyllopodous shield, showing delicate, concentric, parallel lines, was referred in 1872 by Dr. H. Woodward to a *Discinocaris*, possibly '7 inches in diameter.' This was from the Moffat Graptolitic shale at Dobbs Linn, Dumfriesshire. It is in the British Museum; also an oblong fragment with fine parallel lines. Some relics of body-rings, 45 mm. in transverse width, and varying from 5 to 10 mm. fore and aft, from the same beds at Ettrickbrigend, Selkirkshire, are in the same collection.

At Cambridge two fragments of the same large kind of carapace are in the University Museum, from the Conistone mudstone of Skelgill Beck. Collected by Mr. J. E. Marr, F.G.S.

DISCINOCARIS.

Discinocaris	*Browniana*	. Lower or Middle Silurian.
,,	*dubia* (in Goniatite beds)	. Upper Devonian, Hartz.
,,	*lata* ,,	. Upper Devonian, Eifel and Nassau.
,,	*triasica*	. Trias, Hallstadt.
,,	sp. nov.	. Upper Silurian, Westmoreland.
,,	*congener* (in Goniatite beds)	. Upper Devonian, Nassau.
,,	*? gigas*	. Lower and Upper Silurian.

II. SPATHIOCARIS, J. M. Clarke, 1882. 'American Journ. Science,' ser. 3, vol. xxiii. p. 477, and vol. xxv. p. 120, and pp. 124, 125. 'Neues Jahrb. für Min.' &c., 1884, vol. i. p. 181, &c.

Judging from Mr. Clarke's description and figures, this Phyllopod seems to have an oblong or obovate, subconical, patelloid shield, with a narrow anterior or cephalic notch (referred to as being posterior, *loc. cit.*, but apparently as anterior in the 'Neues Jahrb.' *loc. cit.*), reaching back halfway along the shield, ornamented with concentric lines, and, in some specimens, with delicate radii also. In essential particulars this agrees with *Discinocaris*[1] (if regarded as described above); but its notch is peculiar, being very narrow.

[1] Mr. Clarke, at p. 478, comparing this form with *Discinocaris*, speaks of the wedge-shaped cleft as being analogous to the notch of the latter, but says that there is here no 'rostrum or plate acting as another valve to cover the cleft,' and he evidently regarded the notch as abdominal, somewhat like the posterior hollow in the shield of *Apus*, to allow of the protrusion of the abdomen (*see* also 'Amer. Journ. Science,' ser. 3, vol. xxv. p. 124). In the 'Neues Jahrb.' 1884, however, Mr. Clarke refers to the notch as being anterior, but figures it downward in the plate.

1. *Sp. Emersonii*, Clarke, 1882. *Op. cit.* p. 477, pl. O. fig. 1.

This is elliptical-oblong, or elegantly oblong with rounded ends, one of which is parted by a narrow cleft. Length 42 mm.; width 27 mm. by the figures.

1A. *Sp. Emersonii* (?), *loc. cit.* f. 2.

This is referred to as being a young form of the foregoing, but it is obovate[1] (not oblong), and may be specifically distinct. Length 12 mm.; width 8 mm.

1B. *Sp. Emersonii* (?), *loc. cit.* f. 3.

This shows an elliptico-triangular shape, which may be due to imbedment in the matrix, and resembles a lateral portion of an *Aptychopsis*, but it is regarded by Mr. Clarke as a folded *Spathiocaris*.

(If belonging to the former, the shield, when complete, would have been about 40 mm. long and 40 mm. where widest; in shape obovate, with narrow, pointed posterior; and with a relatively shallow nuchal suture, sloping at 20°, and cutting off a broad cephalic portion.)

Mr. Clarke has found many examples of *Spathiocaris* folded laterally (*see* 'Amer. Journ. Sci.' ser. 3, vol. xxv. p. 124).

Spathiocaris Emersonii, as described in the 'Amer. Journ. Sci.' for June 1882, has been found by Mr. Clarke abundantly in some of the Devonian strata of New York State. In 1882 he had already obtained thirty specimens from a layer only a few inches thick; they varied much in size, from a length of 4 mm. to 60 mm.; and a fragment of a large individual, probably 80 or 90 mm. long, was met with.

They occurred in these beds:—

Chemung Group.—Chemung proper, Naples, Ontario co.; Lower Chemung Sandstone, Canadice, Ontario co.

Portage Group.—Upper Portage Sandstone, Wyoming co., Portageville; Upper Black Band, Naples, Ontario co., and elsewhere; Lower Black Band, Bristol, Ontario co.

In the lower muddy shales the associates are the common fossils of the Portage rocks, including *Goniatites complanatus*, *H.* &c. In the bituminous shales of the 'Upper Black Band,' they occur with fish-remains (*Palæoniscus*, &c.), conodonts, annelidan teeth, plant-remains, and sporangia of cryptogams; in the Chemung, in the lowest horizon, with *Leiorhynchus mesacostalis*, Hall: and in the upper only with Crustaceans allied to *Spathiocaris*, namely, *Dipterocaris* (*op. cit.* p. 121, &c.)

2. *Spathiocaris ungulina*, J. M. Clarke, 1884. 'Neues Jahrb. für Min.' &c., 1884, vol. i. p. 182, pl. 4, f. 4.

An oval shield; length (complete), judging by the figures, would be about 34 mm.; width 26 mm. Cephalic notch narrow and deep, reaching nearly to the centre; slope about 75°. Rare, Upper Devonian, from Bicken, near Herborn. Very closely allied to *Discinocaris*.

SPATHIOCARIS.

Spathiocaris Emersonii,	Upper Devonian, New York State. Without Goniatites in the Chemung and Upper Portage Groups. With Goniatites in the Lower Portage Group.
„ *ungulina*,	(in Goniatite bed) Upper Devonian, Nassau.

[1] If looked at, according to our plan, with the anterior end upwards.

III. PHOLADOCARIS, H. Woodward, 1882. 'Geol. Mag.' Dec. 2, vol. ix. p. 388.

The shield of this Phyllopod is peculiar, and is described in careful detail, *loc. cit.* Its main features are that two furrows radiate from the centre backwards, enclosing a narrow triangular space, marked with parallel radiating lines. Radiating and concentric lines ornament the lateral portions of the carapace. In front of the centre two slightly raised elliptical ridges enclose a small space behind the apex of the large V-shaped nuchal suture, and in the fig. 16 remind us of the two forward ridges in *Lisgocaris*; whilst the two furrows behind feebly represent its posterior ridges.

1. *Pholadocaris Leeii*, H. W., 1882. *Loc. cit.* pl 9. f. 16.

The only specimen described with the above characteristics has a triangular-obovate, or nearly cuneiform shield; broadly rounded in front (when complete); narrow and rounded behind. Complete, about 34 mm. long; 16 mm. broad at the widest part. Rostral piece about 10 mm. long, and 10 mm. wide in front; slope of notch about 60°. From the Upper Devonian of Büdesheim in the Eifel.

2. *Pholadocaris*, sp. *Aptychus* of a Goniatite, F. A. Roemer. 'Palæontographica,' vol. iii. 1850, p. 88, pl. 13, fig. 13.

This neat figure of an obovate, notched, concentrically marked, black, filmy fossil from the Goniatiten-Schichten of Altenau, in the Hartz, would serve for some *Discinocaris*, if it were not that the posterior portion is marked with a dark (sunken) elongate-triangular space, beginning behind the centre and widening out slowly to the posterior margin. Altogether we may take the figure to represent an ill-preserved *Pholadocaris*, neatly, but possibly not quite correctly, drawn.

PHOLADOCARIS.

Pholadocaris Leeii, (in Goniatite bed)	Eifel.
„ sp. „	Hartz.

IV. LISGOCARIS, J. M. Clarke, 1882. 'Amer. Journ. Science,' ser. 3, vol. xxiii. p. 478, pl. O, fig. 5; vol. xxv. p. 124.

This also belongs to the group of fossil Phyllopods which have shields without a median dorsal suture. It has concentric lines of growth also, following the marginal contour of the test.

The difference between this and *Discinocaris* is that it has a rounded or elliptically cut cephalic notch (if looked at as we regard it, instead of posterior or abdominal, as at p. 478, *op. cit.*) Its outline is symmetrically subpentagonal. Three ridges leave the apex or centre of the shield, one central and one on each side, and radiate to the hinder margin, which they stretch out, as it were, into three points, with two intervening concave spaces. In front two low ridges pass away obliquely forward and outward from the centre, and between them is the long, narrow, round-ended cephalic notch, the shape of which is distinctive.

1. *Lisgocaris Lutheri*, Clarke, 1882 (*loc. cit.*), is the only described species, and exhibits the features above-given. Its figure is about 40 mm. long and 30 mm. wide; cephalic notch 10 mm. wide at its entrance, 17 mm. long, and not narrowing very much before it begins to curve round at its apex.

From the base of the 'Hamilton Group' of strata, in Ontario County, Western New-York State.

Subsequently Mr. Clarke expressed his wish to include *Lisgocaris* with *Spathiocaris* (*op. cit.* p. 124), because he was certain they agreed in having no median suture; and he thought that neither of them had the rostral piece so often present in *Discinocaris* and *Peltocaris*—we may add *Aptychopsis* and *Cardiocaris* also. In this view we do not coincide; and we think that *Spathiocaris* and *Lisgocaris*, owing to the form of the cephalic notch, may be distinct from each other and from *Discinocaris*, as far as the value of that feature goes, but that, having no median suture, they are very closely allied to that genus. There are *Goniatites* in the 'Hamilton Group' of strata from one of which *Lisgocaris* was obtained.

V. ELLIPSOCARIS, H. Woodward, 1882. 'Annales Soc. Géol. Belgique,' vol. viii. 1882, Mémoire No. 4, p. 45; 'Geol. Mag.' Dec. 2, vol. ix. 1882, p. 444.

Shield or carapace without a median suture, and with a curved nuchal suture. As *Discinocaris* corresponds with *Aptychopsis* in having an angular nuchal suture, so *Ellipsocaris* corresponds with *Peltocaris* in its rounded nuchal suture. See the remarks and woodcuts figs. 1–4, *loc. cit.*

1. *Ellipsocaris Dewalquei*, H. Woodward, 1882. *Loco citato* and woodcut fig. 4.

Shield elongate-oval; nuchal suture semi-oval, not reaching to the centre of the shield; the lateral projections bordering the rostral piece in front are necessarily curved, tapering, and sharp, like flat horns. Complete, the carapace would be about 52 mm. in length; width 24 mm. The rostral piece may have been about 15 mm. long, by 12 mm. wide.

A most interesting feature of this species is its ornament, not consisting merely of numerous fine concentric lines of growth, but retaining the delicate interlinear cross-bars and minute transverse wrinkles seen in *Estheria*, 'Geol. Mag.' *loc. cit.* p. 445.

From the Upper Devonian of Comblain-la-Tour, Province of Liége.

2. *Ellipsocaris*, sp., 'Opercula of Goniatites,' A. von Keyserling; 'Wissenschaftliche Beobachtungen auf einer Reise in das Petschora-Land in Jahre 1843;' 'Geognostische Beobachtungen,' 1846, p. 286, pl. 13, figs. 3–7 (see above, p. 3).

Figs. 3, 5, and 7 have a more or less oval outline, which, with the rounded notch, is suggestive of *Ellipsocaris Dewalquei*. Figs. 4 and 6 are more obovate in their complete outline. Fig. 3 is 19 mm. long, by 12 mm. wide; fig. 7, $7\frac{3}{4}$ mm. by 4·8 mm.; fig. 4, 11 mm. long by 9 mm. wide.

In the Devonian (Domanik) beds of Petschora-land.

ELLIPSOCARIS.

Ellipsocaris Dewalquei	(with Goniatites ?)	Belgium.
,, sp.	(in Goniatite beds)	Petschora-land.

VI. CARDIOCARIS, H. Woodward, 1882. 'Geol. Mag.' Dec. 2, vol. ix. p. 386.

Shield obovate, usually elongate, sometimes short; contracted in the posterior third, notched deeply in front in the fossil state by loss of the rostral portion; more or less truncate, and often indented posteriorly. This modification of the posterior extremity is regarded by Mr. J. M. Clarke as of only specific value; but with us it constitutes the difference between *Cardiocaris* and *Discinocaris*, and the indentation leads us to the *cleft* posterior margin of *Dipterocaris*.

1. *Cardiocaris Roemeri*, H. Woodward, 1882. 'Geol. Mag.' Dec. 2, vol. ix. p. 386, pl. 9, figs. 1–7.

Shield long-obovate, slipper-like. Cephalic portion narrow-triangular, about 15 mm. long in a shield 40 mm. long. Good specimen 35 mm. long (about 45 mm. when complete), 20 mm. in greatest breadth. Fragment of larger shield, probably once 65 mm. long and 40 mm. wide. Another may have been 50 mm. broad and 30 mm. wide. Some small (young) forms, one of them not more than 6 mm. long and 4 mm. broad, are also figured. Slope of nuchal suture at about 60°. In one small specimen the cephalic portion is preserved in place (*op. cit.* p. 387 and f. 5). The presence of this little frontal piece is quite antagonistic to the adaptability of *Cardiocaris* as an operculum to a Goniatite.

Upper Devonian of the Eifel, at Büdesheim, between Gerolstein and Prüm.

2. *Cardiocaris bipartita*, H. Woodward, 1882. 'Geol. Mag.' Dec. 2, vol. ix. pp. 383, 388, pl. 8, figs. 14 and 15.

One of those (f. 14) is much like *C. Roemeri* in shape, but is said to have a dorsal suture, in which case it ought to be placed in or near *Aptychopsis*; probably, however, the dorsal line was merely the mark of an imperfect fold or break along the middle (as in Mr. Clarke's figure of *Spathiocaris Koeneni*, 'Neues Jahrb.' 1884, vol. i. pl. 4, f. 1). The side-margins are rather less convex than in *C. Roemeri*, and the hinder end, which is indented, is proportionally broader. Complete, it may have been 27 mm. long, by 15 mm. wide. Angle of nuchal notch, 60°.

In shape, f. 15 (which is imperfect posteriorly) differs from f. 14; it seems to be more oval, and is certainly more deeply notched in front than f. 14. It was probably 32 mm. long, when complete; 17 mm. wide.

Both the specimens were found in the Upper Devonian at Büdesheim, between Gerolstein and Prüm, in the Eifel.

3. *Cardiocaris Veneris*, H. Woodward, 1882. 'Geol. Mag.' 1882, p. 387, pl. 8, figs. 8–12.

Shield relatively broader and shorter than *C. Roemeri*, and considerably wider in front than behind. The cephalic notch is also relatively broader. Dr. Woodward gives the following measurements:—

Length	(complete), about	30 mm.;	greatest	breadth,	23 mm.
"	"	20	"	"	15
"	"	15	"	"	10

The angle of the slope of the nuchal furrow is uncertain; it varies in different specimens, according to the result of pressure and disturbance, 40° and 45°, 45° & 55°, and 60° and 65°.

4. *Cardiocaris Koeneni* (Clarke), 1844.

Spathiocaris Koeneni, Clarke, 'Neues Jahrb. für Min.' &c., 1884, vol. i. p. 182, pl. 4, f. 1.

A broadly obovate shield, when complete and looked at with anterior margin placed upwards. The fossil is broadly cordate in its present condition, having a wide and rather shallow cephalic notch. It is truncate behind, along the middle of the posterior margin, with a line (sinuous by unequal pressure probably) equal in length to half the width of the carapace. The figured specimen has the dorsum bent in along a median line, but not sutured. According to the figure the length (complete) would be about 48 mm.; width where broadest 49 mm. Nuchal suture sloping at 40°. Five specimens, Upper Devonian, Bicken, near Herborn. The largest example (Mr. Clarke says) measures 45 mm. from the apex of the notch to the posterior margin, and 55 mm. broad. The fossils mostly measure about 33 mm. long, and about 45 mm. broad. He regards *Spath. Koeneni* as a link between *Spathiocaris* and *Cardiocaris*; but the truncation of the posterior margin puts it with *Cardiocaris*, and its wide notch is strange to *Spathiocaris*.

CARDIOCARIS.

Cardiocaris Roemeri	in Goniatite beds	Büdesheim	Upper Devonian.
,, *bipartita*		Büdesheim	
,, *Veneris*		Büdesheim	
,, *Koeneni*		Bicken	

VII. DIPTEROCARIS, J. M. Clarke, 1883. 'Amer. Journ. Science,' ser. 3, vol. xxv. f. 121.

A variety of fossil Phyllopodous shields, oval or ovate in general outline; but this is interrupted by two notches of varying width and depth, one in front and one behind. The anterior or nuchal notch is angular, and analogous to that in *Discinocaris*, *Aptychopsis*, *&c.*; the other varies from a mere split to a broad open Λ-shaped notch. The shield seems to consist of one piece, and was probably ridge-like to some extent, but occasionally pressure has caused the median line to be specially depressed, or otherwise affected, so as to look like the place of a suture. The shields have concentric lines of growth for ornament.

1. In *Dipterocaris pes-cervæ*, J. M. Clarke, *op. cit.* p. 123, figs. 4, 5, the front notch is open, with its outer width almost equal to one of its sides. The hinder notch is very narrow, and reaches up half the length of the shield. Lower Chemung sandstone; Canadice, Ontario co., New York State.

2. *Aptychus vetustus*, d'Archiac and de Verneuil, 1842, 'Trans. Geol. Soc.' ser. 2, vol. vi. p. 343, pl. 26, f. 9, from the Devonian rocks of the Eifel, is a *Dipterocaris*, with a very broad, angular frontal notch, and a narrow hinder split.

3. *Dipterocaris procne*, J. M. Clarke, *op. cit.* p. 122, figs. 2 & 3, has the two notches both wide and deep. It is ridgelike in its dorsal bend.

Middle Chemung (sandstone); Hoskinsville, Ontario co., New York State.

4. *D. pennæ-dædali*, J. M. Clarke, *op. cit.* p. 123, f. 1, has the notches large and deep and unequal, leaving only a small isthmus near the centre to unite the lateral portions. Lower Chemung; Dansville, Livingstone co., New York State.

5. These characters—small isthmus, deep notch, and large laterals, are present also in figure 21, of Plate 14, in the 'Fossils of Girvan,' 1880, and regarded as an undetermined Phyllopod at p. 212. The specimen

was from the Lower Silurian of Penwhapple Burn, near Girvan, Ayrshire; and we wish to give it the name of *Dipterocaris Etheridgei*, in compliment to Mr. R. Etheridge, jun., who has worked so well among the palæozoic Phyllopods and other fossils.

Whether or no the hinder cleft in *Dipterocaris* was ever occupied by a triangular piece, lost after death, we cannot say. No direct evidence supports the idea that there was a portion of the test filling in this posterior notch; but the elongate triangle defined by the radiating furrows in *Pholadocaris Leeii*, and by ridges (?) in *Ph.* sp. (F. A. Roemer's 'Aptychus'), seems to be an analogous feature. On the other hand, the posterior notch in *Dipterocaris* may have had reference to the protrusion of the abdominal somites, as suggested by Mr. J. M. Clarke, 'Amer. Journ. Sci.' 3, vol. xxv. p. 124. Mr. Clarke, *loc. cit.*, considers it probable that the anterior cleft was also permanently open, for the convenient protrusion of the cephalic appendages; but analogy with other *Phyllocarida*, and especially the abrupt termination of the concentric lines of growth on the edges of the notch (as if the lines were continued on a cephalic piece, as in allied forms), are our reasons for retaining the views we have already expressed.

DIPTEROCARIS.

Dipterocaris pes-cervæ	Without Goniatites.	Upper Devonian,	New York State.
„ *vetusta*	With „	„ „	Hartz.
„ *procne*		„ „	New York State.
„ *pennæ-dædali*	Without „	„ „	„ „
„ *Etheridgei*		Lower Silurian,	Scotland.

VIII. PTEROCARIS, Barrande, 1872. *Pt. bohemica*, Barr. 'Syst. Silur. Bohême,' vol. i. Supplem. p. 464, pl. 25, figs. 25, 26.

A single specimen (a cast) of this interesting form has been carefully described by M. J. Barrande in detail. Its apparent relationship to *Aptychopsis* and other fossil Phyllopods is pointed out; its anterior, triangular, apparently fixed, rostral piece, and its open and deep posterior cleft, are described and figured, together with the radiate ornament of the lateral pieces of this cast. The fossil is flat. Broadly obovate in outline (outside the notch). Length 12 mm., width about 12 mm.

In general shape *Pterocaris* corresponds with *Dipterocaris*, and indeed exhibits the cephalic or rostral piece, which has been lost from the other specimens known. The ornamentation, however, as preserved on the cast (apparently of the inner or lower side) is peculiar, being *striæ* radiating from a straight line which reaches along the greatest length of each wing or lateral piece, and is parallel to the median line of the isthmus; or rather the striæ look as if they would converge centrally on the isthmus, if they were not interrupted by the longitudinal line on each wing. In *Dipterocaris* the ornamental lines are concentric with the isthmus.

From the quartzite of D *d* 2 (Lower Silurian = Llandeilo and Caradoc) at Mount Drabow, with *Caryon bohemicum*, *Zonozoe*, 2 spp., and *Cytheropsis testis*.

The last-mentioned fossil is an internal cast apparently, as M. Barrande suggests, of some half-shut Entomostracan bivalve; side-view elongate, subelliptical, with a straight dorsal edge and neatly rounded ends. The edge-view of the cast is like a half-opened bivalve carapace, with a definite strong anterior notch and a small weak posterior indentation between the ends of the valves.

Cytheropsis is not a good generic term; but we cannot offer any additional information on this peculiar form.

Zonozoe complexa and *Z. Drabowensis* (*op. cit.* p. 554, &c.) may possibly prove to be symmetrical opercula of some shells.

M. Barrande's *Cryptocaris* (*op. cit.* pp. 459, &c.) was placed by him next to *Aptychopsis* with considerable doubt. We incline to the belief that most of the examples of this little form correspond with opercula of Gasteropods, and thus are comparable with such fossils as *Peltarion*, which is now known to be the opercule of a *Neritopsis*. We may suggest also that some of the forms referred to *Cryptocaris* have a distant likeness to the opercula of such Corals as *Goniophyllum*, &c.

IX. Crescentilla, Barrande, 1872. *Crescentilla pugnax*, Barr. 'Syst. Sil. Bohême,' vol. i. Supplem. p. 507, pl. 26, figs. 1a–i.

Placed among the doubtful Entomostracan forms by our late friend Barrande, this curious little fossil seems to us to fall into its natural grouping near *Pterocaris* and *Dipterocaris*, for it is *open behind*, and, though found in separate parts, it was also found with sides united, and it may have been *sutured* along the very short line of junction which the shape of its laterals allowed.

If we look at M. Barrande's fig. 1 *b* in a position reversed (upside down) to that in which it is drawn, we shall readily observe that the two reniform lateral pieces, meeting at their convex borders, have the characteristic triangular cephalic piece at one end, and an open notch at the other, just as in *Pterocaris*. The shape, however, of the nearly semicircular or short-reniform laterals, with their outside crescent points, makes them markedly distinct. The test, apparently smooth, and faintly convex, has been replaced by iron-oxide. It is minute, being only a little more than 1 mm. in fore and aft measurement, by about 2 mm. across. Specimens were found in Étage d; some in d 2, near Trubsko; most in d 3, near Trubin: a few in d 4, near Chrustenitz, and d 5, near Koenigshof.

'Thus,' says M. Barrande, 'this species ranges nearly throughout the Quartzites D, *c* to *d* of the *Faune seconde*.'

X. Aptychopsis, Barrande, 1872. 'Syst. Sil. Bohême,' vol. i. Suppl. pp. 436, 455; and H. Woodward, 1872, 'Geol. Mag.' vol. ix. p. 564; 'Report Brit. Assoc. for 1872, 1873,' p. 323.

A circular or elliptical, slightly convex, tripartite shield or carapace; divided by a median 'dorsal' suture extending from the posterior margin forward to within half, or a third, or a fifth, of the length of the test, according to the shape of the latter, and then meeting the apex of a symmetrical V-shaped suture, which extends to the front margin at different angles in different species. This angular ('nuchal') suture forms a line of much weaker resistance than the longitudinal suture; and the carapace has very frequently given way after the death of the animal, and allowed the triangular ('rostral' or 'cephalic') portion to be removed, together with the anterior limbs and soft parts of the animal, as suggested by Dr. H.

Woodward.[1] Thus an angular notch is often present in the forepart of the fossil carapace. The median suture has often been pressed inwards, but more frequently it has parted, leaving the two larger parts of the test separate. These remain as subtriangular plates, straight-edged but angular on the inner margin, and either elliptically curved or almost semicircular on the outer or free borders. They occur usually as black carbonaceous films on the bed-planes of the strata; but sometimes they have a somewhat corneous or chitinous appearance.

A concentric linear ornament covers the whole shield; numerous delicate ridges and furrows, following the curve of the outer margin, converge and are concentric at the point where the dorsal and nuchal sutures meet, at or in front of the centre of the test. The style of ornament is similar to that of the bivalve *Estheria*, which shows a neat arrangement of raised lines of growth, concentric with the umbones. In the case of *Ellipsocaris*, even the interlinear sculpturing is present. ('Geol. Mag.' Oct. 1882, p. 445.) If the two valves of *Estheria* be laid open, their surface would represent the shield of *Aptychopsis*; the open angle then formed by their anterior margins would be analogous to the nuchal notch; and for that of their hinder margins we may find an analogue in the split posterior border of *Dipterocaris* and other forms allied to *Discinocaris* and *Aptychopsis*.

1. *Aptychopsis prima*, Barrande, 1872, and var. *Secunda*. 'Parallèle entre la Bohême et la Scandinavie,' 1856, p. 62. 'Syst. Sil. Bohême,' vol. i. Suppl. 1872, p. 457, t. 33, figs. 1–21. Roemer, 'Leth. Geogn.' 1876, t. 19, f. 3*a*, 3*b* (after Barrande).

This includes, according to M. Barrande, both round and somewhat obovate forms of the tripartite shield-like test, which both Barrande and H. Woodward termed *Aptychopsis* independently in the same year (1872).

Among the figures on plate 33 of 'Syst. Sil. Bohême,' vol. i. Supplem. *circular* forms are represented by figs. 1–8, 12–18, 20, and 21; and more or less *obovate* tests by figs 9–11 and 19.

In the British Museum (Natural History) are some specimens labelled by M. Barrande many years ago, as '*Aptychus ? primus*' and '*Aptychus ? secundus*.' The former were decidedly obovate forms, when perfect, with the two lateral moieties and the frontal (cephalic or rostral) in place; and the latter (when perfect) were nearly or quite round. Evidently our deceased friend had decided to group the two kinds together, by the time he published the Supplemental volume of his great work treating of these Phyllopods. The circular shields found in Bohemia are chiefly from the schistose or slaty mudstone of Borek, with some from Litohlow and Kozel—all in Étage 'E e 1'; and the ovate or obovate forms come from the same geological origin, but in limestone at other localities, as Butowitz, Slawick, and Wohrada, and rare at Kozel.

We think that it will be advisable to distinguish the two forms, by regarding one of them as *varietal*. Keeping M. Barrande's specific term *Aptychopsis prima*, because his extensive series of specimens gave him reason to regard the majority as being rather longer in the fore and aft diameter than in the transverse direction, and therefore not essentially circular, we may look upon the elongate and decidedly obovate forms as

[1] *Quart. Jour. Geol. Soc.* vol. xxii. p. 504; and *Geol. Mag.* Dec. 2, vol. ix. p. 387.

typical, and know them as *Aptychopsis prima*, about 25 mm. long by 20 mm. in width; and with the nuchal suture at an angle of 50°. Two specimens in the British Museum (Natural History) in limestone from Butowitz, and labelled '*Aptychus? primus*,' belong to this form; also figs. 9–11 and 19 in pl. 33 of the 'Sil. Syst. Bohême,' &c.; and two small round individuals labelled '*Aptychus ? secundus*' (15 mm. in each diameter; nuchal suture with slope of 40°), in shaley mudstone from Borek, belong to the varietal form, *Aptychopsis prima*, Barrande, var. *secunda*.

M. Barrande included with doubt another form in this genus—namely, his *Aptychopsis? inflata*, 'Syst. Sil. Bohêm.' vol. i. Suppl. p. 459, pl. 33. figs. 22, 23. But this seems to be an *Entomis*, and may stand as *Entomis? inflata* (Barrande), from the hills between Lodenitz and Bubowitz, Étage E e 2.

There are no Goniatites in 'Étage E,' representing the lower part of the 'Fauna III.,' which is equivalent to the Upper Silurian. There are, however, some Goniatites (five species), rather higher up, in 'Étage F,' which is in the middle part of 'Fauna III.'

M. Barrande's careful and elaborate account of what was known of *Aptychopsis* up to 1872 is almost sufficient in every respect. See the 'Syst. Sil. Bohême,' vol. i. Suppl. 1872, p. 455.

In the Sixth Report on Fossil Crustacea to the British Association for the Advancement of Science, in 1872, Dr. Henry Woodward defined some Phyllopodous species and grouped them under the same name (independently arrived at) as M. Barrande proposed in the same year (see above). See also Dr. H. Woodward's note on *Peltocaris*, *Discinocaris*, and *Aptychopsis* in Nicholson and Etheridge's 'Fossils of the Girvan District,' 1880, pp. 210, 211.

M. Barrande (*op. cit.* p. 455) states that *Aptychopsis* had been found by Professor Angelin in Dalecarlia and Gothland in Upper Silurian strata at about the same horizon as that in which they occur in Bohemia. We cannot, however, learn of the existence of any Scandinavian specimens.

2. *Aptychopsis Wilsoni*, H. Woodward, 1872. 'Sixth Report on Fossil Crustacea—Report British Association for 1872, 1873,' p. 323; 'Geol. Mag.' vol. ix. 1872, p. 565.

This species has a discoidal shield, and was briefly described, in 1872, as having a straight (not circular) nuchal suture (making a triangular cephalic plate) and a well-marked median or dorsal suture, and as measuring $1\frac{1}{2}$ inch in length, by $1\frac{3}{8}$ inch across. There are three specimens of *Aptychopsis Wilsoni* in the British Museum, and they would probably be almost round in outline if quite perfect. They are from the Riccarton beds (Upper Silurian), at Shankend, Slitrig Water, near Hawick; Gad's Linn, near Hawick; and Elliottsfield, near Hawick, Dumfriesshire.

We may add that the cephalic notch is not so deep as in some allied forms; its apex was about one-third of the length of the median suture from the front edge of the shield. The usual concentric lines are apparent on some specimens.

One large specimen would measure 40 mm. in each diameter if complete; its nuchal suture slopes 40°. Another specimen (imperfect) measures 30 mm. across, and has a nuchal slope of 60°; difference of pressure has caused this discrepancy.

3. *Aptychopsis Lapworthi*, H. Woodward, 1872. 'Sixth Report on Fossil Crustacea,' in 'Report Brit. Assoc. for 1872, 1873,' p. 323; 'Geol. Mag.' vol ix. 1872, p. 565; 'Quart. Jour. Geol. Soc.' vol. xxxiv. 1878, p. 331.

This Phyllopod shield was also briefly described by Dr. H. Woodward at the same time and in the same Report with the foregoing. It is oval, 8 lines long by 7 broad (1 line = $\frac{1}{12}$ inch). It is concentrically striate in most of the examples preserved, and in one case it retains the cephalic plate. The best specimen has this plate in place, but the several parts and the edges of the notch have been slightly damaged and disturbed by pressure, so that its angularity is somewhat modified. This is from the Birkhill Shales in Eldinhope Burn on the Yarrow, Selkirkshire. This division of the upper part of the Moffat Shales [1] is regarded as equivalent to the lower part of the Middle Silurian (Lower Llandovery). Another specimen in the British Museum is from the Birkhill Shales at Sundhope Burn, in the same neighbourhood, and another from the Grieston Shales of the Gala Group, at Inverleithen, above the Moffat Group, and equivalent to the upper part of the Middle Silurian. A good specimen measures 17 mm. long by 14 mm. broad. Another appears to have been 23 mm. long by 18 mm. wide. The angle of the nuchal suture may have been about 50°.

A specimen of *Aptychopsis* very similar to, if not identical with, *Aptychopsis Lapworthi*, is in the University Museum, Cambridge, from the Lower-Wenlock beds of Rebecca Hill, Ulverstone. It is labelled '*Peltocaris anatina*, Salter,' and is referred to under that name in the 'Catal. Cambridge Fossils, &c.,' 1873, p. 93. The frontal notch is *angular*, the median sutural line is raised along the depressed shield, and concentric striæ are present.

In another specimen in the same Museum, the test has been narrowed by lateral pressure, acting obliquely across the long axis of the shield, as is indicated by imperfect cleavage-planes crossing the modified test at an angle of about 60°. The frontal notch has been narrowed, its sides made unequal, and its apex somewhat rounded.

This specimen is from Skelgill Beck; collected by Mr. Marr, F.G.S.

What seems to be a similar example of a modified *Aptychopsis*, squeezed into an even narrower and more lanceolate shape, has been figured by Mr. James Dairon in the 'Transactions of the Geological Society of Glasgow,' vol. vii. pl. 7, fig. 35, and referred to in the Explanation of the plate as '*Discinocaris Browniana*, var. *ovalis*, Dairon.'

All the little Phyllopod tests figured in this plate 7 are termed '*Discinocaris Browniana*' by Mr. Dairon; but they appear to belong to other genera. Fig. 29 looks like *Peltocaris aptychoides*. Figs. 31 and 34 are round shields of probably *A. glabra*, H.W. Fig. 35 seems to be a specimen of either *A. Lapworthi* or *A. glabra* much narrowed by pressure; but it may be otherwise. Figure 32 is a discoidal *Aptychopsis*,

[1] The classification of the successive formations in the Moffat district and vicinity has been worked out by Professor Lapworth, see *Geol. Mag.* vol. ix. 1874, pp. 533-536; *Quart. Jour. Geol. Soc.* vol. xxxiv. 1878, pp. 240-346; and *Proceed. Belfast Nat. Field-Club*, ser. 2, vol. i. part 4, Appendix IV. 1878; also *Catal. Western-Scottish Fossils*, by Armstrong, Young, and Robertson, 1876, p. 24. Although numerous Phyllopod shields have been met with, no Goniatites have been recorded from these beds.

but it is rather wider than long (oblately circular), and it has a very wide and deep notch.

4. *Aptychopsis glabra*, H. Woodward, 1872. 'Sixth Report on Fossil Crustacea, Report Brit. Assoc. for 1872,' p. 323; 'Geol. Mag.' vol. x. (1872) p. 565.

This is an almost circular shield when perfect, 'about 7 lines ($\frac{7}{12}$ inch) in diameter,' with a wide and deep notch, and concentrically marked. It is like *A. Wilsoni* in general appearance, but is smaller and different in proportions, having a relatively larger notch. It is also near to the discoidal forms of *A. prima*, Barrande (var. *secunda*). It is from the Buckholm beds of the Gala group, Meigle, Galashiels, Dumfries. About 18 mm. in diameter; nuchal suture sloping at an angle of 50°.

It may be the same as *Cucullella angulata*, Baily, 'Explan. Sheet 135, Geol. Surv. Ireland,' 1860, p. 13, fig. 4 (woodcut). From the Lower Silurian; Cloncannon, co. Tipperary.

Specimens closely resembling *A. glabra* have been noticed and figured by Mr. Dairon in the 'Trans. Geol. Soc. Glasgow,' vol. vii. (1883), p. 177, pl. 7, figs. 31 and 34, from the Moffat Shales.

5. *Aptychopsis*, sp.

A single lefthand portion of the shield of an *Aptychopsis* in black shale is preserved in the British Museum, unfortunately without locality, which may belong to a distinct species. It has the usual elliptico-triangular shape of these separate moieties, but it is relatively broad in front, with its anterior angle rounded, and the slope of the nuchal suture is at about 35°, which makes a low wide cephalic notch. It has delicate concentric lines, and very delicate radiating rugulæ (besides radiate lines due to breakage under pressure). It measured, when perfect, about 27 by 25 mm.

6. *Aptychopsis*, sp.

In the Museum of Practical Geology, London, are five specimens of an *Aptychopsis*, from the Cambrian slaty or schistose strata (known as Tremadoc Slates) at Garth, near Portmadoc, North Wales. They consist of elliptico-triangular moieties of an obovate *Aptychopsis* shield in different states of preservation. The apex of the notch is above the centre of the test (unless altered by pressure), and its slope is at about 50°. The outline of the whole tripartite shield would be broad-obovate. Concentric lines are faintly marked. The shape was probably (when perfect) broader than the long forms of Barrande's *A. prima*. It approaches *A. Lapworthi* also in outline, but it is not quite so full in the posterior curve, though larger altogether—probably 32 mm. long by 30 mm. broad.

7. *Aptychopsis Salteri*, H. Woodward, 1882. 'Geol. Mag.' Dec. 2, vol. ix. p. 389, t. 9, fig. 17.

This distinctly marked species had an ovate outline when perfect, broadest in the hinder half: nuchal suture sloping at about 45°, its apex reaching back a little more than a fourth of the whole length of the test. Length about 35 mm., width 26 mm.

Upper Silurian (Wenlock Shale), at Pencarreg, Caermarthenshire, South Wales.

8. *Aptychopsis*, sp.

In the University Museum at Cambridge is a small discoidal *Aptychopsis* (labelled '*A. anatina*'), which is subcircular or oblately circular (that is, transversely oval, with a broad elliptical contour). It is rather convex; the sutural line remains raised along the somewhat depressed surface; and perhaps the test is now rather broader than at first, but not far from the original size and shape. Concentric parallel lines ornament the surface; nuchal suture at an angle of about 60°; the notch occupying about a third of the length of the shield, which was 20 mm. long by 26 mm. in width.

Collected by Mr. Marr, F.G.S., in the Brathay (Lower Coniston) Flags, at Nanny Lane, Troutbeck, Windermere.

A similar form from Moffat has been figured by Mr. James Dairon in the 'Trans. Geol. Soc. Glasgow,' vol. vii. part 1, 1883, pl. 7, f. 32.

There is a somewhat similar oblately circular *Aptychopsis* in the British Museum, from the Gala Group, Gala Hill, Galashiels; but it is smaller, and has a relatively larger notch. It seems to have been 9 mm. in length (fore and aft), and 12 mm. wide. The slope of the nuchal suture is about 50°, and the notch reaches half-way down the test: this, however, has suffered considerable vertical pressure.

	Shape	Geological horizon
APTYCHOPSIS.		
1. *A. prima*, Barrande	Obovate	Upper Silurian
1*. *A. prima*, var. *secunda*	Round	Upper Silurian
2. *A. Wilsoni*, H. W.	Round	Upper Silurian
3. *A. Lapworthi*, H. W.	Oval	Middle Silurian
4. *A. glabra*, H. W.	Round	Upper Silurian
5. *A.* sp.	Obovate	?
6. *A.* sp.	Obovate	Tremadoc Slates
7. *A. Salteri*, H. W.	Ovate	Upper Silurian
8. *A.* sp.	Oblate	Upper Silurian

No Goniatites have been found with any of the above.

[N.B.—The new species will receive names when they are figured.]

XI. PELTOCARIS, Salter, 1863. *Dithyrocaris*, Salter, 1852, 'Quart. Jour. Geol. Soc.' vol. viii. p. 391; *Ceratiocaris*, Salter, 1860, 'Ann. Mag. Nat. Hist.' ser. 3, vol. v. p. 161; *Peltocaris*, Salter, 1863, 'Quart. Jour. Geol. Soc.' vol. xix. p. 87.

This Phyllopod has a discoidal, round or oval, tripartite shield, with a straight median dorsal suture, and a curved nuchal suture, which, giving way after death more easily than the other, has left in some instances a rounded, elliptical, or semi-oval cephalic notch in the shield. The separate lateral pieces of the test have an inner concave curve meeting the convexity of the outer margin, instead of a straight sloping inner edge as in *Aptychopsis*. These two lateral moieties, however, are not so frequently found separate as is the case with *Aptychopsis*. In some instances a smaller notch appears at the bottom or apex of the curved notch, sometimes with a little escutcheon peculiar to it; but this feature requires much more attention. The shield is concentrically striate as in *Aptychopsis*.

1. *Peltocaris aptychoides*, Salter, 1852, 'Quart. Jour. Geol. Soc.' vol. viii. 1852, p. 391, pl. 21, f. 10; this figure shows a specimen oblately circular, and probably squeezed obliquely. 'Ann. Mag. Nat. Hist.' 1860, *l. c.*

'Quart. Jour. Geol. Soc.' vol. xix. 1863, p. 88, f. 1 (woodcut) gives a circular form; but at p. 90, f. 4 (woodcut) gives an oval outline.

In 1866 ('Quart. Jour. Geol. Soc.' vol. xxii. p. 504, pl. 25, f. 6) Dr. H. Woodward gave a careful figure of this species from a good specimen (measuring $12\frac{1}{2}$ mm. in length and 10 mm. in width[1]), giving it its true oval outline, rather blunt at the ends, the rostral piece making a distinct curve of its own at the front (Moffat). A distorted specimen is figured in the 'Proc. Belfast Nat. Field Club,' 1877, Appendix, pl. 7, f. 24*a*, by Messrs. Lapworth & Swanston, from Tieveshilly, near Portaferry, Co. Down, Ireland. This is from either the top of the Middle Silurian or the base of the Upper Silurian (*op. cit.* p. 122). H. Woodward's figure is reproduced in illustration here, fig. 24*b*; and again by Mr. J. Dairon, 'Trans. Geol. Soc. Glasgow,' 1883, pl. 7, f. 29, for a Moffat specimen.

Some specimens in the Museum of the Geological Survey are oval. One ($D\frac{4}{46}$), almost perfect, is a pyritous film, with the rostral piece in place, and with obscure concentric lines; from the Llandeilo formation; locality unknown. Specimen $D\frac{4}{47}$ is a black film; the shield has been oval, but one half is modified by pressure. Upper Llandeilo; Duff-Kennel, Dumfries.

In the Museum at Jermyn Street there is also an imperfect *Peltocaris* ($D\frac{4}{48}$, from Moffat), of relatively large size, length ?, width 24 mm., very delicately and regularly concentric in its linear ornament; and it seems to show what Mr. Salter intimated at p. 88, 'Quart. Jour. Geol. Soc.' vol. xix. —namely, that the umbones, or angles at the front end of the median sutures, may come away by the weakness of a small curved sutural line bounding them and concentric with the striæ. See also Mr. Salter's drawing of the notch in 'Quart. Jour. Geol. Soc.' vol. viii. pl. 21, f. 10.

In the British Museum, a specimen (from the Grieston beds, Gala Group, Rotten Gair, Inverleithen), slightly modified by pressure, was probably almost oval in outline, 15 by 14 mm. Another, also broadly oval when perfect, length about 19 mm., width 16 mm., has somewhat sinuous sides to the notch, that is, it widens in the middle and then contracts, forming a small notch at its apex. Something like this, but not quite the same, is seen in the figures of the natural size and enlarged at p. 88, 'Quart. Jour. Geol. Soc.' vol. xix.; it more closely resembles fig. 10, pl. 21, 'Quart. Jour. Geol. Soc.' vol. viii.

2. *Peltocaris anatina*, Salter, 1873.

In the 'Catal. Palæoz. Fossils Cambridge,' 1873, at p. 93, Mr. Salter mentions this species, but it is not figured. The diagram annexed to it, and given in illustration of the generic type, is *P. aptychoides*. That a *Peltocaris* was intended here is evident from the words, 'its semi-oval rostrum is seldom found;' but the specimen (from Rebecca Hill) labelled with this name in the Cambridge Museum is an *Aptychopsis* (with *angular* notch). Mr. Salter's intended species cannot therefore be recognised at present.

In this Museum there is an oval Phyllopod shield, with a semi-oval notch, but it has been somewhat narrowed by lateral pressure, and the notch may have been modified by the same cause. The suture, however, cannot be made out: if it be absent, the specimen belongs to another

[1] The statement that the figure is magnified three times seems to be a mistake in the explanation of the plate.

genus, of course. Length (as it is) 23 mm., width 12 mm. This fossil was collected by Mr. Marr, F.G.S., at Long Sleddale in a Graptolitic mudstone of the Coniston series, and has been thought to be such as Salter intended for his *P. anatina*.

3. *Peltocaris*, sp.

In the British Museum, two specimens of a small *Peltocaris* in the Moffat Anthracitic shale from Wasthope Burn, at St. Mary's Loch, shows an obovate outline, broad and round anteriorly (when perfect), narrowed and pointed behind; almost cordate. A portion of the front plate remains in the semioval notch of one of the specimens. Length probably 14 mm., width 10 mm.

4. *Peltocaris*, sp.

In shape much like *Aptychopsis* No. 8, page 18; small, oblate or transversely oval, but with a very wide *semicircular* notch. In the British Museum; from the Moffat anthracitic shale of Belcraig, Annandale (either the Birkhill or Hartfell series=Lower Llandovery, or Caradoc-Bala). Length fore and aft (shortened by pressure) probably 9 mm.; transverse (rather increased) 13 mm.

In the Cambridge Museum is a similar but still smaller *Peltocaris*, shortened and widened by the mudstone having been squeezed horizontally. Fore and aft diameter probably 6 mm., transverse (increased by squeeze) 9 mm. Collected by Mr. Marr, F.G.S., in the Coniston Mudstone at Skelgill Beck, near Ambleside.

5. *Peltocaris*? *Harknessi*, Salter, 1863. 'Quart. Jour. Geol. Soc.' vol. xix. p. 89, fig. 2 (woodcut).

Shape indeterminate; it may be a piece of any large species, and the author was uncertain as to its alliance. Anthracite beds (of Llandeilo age), Dumfriesshire.

PELTOCARIS.	Shape	Geological horizon
1. *Peltocaris aptychoides*, Salter	Oval	Lower and Middle Silurian.
2. *P. anatina*, Salter?	?	?
3. *P.* sp.	Oblate	Lower Silurian.
4. *P.* sp.	Oblate	Lower or Middle and Upper Silurian.
5. *P.*? *Harknessi*, Salter.	?	Lower Silurian.

No Goniatites have been found with any of these.

XII. PINNOCARIS, R. Etheridge, Jun., 1878. 'Proc. R. Phys. Soc. Edinb.' vol. iv. 1878, p. 167; Nicholson & Etheridge, Jun., 'Fossils of the Girvan District' (1880), p. 207.

Carapace bent and probably sutured along the back. Lateral pieces, found apart, in outline like the valves of a *Pinna*; dorsal margin straight; front edge rounded (in some cases semicircular, in others elliptically rounded); ventral margin sinuous, fully convex anteriorly, sloping and sometimes partly concave posteriorly. Concentrically striate, with delicate lines following the contour of the margin and centering on a kind of umbo situate at about a third of the length of the valve from its front edge.

Where the front edges are elliptically rounded, there would be a slight notch in the same position as that in *Aptychopsis*; but there is no evidence of any cephalic or rostral piece having occupied it. On the contrary, the genus may have been truly bivalve, like *Estheria* and other such Phyllopods. This genus is known in the Lower and Upper Silurian.

1. *Pinnocaris Lapworthi*, R. Etheridge, Jun. 'Proc. R. Phys. Soc. Edinb.' vol. iv. (1878), p. 169, pl. 2, figs. 3–5; 'Fossils of Girvan,' &c.' p. 280, pl. 14, figs. 17–20.

Figs. 18, 19, and 20 have the postero-ventral edge of the valve much more contracted than fig. 17 (imperfect) would have if completed according to the contours of its remaining lines of growth. Possibly a *variety* is here indicated. Moreover, the front edge of fig. 17 is much more rounded (more semicircular) than the others, admitting of little or no cephalic piece. These are from the Lower Silurian at Balcletchie, Girvan, Ayrshire. A specimen of the form or variety shown by fig. 17—that is, with the hinder portion less pinched in—is in the British Museum, from the Upper Silurian of Kendal.

The shield is triangular-obovate, if the two lateral pieces be laid out together.

Length mm.	Greatest width of different examples mm.
32	12
30	10
28	8

No Goniatites accompany these specimens.

Caudal Appendages.

From the analogy of allied forms, we should expect that these Apudiform Crustaceans had more or less extended abdominal segments and caudal spines. With regard to this part of their organism we have not much to remark, except that a few such styles or stylets as are attached to the telson in known forms have been found in strata containing *Discinocaris*, *Peltocaris*, or *Aptychopsis*. Thus, at the Skelgill Beck, Ambleside, in the Coniston (Upper Silurian) mudstones, in which *Discinocaris* and *Peltocaris* occur, Mr. J. E. Marr found a small tapering caudal spine, 15 mm. long, and delicately striate (now in the Cambridge Museum). This may have belonged to one of the forms just mentioned. So, also, there is a small thin spine, 35 mm. long, and apparently dotted with the bases of minute prickles, in the British Museum, from the Riccarton (Upper Silurian) beds of Shankend, near Hawick; and two (probably the remnant of a set of three), one 35 mm long and fluted, and the other 20 mm. long, from the Buckholm beds (Upper Silurian) of the Gala group, Meigle Hills, Galashiels. These are large enough for *Ceratiocaris*, but only *Aptychopsis* and *Peltocaris* are known in these strata.

We may add that a few small caudal spines, 20 mm. long, have been found by Mr. Marr in the Upper Arenig Slates at the Nantlle tramway, Pont Seiont, near Caernarvon. Here they are associated with *Caryocaris*. See 'First Report on the Palæozoic Phyllopoda.'

Tenth Report of the Committee, consisting of Professor E. HULL, Dr. H. W. CROSSKEY, Captain DOUGLAS GALTON, Professors J. PRESTWICH *and* G. A. LEBOUR, *and* Messrs. JAMES GLAISHER, E. B. MARTEN, G. H. MORTON, JAMES PARKER, W. PENGELLY, JAMES PLANT, I. ROBERTS, FOX STRANGWAYS, T. S. STOOKE, G. J. SYMONS, W. TOPLEY, TYLDEN-WRIGHT, E. WETHERED, W. WHITAKER, *and* C. E. DE RANCE (*Secretary*), *appointed for the purpose of investigating the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from those Formations. Drawn up by* C. E. DE RANCE.

THE Chairman and Secretary of your Committee are both unavoidably obliged to be absent at the Montreal meeting, which is a source of regret to themselves; the more so that, this being the case, it has been thought advisable to delay presenting their final Report on the Circulation of Underground Waters in South Britain until next year, when the Committee will have been twelve years in existence. During these years particulars have been collected of the sections passed through by a very large number of wells and borings; a daily record has been obtained of the height at which water stands in many of these wells; investigations have been carried out as to the quantity of water held by a cubic foot of various rocks, by Mr. Wethered; and as to the filtering power of sandstones, and the influence of barometric pressure and lunar changes on the height of underground waters, by Mr. I. Roberts. During the present year the attention of the Committee has been directed to the remarkable influence of the earthquake which visited the east and east-central counties of England, in March last, in raising the levels of the water in the wells of Colchester and elsewhere.

More detailed information is still required as to the proportion of actual rainfall absorbed by various soils, over extended periods representing typical dry and wet years. Information on these heads and on other points of general interest bearing on the percolation of underground waters, referring to observations made in Canada or the United States, would be gladly welcomed by the Committee, and would be incorporated in their eleventh and final report to be presented next year.

Appendix—Copy of Questions circulated.

1. *Position* of well or shafts with which you are acquainted? **1a.** State *date* at which the well or shaft was originally sunk. Has it been deepened since by sinking or boring? and when? **2.** Approximate *height* of the surface of the ground above Ordnance Datum (mean sea-level)? **3.** *Depth* from the surface to bottom of shaft or well, with diameter. *Depth* from surface to bottom of bore-hole, with diameter? **3a.** *Depth* from the surface to the horizontal drift-ways, if any? What is their length and number? **4.** *Height* below the surface at which water stands *before* and *after* pumping? Number of hours elapsing before ordinary level is restored after pumping? **4a.** *Height* below the surface at which the water stood when the well was first sunk, and height at which it stands now when not pumped? **5.** *Quantity* capable of being pumped in gallons per day of twenty-four hours? Average quantity daily pumped? **6.** Does the *water-level* vary at different seasons of the year, and to what extent? Has it diminished during the last ten years? **7.** Is the ordinary *water-level* ever affected by local rains, and, if so, in how short a time? And how does it stand in regard to the level of the water in the neighbouring streams, or sea? **8.** *Analysis* of the water, if any. Does the water possess any marked *peculiarity*? **9.** *Section*, with nature of the rock passed through, including cover of Drift, if any, with *thickness?* **9a.** In which of the above rocks were springs of water intercepted? **10.** Does the cover of Drift over the rock contain *surface springs*? **11.** If so, are these *land springs* kept entirely *out* of the well? **12.** Are any large *faults* known to exist close to the well? **13.** Were any *brine springs* passed through in making the well? **14.** Are there any *salt springs* in the neighbourhood? **15.** Have any wells or borings been discontinued in your neighbourhood in consequence of the water being more or less *brackish?* If so, please give section in reply to query No. 9. **16.** Kindly give any further information you can.

Fifth and last Report of the Committee, consisting of Dr. H. C. Sorby, *F.R.S., and* Mr. G. R. Vine, *appointed for the purpose of reporting on Fossil Polyzoa. Drawn up by* Mr. Vine.

The classification which has been adopted in this Report is that formulated by the Rev. Thomas Hincks for his work on British Marine Polyzoa, which seems to be in the main accepted by Mr. A. W. Waters for his various papers since the publication of Hincks's work.

The classification of D'Orbigny [1] was based upon certain characters which, as Mr. Hincks says, had one good feature at least: his family groups had a wide range, and embraced many diversities in the mode of growth. 'His genera, on the other hand, are often founded on utterly trivial features, and have been multiplied indefinitely to represent every insignificant variation of habit.' Mr. Waters, in his paper on the 'Bryozoa from the Pliocene of Bruccoli,' says that the classification was based upon many characters by D'Orbigny, without his 'understanding their zoological signification, and the consequence was that some forms could actually belong to several genera . . . . D'Orbigny attached much greater importance to the form of the cell than to the mode of aggregate growth, and in some cases signified the form of a colony by an affix, so that there was *Eschara* and *Rept-eschara*, the first erect and the second incrusting.' His knowledge, however, 'of Polyzoan form is perhaps unsurpassed, and by his clear diagnosis and splendid plates he has given us a new revelation of the structural variety and beauty of the class.' [2]

'We owe to Professor Smitt the first serious attempt to substitute a natural system for the purely artificial arrangement hitherto in use. . . . He has aimed at a genealogical classification, starting with the proposition that the variations of species follow the line of their development, and may be in a great measure explained by it.' In dealing, however, with this question Mr. Hincks points out how difficult to the mere systematist the attempt to classify upon genealogical principles would be—'if it should ever be feasible'—and if this would be difficult in dealing with living, the difficulties would be innumerable in dealing with fossil species. In spite of this, then, there is another important feature in Professor Smitt's system that is far more practicable . . . . 'the place which he assigns to the *Zoœcium* in the construction of families and genera. The mere mode of growth he treats as a perfectly subordinate character, and bases his divisions chiefly on the essential element of the structure of the *cell*. In practice, this principle applies chiefly to the

[1] *Pal. Franç. Ter. Crét.* vol. v.

[2] Hincks, *op. cit.* p. cxx.

Cheilostomata—but the revolutionary step involves the breaking up of a large proportion of the older genera and the wide dispersion of forms hitherto most closely associated . . . . The variations of habit, which have been made the criteria of genera, may occur within the limits of a species. It is not the mode in which the cells combine, *but the cell itself* that is the true test of relationship and the essential basis of a natural group.' [1]

With the Cyclostomata we have an increase of difficulties when dealing with the cell alone, and it is almost impossible to suggest or carry out a natural grouping of forms belonging to this sub-order. Yet even here we have many special features in cell structure and cell arrangement that may be advantageous to the systematist, and it is to be hoped that my endeavours to keep certain groups intact may not be wholly illusory.

With regard to the second and third divisions of my Report, a few words will, I think, suffice for the general student at least. At the present time it is almost impossible to obtain a copy of the works, or even lists of the species, alluded to or described by many very successful labourers in my own special line of research, and, even if it were possible, the descriptive text is as a matter of course found only in books published in the mother tongue of the describers. Thus we have works on Fossil Polyzoa published in the Swedish, Dutch, German, Italian, and French languages, but very few, until quite recently, in the English. I now reproduce, for the benefit of others, these almost inaccessible treasures, and for the first time, I believe, have furnished to the palæontologist, if not complete, very nearly complete lists of all known Polyzoan forms, from the Upper Cretaceous epochs to the latest of the Glacial beds of Scotland.

It may be well to address a few words to special workers on this group. I shall be glad to exchange material from Silurian, Carboniferous, Jurassic, and Miocene beds of North Italy, for material from any horizon, not so much for the purpose of the mere possession of forms, but for the higher purpose of making a critical examination of the whole of our Fossil Polyzoa. In the exchanges—if any follow my request—I shall regard of greater importance fewer forms if the strata whence obtained are carefully noted. In the work on which I am engaged it will be evident to all that specimens indifferently selected, or whose horizon is unknown, are of but small value in a palæontological study like the present one.[2]

Sub-order I. CHEILOSTOMATA, Busk.

Family I. AETEIDÆ.

AETEA, Lamouroux.

Family II. EUCRATIIDÆ.

EUCRATEA, Lamouroux.
GEMELLARIA, Savigny.
SCRUPARIA, Hincks.
HUXLEYA, Dyster.
BRETTIA, ,,

Family III. CELLULARIIDÆ.

CELLULARIA, Pallas.
MENIPEA, Lamouroux.
SCRUPOCELLARIA, Van Beneden.
CABEREA, Lamouroux.

Family IV. BICELLARIIDÆ.

BICELLARIA, Blainville.
BUGULA, Oken.
BEANIA, Johnston.

[1] Hincks, *op. cit.* pp. cxxi. and cxxii.
[2] Address, G. R. Vine, Attercliffe, Sheffield.

Family V. NOTAMIIDÆ.
NOTAMIA, Fleming.

Family VI. CELLARIIDÆ.
CELLARIA, Lamouroux (part).

Family VII. FLUSTRIDÆ.
FLUSTRA, Linnæus.

Family VIII. MEMBRANIPORIDÆ.
MEMBRANIPORA, Blainville. MEGAPORA, Hincks.

Family IX. MICROPORIDÆ.
MICROPORA, Gray. SETOSELLA, Hincks.
STEGANOPORELLA, Smitt.

Family X. CRIBRILINIDÆ.
CRIBRILINA, Gray. MEMBRANIPORELLA, Smitt (part).

Family XI. MICROPORELLIDÆ.
MICROPORELLA, Hincks. CHORIZOPORA, Hincks.
DIPORULA, Hincks.[1]

Family XII. PORINIDÆ, D'Orb. (part).
PORINA, D'Orbigny. LAGENIPORA, Hincks.
ANARTHROPORA, Smitt (part). CELLEPORELLA, Gray.

Family XIII. MYRIOZOIDÆ.
SCHIZOPORELLA, Hincks. SCHIZOTHECA, Hincks.
MASTIGOPHORA, Hincks. HIPPOTHOA, Lamouroux.
RHYNCHOPORA, Hincks.

Family XIV. ESCHARIDÆ.
LEPRALIA, Johnston (part). PHYLACTELLA, Hincks.
UMBONULA, Hincks. MUCRONELLA, ,,
PORELLA, Gray. PALMICELLARIA, Alder.
ESCHAROIDES, Smitt. RETEPORA, Imperato.
SMITTIA, Hincks.

Family XV. CELLEPORIDÆ.
CELLEPORA, Fabricius (part).

Sub-order II. CYCLOSTOMATA, Busk.

Family I. CRISIIDÆ.
CRISIA, Lamouroux (part).

Family II. TUBULIPORIDÆ.
STOMATOPORA, Bronn. ENTALOPHORA, Lamouroux.
TUBULIPORA, Lamarck. DIASTOPORA, Lamx. (part).
IDMONEA, Lamouroux.

[1] In the body of the work I have inserted from his writings on Foreign Cheilostomata, *Ann. Mag. Nat. Hist.*, another family—MONOPORELLIDÆ—founded by Mr. Hincks. In this family, in the genus *Monoporella*, seven fossil species are described by Mr. Waters.

Family III. HORNERIDÆ.
HORNERA, Lamouroux.

Family IV. LICHENOPORIDÆ.
LICHENOPORA, Defrance. DOMOPORA, D'Orbigny.

Class POLYZOA.

= BRYOZOA, Ehrenberg, Reuss, Roemer, Manzoni, Waters, &c.
= *Bryozoa* in part of American writers on Palæozoic Polyzoa.

Sub-class HOLOBRANCHIA, E. Ray Lankester. Group *a*. ECTOPROCTA, Nitsche.

Order GYMNOLEMATA, Allman.

POLYPIARIA INFUNDIBULATA, Gervais, 'Ann. des. Sc. Nat.' 1837.
POLYZOA INFUNDIBULATA, Busk, 'Brit. Mus. Catalogue.'

Sub-order, CHEILOSTOMATA, Busk.
= CELLEPORINA, Ehrenberg.

'Orifice of the zoœcium closed by a movable opercular valve. Ova usually matured in external marsupia (ova-cells). Avicularia and vibracula (appendicular organs), frequently present.'—Hincks' 'Brit. Mar. Polyzoa,' vol. i. p. cxxxvi.

Family I. AETEIDÆ, Hincks, Smitt.

In Mr. Busk's classification which prefaces the 'Crag Polyzoa' Monograph, published in 1859, the genus *Aetea* is one of the genera of the group *Hippothoidæ*. But Smitt and also Hincks place the species of *Aetea* in a family by themselves. Mr. A. W. Waters says,[1] 'the difficulty is very great as to the position of *Aetea*, as it has relationships with the *Cheilostomata*, and also with *Ctenostomata*, in having a collar, as seen in the Naples specimens, and which Smitt pointed out in 1867; and whether it will have to be placed in a new sub-order—*Stolonata*, Carus, or *Stolonifera*, Ehlers—is yet problematic.' Mr. Hincks, however (*op. cit.* p. 2), admitting that the *Aeteidæ* constitute a peculiar group, agrees 'with Smitt in ranking them as a family distinguished by the Ctenostomatous cast of its structure. On the other hand, it must be noted that they are allied to *Eucratea* through the character of the polypide and in some other points.'

The family contains a single genus, and so far as my knowledge goes I have but few notices of fossil species; nevertheless, in making a full record of the whole of the fossil Polyzoa, it appears to me unwise to pass over those genera of which we have few fossil representatives, especially as one of the objects of this Report is to furnish the student with as full a list of synonyms, both of genera and species, as the means at my disposal will allow.

[1] 'Bryozoa of the Bay of Naples,' *Ann. Mag. Nat. Hist.*, February 1879.

Genus Aetea, Lamouroux.

1812. *Aetea*, Lamx., Busk, Smith. 1812. *Anguinaria*, Lamk (without character), Johnston. 1815. *Falcaria β*, Oken. *Cercaripora* (for *Aetea truncata*, *&c.*), Fischer.

Generic character. *Zoœcia* calcareous, tubular, erect, with a membranous area on one side; distributed along a more or less adherent, creeping fibre, dilated at intervals; orifice terminal. *Oœcia* none. Hincks (*op. cit.* p. 3).

Mr. A. W. Waters ('Bryozoa Nap.' *op. cit.* 1879, p. 115) says: 'I have noticed in the Brit. Mus. Collection that the *Aeteidæ* dissolved the shells on which they grew, and thus a permanent record is left. It is known that several Bryozoa have this power; and the idea suggests itself that some of the phenomena mentioned by Fischer[1] are of this kind, and it may not be useless to point out that in many cases it is impossible to distinguish fossil *Aetea* from *Hippothoa*.' I am glad to give currency to these hints, because in the Palæozoic rocks of Cincinnati there is a species described by E. O. Ulrich, which he named *Ropalonaria venosa*, Ulrich, which the author describes as being related to *Hippothoa* (which I question) 'but in the form and arrangement of the cells they differ widely' ('Cin. Soc. Nat. Hist. Ap.' 1879). I have in my possession a specimen of this species incrusting the Coral *Streptelasma corniculum*, Hall, and wherever the cells are broken the former existence of the fossil may be traced by the method of 'dissolving' referred to by Mr. Waters. Two species of *Aetea* are recorded by Manzoni:—

1. Aetea recta, Hincks=? *R. sica*, Couch: Manzoni = *Hippothoa sica*, Couch? (See Hincks's note, p. 7, 'Brit. Mar. Pol.')= *Stomatopora gallica*, D'Orb., 'Pal. Franç. Terr. Crét.' v. 836= *A. sica*, Norman, 'Quart. Jour. Micr. Soc.' n. s. viii. 216= *A. anguina*, B, forma *recta*, Smitt (see ref. in Hincks)=*A. sica*, Couch, Manzoni, 'Castrocaro,' p. 6, pl. vii. fig. 69.[2]
2. Aetea anguina, Hincks (Busk, Heller, Smith, Norman). *A. anguina*, Hincks. (Manzoni, 'Castrocaro,' p. 6, pl. vii., pl. vi. fig. 70.)

Both these species are described as 'frequent' by Manzoni at Castrocaro, and also living.

A long list of synonyms of this species is given by Hincks, 'Brit. Mar. Pol.' p. 4.

Family II. Eucratiidæ, Hincks.

This family embraces the genera *Eucratea*, Lamx.; *Gemellaria*, Savigny; *Scruparia*, Hincks; *Huxleya*, Dyster, and *Brettia*, Dyster, and the whole of the Family Gemellaridæ, Busk, except the anomalous genus *Notamia* (*Dimetopia* and *Calwellia*). *Didymia* is distinguished by a different type of cell.

Genus Eucratea, Lamx., 1812.

1812. *Eucratea*, Lamx., Johnston, Smitt. 1813. *Scruparia*, Oken, Busk; *Sertularia*, (pt.) Linn.; *Cellularia*, (pt.) Pallas; *Cellaria*, (pt.) Ellis and Sol. 1830. *Unicellaria*, (pt.) Blainv. 1850. *Catenaria*, (pt.) D'Orb.

[1] *Hypophorella expansa*, 'Ein Beitr. zur Kenntn. der minirenden Bryozoen, von Ehlers, Kön. Gesellsch. d. Wissensch. Göttingen, 1867.

[2] *Alecto parasita*, Heller: Manzoni in Index to Plates, p, 63, 'Castrocaro.'

Genus Gemellaria, Savigny, 1811.

Gemellaria, Van Ben., Johnston, D'Orbigny ; Busk, 'Brit. Mus. Cat.'; Smitt. 1815. *Scruparia, β*, Oken. 1820. *Semicellaria*, Blainv. *Loncaria*, Lamx., and *Crisia*, sp. Lamx. 1828. *Notamia*, Flem. 1830. *Loricula*, Cuvier.

Neither these nor the other genera accepted by Hincks contain, so far as I am aware, fossil species.

Family III. Cellulariidæ, Busk, 'Brit. Mus. Cat.'

Cellularidæ, (part) Johnston; *Cellulariadæ* and *Cabereadæ*, Busk, Brit. Mus. Cat.; *Cellularieæ*, (part) Smitt.

'*Zoœcia*, in two or more series, closely united and ranged in the same plane; avicularia and vibracula, or avicularia only, almost universally present, sessile. *Zoarium* erect, dichotomously branched.'—Hincks, *op. cit.* p. 30.

Genus Cellularia, Pallas.

'*Zoarium* jointed. *Zoœcia* in two or three series, many in each internode, contiguous; dorsal surface perforated. *Avicularia* and *vibracula* usually wanting: occasionally an *avicularium* on a few of the cells in an internode.'—Hincks, *op. cit.* p. 33.

Ibid. Busk, Smitt, part; *Bugula*, part Gray.

3. Cellularia Peachii, Busk (See Hincks, p. 34, vol. i. pl. v. figs. 2–5, vol. ii. 1880) = *C. neritinà* var., Johnst. 'Brit. Zoop.' p. 340 = *Bugula neretina*, var. *b*, *a*, *c*, *d*, *e*, 'Brit. Mus. Cat.'

This is the only recent British species of this genus. Mr. Hincks says that in some points of the structure there is an approach to the genus *Nellia*, Busk, *op. cit.* p. 35.

4. Cellularia Peachii, Busk, 'Cat. West Scotch Fos.' p. 134, ed. 1876.

This form is present in minute fragments in the Garvel Park beds, but the form differs slightly in the shape of the cells—less elongated—from recent forms. In the Miocene Beds of Montecchio, North Italy, there are small fragments of a form similar to the Garvel Park specimens, but I cannot satisfy myself that these are really allied to *Cellularia* as here defined.

Post-Tertiary formation: Scottish Glacial beds, Garvel Park. (?) Miocene: Montecchio Maggiore beds, North Italy.

Genus Menipea, Lamx.

1812. *Ibid.* Lamx. and part *Crisia*, Lamx.; *Menipea*, Lamx., Busk, Wyville Thomson; *Tricellaria*, Flem.; *Cellularia*, (part) Johnst., Smitt. 1849. *Cellarina*, (part) Van Ben.; *Emma*, Gray, Busk.

'*Zoœcia* oblong, widest above, attenuated and often elongated downwards; imperforate behind, with a sessile lateral avicularium (often wanting), and usually one or two avicularia on the front of the cell.' No vibracula. *Zoarium* jointed.'—Hincks, *op. cit.* p. 36.

The type of the genus is *M. cirrata*, Lamx., a large species with six cells in the internode, and is described as found in the Indian Ocean, and also in the Mediterranean Sea. The genus has a wide geographical range, but I find hardly any records of the existence of fossil species.

One of the two British recent examples is *M. Jeffreysii*, Norman, and of this minute fragments only were obtained in the Shetland dredgings by Mr. Jeffreys and Mr. Norman, particulars of which are given in former reports by these authors.

5. Menipea ternata, Ell. & Sol., var. Norman (?) = *Cellaria* ibid., Ell. & Sol. (See Hincks, p. 38).

Post-Pliocene: Glacial beds, Garvel Park.

The fragments found in the Garvel Park beds are very minute. 'Cat. West Scot. Foss. 1876.'

6. Menipea innocua, Waters. 'The front surface corresponds very much with *M. Jeffreysii*, Norman, but the dorsal surface is different.'—Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 261, pl. ix. f. 24.

Miocene: Mt. Gambier, South Australia.

Genus Scrupocellaria, Van Beneden.

Bicellaria sp., Blainv.; *Cellaria* sp., Johnst. & Smitt; *Cellaria* sp., Ellis & Sol., Lamk.; *Scruparia* sp., Oken; *Canda* sp., Busk.

'*Zoarium*, jointed. *Zoœcia* numerous in each internode, rhomboid; aperture with or without an operculum; a sessile avicularium placed laterally at the upper and outer angle, and a vibraculum in a bend or sinus on the lower part of the dorsal surface; frequently an avicularium on the front of the cell.'—Hincks, p. 43, *op. cit.*

Post-Glacial deposits; Coralline Crag.

7. Scrupocellaria scruposa, Linn.; Van Ben., Busk=*Bicellaria* ibid. Blainv.=*Cellularia* ibid. Waters.
8. Scrupocellaria elliptica, Reuss (range in time from recent to Up. Oligocene)=*Bactridium ellipticum*, Reuss, 'Foss. Bry. Öst.-ungar.'=*Bactridium ellipticum*, Reuss, 'Pal. Stud. Alt. Tert. Alp.' =*Canda elliptica*, D'Orb., 'Pal. Franç.' v. p. 372=*Bactridium granuliferum*, Reuss 'Öst.-ung.' p. 56=*Canda granulifera*, D'Orb. 'Pal. Franç.' v. p. 332 = *Canda granulifera*, Reuss, 'Foss. Fauna Steinsalz' = *Bicellaria granulifera*, Reuss, 'Zeits. Deutsch., &c.'—*Scrupocellaria inermis*, Norman, 'Quart. Jour. Micr. Soc.' n. s. viii. 215, 1868.
9. Scrupocellaria Hagenouii, Reuss, Miocene = *Bactridium* ibid.
10. Scrupocellaria schizostoma, Reuss. Miocene = *Bactridium* ibid. 'Öst.-ungar.' p. 56=*Canda schizostoma*, D'Orb. 'Pal. Franç.' v. p. 332.
11. Scrupocellaria scabra, Van Ben. (Glacial deposits, Scot. Miocene, Australia). For synon. see Hincks 'Brit. Mar. Pol.' p. 48; Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix.
12. Scrupocellaria reptans, Linn.
13. Scrupocellaria scabra, Van Ben. Glacial deposits, Scot.: Duntroon, Paisley.
14. Scrupocellaria scabra, var. elongata, Smitt. Glacial deposits, Scot.: Garvel Park.
15. Scrupocellaria (Canda) fossilis, Waters. Mt. Gambier, Australia. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 322; 'near *Canda arachnoides*, Lamx.'—Waters.

Mr. Waters, in other papers, cites different localities.

The identification of fossil *Scrupocellariæ* is difficult, because, the fragments of species being minute, the characters have to be made out very cautiously.

Genus CABEREA, Lamouroux.

=*Cellaria* sp., Lamk.; *Flustra* sp., Flem., Johnst.; *Selbia*, Gray; *Flabellaria*, Gray; *Canda* sp., D'Orb.

'*Zoarium* not articulated. *Zoœcia* in two or more series, subquadrangular or ovate, with a very large aperture. Sessile avicularia on the side and front of the cells, the lateral avicularium minute. Vibracular cells very large, placed in two rows, stretching obliquely downwards across the back of the *Zoœcia*, which they almost cover, to the median line, notched above and traversed through a great portion of their length by a shallow groove. Setæ usually toothed on one side.'—Hincks, 'Mar. Polyz.' p. 57.

Fossil *Caberea* are, like the *Scrupocellaria* previously described, also difficult of specific identification; but the genera being so cosmopolitan, it would be surprising indeed if fragments were not distinguishable. The size of the vibracula is one of the peculiar features of *Caberea*, and the many characters of the genus given by Mr. Hincks ought to make the study of species peculiarly attractive. But much of our knowledge concerning fossil forms is furnished by Mr. A. W. Waters in his series of Papers on Australian Bryozoa. Even he, however, has had to depend in one instance on a single row of cells, while in others the 'opercula,' and the large erect avicularium have helped in the determination of specific forms.

16. CABEREA ELLISII, Fleming (Hincks, p. 59.) = *Flustra* ibid., Flem.; *F. setacea*, Flem., Johnst.; *Cellularia Hookeri*, part, Johnst.; *Bicellaria Hookeri*, Blainv.; *Caberea Hookeri*, Busk, Gosse; *Flabellaria setacea*, Gray. Glacial and Palæolithic.
17. CABEREA BORYI, Audouin, Waters = *Crisia Boryi*, Aud. = *Selbia zelanica*, *Caberea* ibid., Gray, Busk; *Caberea Boryi* = *C. patagonica*, Busk=*Canda Boryi*, D'Orb, 'Pal.'; Glacial, British; Miocene, Australia.
18. CABEREA RUDIS (?), Busk. Glacial, British; Australia, Miocene. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., vol. xxxviii.
19. CABEREA GRANDIS, Hincks. Glacial, British; Australia, Miocene. Waters.
20. CABEREA LATA, Busk. Australia, Tert. Poly. Etheridge, jun., 'Synopsis.'

Family IV. BICELLARIIDÆ, Busk, Smitt.

Genus BICELLARIA, Blainville.

In his remarks on the family BICELLARIIDÆ Mr. Hincks says: 'The *zoarium* assumes two very different and strongly contrasted conditions within the limits of this family; and it is only after carefully examining the entire series of forms included in it that we recognise the close affinity of such divergent genera as *Bicellaria* and *Bugula*. The two are connected and linked together by the genus *Bugula* and the genus *Diachoris*, of which latter we have no representatives on our coast.'—'Brit. Mar. Pol.' 64. We have no fossil *Bicellaria*, and only one, I believe, of *Bugula*.

Genus Bugula, Oken.

There has been a variety of names for species of this genus, the most distinctive of which are *Ornithopora* and *Ornithoporina*, D'Orb. 'Pal. Fr.,' and *Achamarchis*, Lamx.

'*Zoarium* erect, phytoid. *Zoœcia* boat-shaped or subquadrangular, elongate, united in two or more series; aperture occupying a large proportion (occasionally the whole) of the front, not turned upwards or oblique. *Avicularia* in the form of a bird's head, pedunculate and jointed, usually one on each cell.'—Hincks, 'Brit. Mar. Pol.' p. 73, and for synonyms, &c.

21. Bugula turbinata, Alder. = *Cellularia avicularia*, Pallas. Scotch Glacial beds, Duntroon.

Genus Beania, Johnston.

No fossil representatives known to me.

Family V. Notamiidæ, Hincks.

Genus Notamia, Fleming.

No fossil representatives known to me.

Family VI. Flustridæ, Smitt.

In the placement of this family I have put it before rather than after Cellariidæ—Fam. VI. of Hincks—more for convenience sake than for the desire of alteration by any suggestive change. The Flustridæ is Fam. VII. of Hincks, but as my real work upon fossil species will begin with the Cellariidæ, and as I have no record of fossil forms which belong to this family consisting of a single genus, *Flustra*, Linn., I wished to prevent a further break in what will follow.

(Catenicellidæ, Busk—'Crag Polyzoa.')

Mr. A. W. Waters, in his papers on 'Australian Fossil Bryozoa,' has given a list, with details and descriptions, of sixteen species of fossil *Catenicella*, but as the classificatory position of this group is not as yet decided upon, I can do no more than give the names of the various species and then refer the reader to the papers of the author, already fully referred to in this Report. In the paper on 'Fossil Bryozoa,' &c., 'Quart. Jour. Geol. Soc.' 1883, Mr. Waters has given diagrams of the 'globolus' of *Catenicella* and the names of the various morphological structures. The following are the species of Mr. Waters which he considers as new:—

1. Catenicella cribriformis, Waters.
2. " flexuosa, "
3. " marginata, "
4. " ampla, "
5. " solida, "
6. " internodia, "
7. " lævigata, "
8. " longicollis, "
9. " circumcincta, "
10. Catenicella alata, Thomson.
11. " Harveyi, "
12. " elegans, Busk;
13. " " var. Buskii, Thom.
14. " ventricosa, Busk.
15. " hastata, "
16. " taurina, "

Family VII. CELLARIIDÆ, Hincks.

= SALICORNARIADÆ, Busk; and Reuss (part); ? VINCULARIADÆ, Busk; CELLARIEÆ, Smitt.

'*Zoœcia* usually rhomboidal or hexangular, disposed in series round an imaginary axis, so as to form cylindrical shoots. *Zoarium* erect, calcareous, dichotomously branched.'

In this diagnosis Mr. Hincks (*op. cit.* p. 103) says: 'I have not included the jointed condition of the *zoarium*, as it must be accounted more than doubtful whether this character is of sufficient importance to warrant the relegation of such closely allied forms as *Cellaria* and *Vincularia*, Defrance, to different family groups.' . . . . In a portion of his work ('Ann. Mag. Nat. Hist.' Feb. 1881, p. 155), 'Contributions towards a General History of the Marine Polyzoa,' Mr. Hincks appropriates the genus *Vincularia*, Defrance, in part, as a genus of the family MICROPORIDÆ—referred to further on—remarking on *Vincularia abyssicola*, Smitt, that the 'Zoœcial character of this generic type' is 'essentially Membraniporidan.' Acting upon this hint, and in accordance with the general thoroughness of his work, Mr. Waters, in several of his suggested changes of generic names, places many forms, which other authors may regard as *Vincularia*, among the *Membranipora*, with the remark, '*Vincularia forma.*' As the name is likely to linger in our lists, but without any genuine generic fixity—or, in other words, without generic meaning in Mr. Hincks's classification—it may be as well to give as full a history of the fossil group as possible under present circumstances.

Defrance says ('Dict. d. Sc. Nat.' tome 58, p. 214): 'We have given the generic name of *Vincularia* to little quadrangular bodies which are scarcely the size of a horse-hair, and which we find in a layer of the Calcaire Grossier (= our Bracklesham beds) in the environs of Paris. They are two or three lines long, but they are not obtained perfect to their terminations. . . . They have small grains on the four sides of the little cells, the end one of which seems to be a sort of very small hole.' Defrance gives several localities where the genus has been found, but one particular form which he names *V. fragilis* is briefly described and figured in the 'Vilnes du Mus.,' and the author infers that his *Vincularia* may have had some relationship to *Flustra* (? *F. fistulosa*, Linn., 'Fauna Suec.' ii. 2234), which Hincks gives as a synonym of *Cellaria fistulosa*, Linnæus.

The next considerable addition to our knowledge of so-called *Vincularia*—in this country, at least—is furnished by M'Coy ('Carb. Foss. of Irel.' 1844). M'Coy says he accepts the genus of Defrance 'for those species without lateral branches, and having more than two rows of pores. I have not separated those specimens which have the pores all round from those having them on one side only, as it seemed impossible to separate generically such species as *V. parallela* (*Flustra* ? *parallela*, Phillips) from *V. raricosta*, M'Coy.' Since M'Coy wrote the above the species have again had to submit to changes, but both the species of *Vincularia* given by him were transposed to D'Orbigny's genus *Sulcoretepora*.

M. d'Eichwald, in his 'Palæontology of Russia,' as well, I believe, as in his other writings, adopts Defrance's genus *Vincularia*, and he gives *Glauconome*, (part) Münster, as a synonym. He describes several new species—*V. muricata*, *ornata*, and *raripora*. Through the kindness of Prof. Ferd. Roemer, of Breslau, I have received tracings and descriptions of D'Eichwald's species. The author says that 'the Polyzoary is microscopically cylindrical or angular, with from four to twenty corners, fixed by the base, simple or ramose, and that the branches are of the same as the principal stem. The genus is rarely found in the Greywacke, in the Carboniferous limestone, and is more frequent in the Cretaceous and Tertiary strata.'[1] *Vincularia muricata* is very much like M'Coy's *V. megastoma*, and *V. ornata* appears to be the more perfect form of *V. muricata*—all allied to, if not identical with, *Rhabdomeson* (Millepora) *gracile*, Phillips. *V. raripora*, D'Eich., is different from the others, but the horizon (Carboniferous) is the same. The author says: 'This very graceful polyzoon is in fragments of two lines long by a quarter of a line in width. It is cylindrical, bi- and tri-furcating. The cells elongate, oval, rather deep, almost flat; there are from three to four in a transverse row, separated from each other by a sufficiently wide space, which is sometimes of the width of the cells themselves.' I know of no British Carboniferous fossil that would answer wholly the description of D'Eichwald. In the peculiar mode of branching and bifurcating the nearest approach to it is the *Hyphasmopora* of Mr. Robert Etheridge, jun., but in this fossil there are so many peculiar features that, if these had been seen by D'Eichwald, he would have directed attention to them.

In his various writings Dr. A. E. Reuss adopts the genus *Vincularia*, Defrance, for certain forms having a peculiar 'Escharidean character,' and one characteristic of *Vincularia*, of Reuss, is that the cells are arranged round 'an imaginary central axis'; but Dr. Reuss honestly states ('Palæon. Stud.') that he is unable to distinguish between *Vincularia* and the *Escharidæ*.

As, however, other authors may have some doubts about the *Cellariidæ* character of some of the species of *Vincularia* of the Cretaceous and Tertiary epochs described by Hagenow and Reuss, I shall for the present keep the genus distinct, placing against the described forms those synonyms which seem to be the most likely to be correct, or otherwise giving the references and restrictions furnished by the authors themselves. Mr. Hincks, however, upon reconsideration, suppresses the name *Vincularia* as a distinct genus for recent species. I merely retain the name for fossil species for the convenience of future workers, and because many of the forms described are not in my cabinet.

Genus VINCULARIA, Defr. = *Glauconome*, (part) Goldfuss.

Division URCEOLATA, Hagenow.

Maestricht Beds.

22. VINCULARIA AREOLATA, Hagenow, Tab. VI. fig. 12, 'Die Bryozeen der Mastrich. &c.' 1851.
23. VINCULARIA BELLA, Hagenow, Tab. VI. fig. 13, 'Die Bryozeen der Mastrich. &c.' 1851.
24. VINCULARIA CANALIFERA, Hagenow, Tab. VI. fig. 14, 'Die Bryozeen der Mastrich. &c.' 1851.
25. VINCULARIA PROCERA, Hagenow, Tab. VI. fig. 15, 'Die Bryozeen der Mastrich. &c.' 1851.
26. VINCULARIA GOLDFUSSII, Hagenow, Tab. VI. fig. 15 = *Cellaria* ibid., Hag.

[1] *Lethæa conica*, pl. 2.

Miocene.

27. VINCULARIA CUCULLATA, Reuss, *loc. cit.* p. 60, 'Foss. Bry. Öst.-ungar.' (p. 72, *Eschara costata*); *Eschara Reussi*, Stol. (Rss. 'Faun. deutsch. Oberoligocän.' ii. p. 36); *Vincularia Haidingeri*, Rss. ('Pal. Stud. Ält. Tert. Alp.' ii.).
28. VINCULARIA BINOTATA, Reuss.
29. VINCULARIA GEOMETRICA, Reuss, pl. 33, fig. 16, 'Pal. Stud. Ält. Tert. Alp.'
30. VINCULARIA EXARATA, Reuss, pl. 34, fig. 1 = *Cellaria* ibid., 'Pal. Stud. Ält. Tert. Alps.'
31. VINCULARIA IMPRESSA, Reuss, pl. 34, fig. 2, 'Pal. Stud. Ält. Tert. Alp.'

Lower Oligocene.

32. VINCULARIA ESCHARELLA, Roemer, Tab. I. fig. 1, 'Polypar. Norddeutsch. Tert. Gebirgs.'
33. VINCULARIA PORINA, Roemer, Tab. I. fig. 2. (The other species of Roemer are referred to Goldfuss's types.)

Genus CELLARIA, (part) Lamouroux.

Cellaria, (part) Solander, Lamouroux; *Salicornaria*, Cuvier, Busk; *Farcimia*, Fleming; *Salicornia*, Schweigger.

'*Zoarium* jointed at intervals, the internodes connected by flexible horny tubes. *Zoœcia* depressed in front and surrounded by a raised border, disposed in quincunx. *Avicularia* immersed, irregularly distributed, situated above a cell or occupying the place of one. *Oœcia* immersed.'—Hincks, *op. cit.* p. 104.

'The genus *Cellaria* reaches back as far as the Cretaceous epoch at least, during which they formed a very small group, while at the same period a large number of the allied group *Vincularia* flourished . . . . and the genus ranges from shallow to very deep water. Sir Wyville Thomson found forms referable to the family which were obtained during the "Challenger" voyage at depths between 2,000 and 3,000 fathoms.'—p. 106.

Mr. A. W. Waters, in the first of his very valuable contributions[1] on the Fossil Bryozoa of Australia, gives some very technical points which came out in a rather prolonged study of recent *Cellaria*, and confirmed by him in the closer study of fossil forms. As some of his observations will be of extreme value as a check in the creation of new species out of forms belonging to one or other of the few known types, it may be well to reproduce some of his remarks, especially as Mr. Waters has been compelled to found at least two new species in the course of his investigations.

Mr. Waters says: 'The shape of the cell is so variable that it is perfectly useless as a character . . . . then the bordering rim, which is a character of *C. Johnsoni*, Busk, is sometimes found on one part of a colony of *C. fistulosa* and absent in other parts; next I found the shape of the ovicellular opening equally unsatisfactory—for in most undoubted specimens of *C. fistulosa* from Naples it occurs in some cells as a minute orbicular opening, then it is elongate oval, and in other apparently older ovicells a broad semicircular line is formed, which changes to a transversely oval opening, resembling that figured by Hincks as a

[1] *Quart. Jour. Geol. Soc.* August 1881, pp. 319, 320.

character of *C. sinuosa.* In the same specimen, before any ovicells are formed, the aperture is very near the top of the zoœcium; but afterwards its position is near the centre. Having found the position of the aperture, the shape of the ovarian opening, the shape of the zoœcium and of the bordering rim unsatisfactory characters, there only remained the avicularia; and in all the specimens I have examined I have found one form constant. The *C. fistulosa* from the Mediterranean has its rounded avicularium above the zoœcium; the *C. sinuosa* has a diagonal avicularium pointed downwards, with the lower part raised; the *C. Johnsoni,* from Rafallo, Italy, and New Guinea, has a zoœcial avicularium with a projecting hood above, as figured by Hincks. I find my observations on the recent species entirely confirmed by the examination of a large number of fossil forms.' It is very evident from this, that of the whole of the synonyms given below from Reuss and others, many still merit re-examination, and it must be remembered that in giving them from these respected authors, I give them upon their authority only. Of course Mr. Waters's synonyms may be taken as evidence of work along the lines which he himself has laid down.

34. Cellaria fistulosa, Linn., Hincks, 'Brit. Mar. Polyz.;' Reuss, 'Foss. Bry. Öst.-ungar.' ? = *Salicornaria farciminoides*, Johnst., Busk, Reuss (for other recent forms as synonyms see Hincks, p. 146) = *S. farciminoides*, Stoliczka, 'Foss. Bry. Tert.' Grünsand, Orakei Bay = *Glauconome marginata*, Münst., Goldf. 'Petrefac. Germ.' p. 100 = *Cellaria marginata*, Reuss, 'Wien. Tertiär.' p. 59 = *Salicornaria marginata*, Stol. *loc. cit.* p. 150 = *Vincularia marginata*, Roem. 'Pol. d. Norddeutsch. Tert.' p. 105 = *Vincularia submarginata*, D'Orb. 'Pal. Fr.' v. p. 60 = *Vincularia Reussi*, D'Orb. 'Pal. Fr.' v. p. 60 = *Vincularia Reussi*, D'Orb. 'Pal. Fr.' v. p. 60 = *Glauconome rhombifera*, Münst., Goldf. 'Petrefac.' p. 100 = *Salicornaria rhombifera*, Reuss, 'Fauna deutsch.' ii. p. 15 = *Cellaria affinis*, Reuss, 'Sitzungsber. ält. Wiss.' 1855, p. 259 = *Vincularia rhombifera*, Roem. *loc. cit.* 6 = *Salicornaria crassa*, S. W. 'Ann. Mag. Nat. Hist.' xiii. p. 7 = *Salicornaria crassa*, Busk, 'Crag Pol.' p. 22.

Localities.—Living, widely distributed. Fossil: Mount Gambier, common; and also from the Pliocene and Miocene of Europe. 'But as we cannot be quite sure of the descriptions of Reuss and others, that *Salicornaria farciminoides* does not include other species, it is best to refrain from giving localities.'—Waters.

35. Cellaria malvinensis, Busk = *Salicornaria* ibid., Busk, 'Mar. Poly.' p. xviii. pl. lxiii. figs. 1, 2 = *Cellaria* ibid., Waters, Bryoz. S. Victoria, 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 321, pl. xiv. fig. 3.

Localities.—Living: Falkland Island, South Patagonia (Darwin). Fossil: Mount Gambier.

36. Cellaria ovicellosa, Stol. = *Salicornaria* ibid., Stol. 'Foss. Bry. Orak.' p. 151, pl. xx. figs. 9, 10 = *Cellaria* ibid., Waters, *op. cit.* p. 321, pl. xiv. figs. 4, 5, 6; pl. xvii. fig. 62.

Localities.—Orakei Bay, New Zealand (Stol.), Mount Gambier.

37. Cellaria globulosa, Waters, *op. cit.* p. 321, pl. xiv. figs. 16, 17. Differs from *Cellaria* (Eschara) *aspasia*, D'Orb., and also from *Melicerita angustiloba*, Busk, which are near allies.

Localities.—Yarra Yarra, Victoria.

38. Cellaria perampla, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 260.

Locality.—Mount Gambier.

39. Cellaria angustiloba, Busk=*Melicerita* ibid., Busk, 'Quart. Jour. Geol. Soc.' xvi. p. 261 = *Melicerita* ibid., T. Wood, 'Geo. Obser. South Aust.' p. 73 = *Melicerita* ibid., 'Foss. Bry. Orak.' p. 155, p. xx. figs. 15, 18 = *Cellaria angustiloba*, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 260, pl. ix. fig. 28, 29, 30.

Localities.—Mount Gambier (Woods), Orakei Bay (Stol.), Bairnsdale, Muddy Creek.

Related probably (as *Cellaria*) to *Melicerita Charlesworthii*, M.-Ed.; *Escharinella elegans*, D'Orb.; *Membranipora stenostomata* and *Eschara* sp., described by Hagenow.

40. Cellaria sinuosa, Hassall (see Hincks, p. 109) = *Farcimia* ibid. Hassall, 'Ann. N. H.' vi. 172, pl. vi. figs. 1, 2 = *Farcimia spathulosa*, Hassall, ibid. xi. p. 112 = *Salicornaria sinuosa*, Johnst., Busk, Alder. = *Salicornaria farciminoides* var., Busk, 'Brit. Mus. Cat.' = *Salicornaria farciminoides*, ? Manzoni, 'Bry. Foss. Ital.' pt. iv. pl. i. fig. 1, 2 (*fide* Hincks).

Locality and Range.—Eng. Crag, Busk; Ital. Pliocene Quaternary, Livorno (Manzoni). Near Mt. Gambier, South Austral. (Rev. J. E. Wood).

41. Tubucellaria cereoides, Ell. and Sol. (*Onchopora*, Busk) = *Cellaria Michelini*, Reuss, 'Foss. Pol. d. W. Tert.' p. 61, pl. viii. figs. 1, 2 = *Tubucellaria opuntioides*, D'Orb. 'Pal. Fr.' v. p. 336 = *Cellaria Michelina*, Stol. 'Foss. Bry. Orak. Bay;' Reuss, 'Pal. Stud. alt. Tert.' p. 47; 'Foss. Fau. Steinsalz.' p. 96.

Locality.—Eocene, Grignon; Oligocene, Miocene, many localities in Austria and Hungary; Pliocene and Recent Seas.

Family VIII. Membraniporidæ, Smitt.

Celleporidæ, (part) Johnst.; *Flustrellaridæ*, (part) D'Orb.; and in part *Escharidæ*, *Escharellinidæ*, *Flustrellidæ* and *Electrinidæ* of D'Orbigny, 'Pal. Fran. T. Crét;' *Membraniporidæ*, (part) Busk.

'*Zoarium* calcareous, or membrano-calcareous, incrusting (and erect). *Zoœcia* forming an irregular continuous expansion, or in linear series, with raised margins, and more or less membranaceous in front.'—Hincks, p. 126.

The family Membraniporidæ represents, says Mr. Hincks, an earlier stage of zoœcial development as compared with the two which follow—the *Microporidæ* and the *Cribrilinidæ*—in that the calcification of the cell is always more or less imperfect. In a large proportion of cases the whole of the front is merely closed in by a membrane.—*Op. cit.* p. 126.

Genus Membranipora, Blainville.

Eschara, (part) Pallas; *Flustra*, (part) Linn., Lamarck, Fleming, Lamx., Audouin; *Discopora*, (part) Lamk.; *Cellepora*, (part) Hagenow, Reuss, D'Orbigny (for species with a calcareous lamina); *Annulipora* sp., *Conopeum* sp., *Callopora* sp., and *Amphliblestrum* sp., Gray; *Marginaria* and *Dermatopora* sp., Hagenow.

'*Zoarium* incrusting. *Zoœcia* quincuncial, or irregularly disposed, occasionally in linear series; margins raised, front depressed; wholly or in part membranaceous.'—Hincks, p. 128.

42. Membranipora Lacroixii, Audouin = *Flustra Lacroixii*, Savigny, Egypte, pl. x. fig. 9, Hincks = *Flustra distans*, Hassall, 'A. N. H.' vii., 1841, p. 369 = *Flustra Peachii*, Couch, '9th Rep. Cornw. Polytech. Soc.' 81 = *Membranipora Peachii*, Couch, 'Cornwall Fauna,' iii. 120 = ? *Membranipora membranacea*, Johnst. 'B. Z.' 2nd ed. pl. lvi. fig. 11–12 = *Conopeum reticulum*, Gray, 'B. M. Rad.' 108 = *Membranipora Lacroixii*, 'Brit. M. Cat.' ii. p. 60 = *Membranipora reticulum*, Reuss, 'Foss. Polyp. d. Wiener Tertiärbeck.' 98, pl. xi. fig. 25 = *Biflustra Lacroixii*, Smitt, 'Flor. Bryoz.' pl. ii. 18, p. iv. figs. 85, 86. Reuss gives = *Membranipora Savartii*, Busk, 'Crag Pol.' p. 31.

Locality and Range.—Coralline and Red Crag; (part) Mid. Pliocene; Palæolithic (A. Bell); Austro-Hungarian Miocene and Pliocene deposits, Vienna Basin (Reuss); Italian Pliocene beds, Volterra (Manzoni); Post-Pliocene (Dawson).

43. Membranipora monostachys, 'Brit. Mus. Cat.' ii. 61; 'Crag Poly.' p. 31, pl. ii. fig. 2; Hincks, 'Devon Cat. Brit. Mar. Polyz.' p. 131, pl. xvii. fig. 3–4; pl. xviii. fig. 1–4 = *Flustra distans*, Landsb. = ? *Flustrellaria pustulosa*, D'Orb. 'Pal. Franç. Terr. Crét.' v. 526 = ? *Membranipora nobilis*, Reuss, 'Foss. Polyp. d. W. Tertiärb.' 98.

Locality and Range.—Red Crag, Vienna Basin, Reuss.

44. Membranipora catenularia, Jameson, Hincks, p. 134 = *Pyripora ramosa*, D'Orb. 'Pal. Fr. Terr. Crét.' v. 539.

Locality and Range.—Palæolithic, Red Crag, and Cor. Crag, Scotch Glacial Dep., Post-Pliocene dep. Canada (Dawson); Italian Pliocene, Calabria (Manzoni); Pliocene of Bruccoli, Sicily (Waters).

45. Membranipora pilosa, Linnæus, Hincks, p. 137 = *Reptelectrina* ibid., D'Orb., and *R. dentata*, D'Orb. 'Pal. Franç. Terr. Crét.' v. 334.

Locality and Range.—Cor. Crag, Palæolithic (A. Bell); Australia (Waters).

46. Membranipora membranacea, Linn. (H. p. 140) = *Reptoflustra telacea*, D'Orb., 'Pal. Franç. Terr. Crét.' v. 328.

Range.—Coralline Crag, Palæolithic (Bell).

47. Membranipora lineata, Linn. (H. p. 143) = *Replectrina* ibid., D'Orb. 'Pal. Franç. Terr. Crét.' 334.

Range.—Italian Pliocene and Miocene dep. (Manzoni); S.W. Victoria, Australia (Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 323).

48. Membranipora craticula, Alder (H. p. 147), Scotch Glacial dep. (Geikie).

49. Membranipora unicornis, Flem. (H. p. 154), Scotch Glacial dep. (Geikie)

50. Membranipora Dumerilii, Aud. (H. p. 156) = *M. Pouilletii*, Busk, 'Crag Pol.' p. 32; Scotch Glacial dep.

51. Membranipora Flemingii (H. p. 162).

Range.—Pliocene, Castrocaro (M.); Scotch Glacial beds (Geikie); Palæolithic; Clays of Western Scot. (Bell).

52. Membranipora var. *gregaria*, Heller, 'Bry. Bay Nap.,' 'A. M. N. H.' Feb. 1879 = *M.* ibid., Heller, 'Die Bry. des Adriat.' = *M. aperta*, Manzoni, 'Bri. del Pl. di Castrocaro,' p. 9, pl. i. fig. 4 = ? *M. aperta*, Busk, 'Crag Pol.' p. 34.

Range.—Pliocene; Eng. Crag; Castrocaro.

53. MEMBRANIPORA ROSELLI, Aud. (H. p. 166), ? fossil.

54. MEMBRANIPORA TRIFOLIUM, S. Wood (H. p. 167), Busk, 'Crag Polyz.' 32, pl. iii. figs. 1, 2, 3, 9 (part).

Range.—Cor. Crag, Red Crag (A. Bell).

55. MEMBRANIPORA ANGULOSA, Reuss (Waters, B. Nap. Bry., A. M. N. H. p. 122); Reuss, 'Bry. Öst.-ungar.' p. 93 = *Cellepora* ibid. Reuss, D'Orb. 'Pal. Fr.' v. 398 = *Eschara excavata*, Reuss, 'Foss. Pol. W. B.' p. 72 = *Eschara subexcavata* D'Orb. *l.c.* p. 103 = ? *Membranipora deplanata*, Reuss, 'Foss. Pol. W. T.' p. 72, pl. viii. 6, 36 = ? *Hemeschara trapezoidea*, Reuss, 'Bry. v. Crosaro,' pl. xxix. fig. 14.

Range.—Abundant in the Eocene, Miocene, and Pliocene, from many localities in Austria, Hungary and Italy; Rhodes (Manzoni). Living: Florida, ? *Mollia antiqua*, Smitt; ? *Membranipora antiqua*, Busk, 'Quart. Jour. Micr. Soc.' vol. vi. p. 262.

56. MEMBRANIPORA CYLINDRIFORMIS, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 323, pl. xviii. fig. 74.

Mt. Gambier, Australia.

57. MEMBRANIPORA MACROSTOMIA, Reuss (Vincularia forma), 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 323, pl. xiv. figs. 18–19 = *Cellaria macrostoma*, Reuss, 'Foss. Pol. d. Wien. Tert.' p. 64 *Biflustra macrostoma*, Reuss, 'Die Foss. Anth. u. Bryoz. der Sch. von Crosaro, p. 274 = *Flustrellaria macrostoma*, Manzoni, 'I Bri. Foss. del Miocene d' Aust.' &c., p. 67 = ? *Biflustra papillata* Stol., 'Foss. Bry. Orak. Bay,' p. 154 = ? *M. loxopora*, Rss. Bairnsdale (Eschara forma), Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 504.

Locality and Range.—Oligocene (Bartonia), Val di Lonte; Miocene, Nussdorf (Manz.); Orakei Bay (Stol.); Mount Gambier, Australia (Waters).

58. MEMBRANIPORA ARGUS, D'Orb., Waters (*op. cit.* vol. xxxvii. p. 324, pl. xiv. fig. 20, 21) = *Vincularia argus*, D'Orb. 'Pal. Franç.' p. 253.

Range.—Cretaceous: Meudon, S.W. Victoria, Australia (Waters).

59. MEMBRANIPORA CONCAMERATA Waters (Vincularia forma), *op. cit.* p. 324, pl. xiv. figs. 22–23 = ? *Vincularia gracilis*, D'Orb. 'White Ch. France.'

Range.—Cretaceous ?: S. W. Victoria, Australia.

60. MEMBRANIPORA LUSORIA, Waters, (Vincularia forma), *op. cit.* p. 324, pl. xiv, fig. 14, pl. xviii. fig. 82 ? allied to *Nellia simplex*, Busk, *Quadricellaria* sp., D'Orb., *M. lusoria* var. *coarctata*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix. p. 434; allied to *Cellaria cactiformis*, D'Orb. 'Pal. Fr.' pl. 561, figs. 1–4.

Range.—S.W. Victoria, Busk; variety, Waurn Ponds.

61. MEMBRANIPORA MAORICA, Stol. (Waters), (Vincularia forma), 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 325, pl. xiv. fig. 69 = *Vincularia id.* Stol., 'Foss. Bry. Orak. Bay,' p. 153 = *Vincularia* ? *maorica*, Hutton, 'On some Australian Poly.' p. 23 = *Vincularia maorica*, T. Wood, 'Corals and Bryz. of the Neozoic Period, N. Z.'

Range.—Living: Tasmania (Hutton). Fossil: Orakei Bay; Hutchinson's Quarry, Oamaru; Up. Eocene of New Zeal. geologists.

62. MEMBRANIPORA GEMINATA, Waters, *op. cit.* p. 325, pl. xvi. fig. 55 (S. W. Victoria, Aust.), H. W. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 262, pl. ix. fig. 25.

63. MEMBRANIPORA CONFLUENS, Reuss = *Escharina confluens*, Reuss, 'Verstein. der böhm. Kreid,' p. 68 = *Membranipora confluens*, Reuss, *M. pedunculata*, Hincks. For remarks on allies of the above, see paper of A. W. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 262.

Range.—Living: Ceylon. Fossil (Cretaceous), Hundorf and Strehlen, Schillinge, near Bilin (Cenomanian); (Pliocene), Castel Arquato ?, S. W. Victoria, Mt. Gambier.

64. MEMBRANIPORA OVALIS, D'Orb. *op. cit.* p. 262. Mt. Gambier.

65. MEMBRANIPORA TRIPUNCTATA, Waters, pl. i. fig. 35, *op. cit.* p. 262. Mt. Gambier.

66. MEMBRANIPORA RADICIFERA, Hincks, pl. ii. figs. 26, 27, *op. cit.* p. 262. Mt. Gambier. Living: Bass's Straits.

67. MEMBRANIPORA DENTATA, D'Orb. *op. cit.* p. 263, pl. viii. fig. 14 = *Flustrellaria dentata*, D'Orb. 'Pal. Fr.' p. 525 = *Membranipora annulus*, Manzoni, 'Bri. Foss. Ital.' 4ta. cont. Castrocaro, p. 12, pl. i. fig. 9.

Range.—Cretaceous (Senonian); Pliocene (Manz); Helvetian, Zanclean, Astian and Sicilian beds. Mt. Gambier, Aust. (Waters).

68. MEMBRANIPORA ARTICULATA, Waters (Vincularia forma), *op. cit.* p. 264, pl. viii. figs. 15–16.

69. MEMBRANIPORA PERVERSA, Waters (Vincularia forma), *op. cit.* p. 264, pl. ix. fig. 32.

Range.—Mt. Gambier.

70. MEMBRANIPORA APPENDICULATA, Reuss (Eschara forma); Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 504, pl. xxii. figs. 2 to 5 = *Cellepora* ibid., Rss. 'Foss. Polyp. d. Wien. Tert.' p. 96 = *Membranipora* ibid., Rss. 'Die Foss. Bry. des Öst.-ung.' p. 41 = *Membranipora Cyclops*, Busk, 'Mar. Poly.' p. 61.

Range.—Fossil: Miocene, Europe; Upper Oligocene, Astrupp; Mid. Oligocene, Mt. Gambier, Australia. Living: New Zealand.

71. MEMBRANIPORA ROBORATA, Hincks, 'Gen. Hist. of Mar. Poly.,' 'Ann. Mag. Nat. Hist.' ser. v. vol. viii. p. 69, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 433.

Range.—Fossil: Waurn Ponds, Australia. Living (bilaminate): New Zealand.

72. MEMBRANIPORA OCULATA, Busk (Waters) *op. cit.* p 434, pl. xii. fig. 22 = *Nellia oculata*, Busk, Smitt, Macgillivray.

Range.—Living, widely distributed; fossil, Waurn Ponds, Australia.

73. MEMBRANIPORA ARETHUSA, D'Orb. (Waters), *op. cit.* p. 434, pl. xii. fig. 19 = *Eschara* ibid., *E. actæa*; *E. gallica*, D'Orb. 'Pal. Franç.'; and allied to *Semieschara disparilis*, D'Orb., as well as many other sp. of D'Orb.

Range.—Cretaceous, France; Muddy Creek, Australia.

Genus MEGAPORA, Hincks.

Only one living species of this genus is given by Hincks ('Brit. Foss. P.' p. 171), which is *Megapora ringens* = *Lepralia* ibid., Busk. I know of no fossil forms.

Family IX. MICROPORIDÆ, Smitt.

Hincks, *op. cit.* p. 172. *Membraniporidæ*, (part). Busk.

'*Zoœcia* with the front wall wholly calcareous; margins elevated.' —Hincks, p. 172.

This family group is a very important one, as it entirely eliminates from the series all those forms that have a membranous area in the front of the cell.

Genus MICROPORA, Gray.

= *Reptescharellina*, D'Orb.

'*Zoarium* incrusting. *Zoœcia* with prominent raised margins; front depressed, wholly calcareous; orifice semicircular, or suborbicular, enclosed by a calcareous border.'—Hincks, p. 173.

74. MICROPORA COMPLANATA, Norman (Hincks, p. 175) = *Lepralia* ibid., Norman, 'A. M. N. H.' Jan. 1864, p. 84, pl. x. fig. 4 = *Membranipora Smitti*, Manzoni, 4th Contr. 'Ital. Foss. Bryoz.'

Range.—Living, but of unknown locality: Italian Pliocene deposits.

75. MICROPORA HIPPOCREPIS, Goldf. ('Petrefac.' i. p. 26; tab. 9, f. 3); Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 264 = *Cellepora* ibid., Reuss, 'Foss. Polyp. d. Wien. Tert.' p. 94; Hagenow, 'Die Bry. Maest. Kreideb.' p. 91, pl. vi. fig. 17 = *Membranipora bidens*, Busk, 'Crag Pol.' p. 34, and 'Quart. Jour. Geol. Soc.' vol. xvi., p. 260 = *Membranipora Rosselii*, Manzoni, 'Bri. Foss. Ital.' 4th Contr. p. 11 = *Membranipora bidens*, Rss. 'Die Foss. Bry. Öst.-ungar.' p. 43; Manzoni, 'Bri. Castrocaro,' p. 15; Waters, 'Bry. from Bruccoli,' 'Tr. Manchester Soc.' vol. xiv.

Range.—Fossil: Cretaceous, Maestricht; Miocene; Pliocene Cor. Crag, Castrocaro; Bruccoli, Sicily. Living, only at Capri, from the coral fisheries (A. W. W.).

76. MICROPORA ORDINATA, Waters (Eschara form), Waters, *op. cit.*, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 435. No figures.

77. MICROPORA CAVATA, Waters (Eschara form), Waters, *op. cit.*, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 435. No figures.

Range.—Miocene; Australia, Waurn Ponds.

Genus STEGANOPORELLA, Smitt.

Membranipora, (part) auctt.; *Reptescharellina*, (part) D'Orb.; Smitt, 'Flor. Bry.' *Steganoporella.*

'*Zoarium* incrusting or (occasionally) rising into foliaceous expansions. *Zoœcia* with the external characters of Micropora, but having an inner chamber occupying the whole of the cavity below, and above narrowed into a tubular passage, which either communicates directly with the orifice or opens into a second chamber immediately beneath it.'—Hincks, p. 176.

78. STEGANOPORELLA SMITTII (Hincks, p. 178) = *Membranipora Andegavensis*, Busk, 'Crag Pol.' p. 35, pl. ii. figs. 5 and 9.

Range.—Coralline Crag.

79. STEGANOPORELLA PATULA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., pl. ix. fig. 31, p. 265 (*Micropora patula*, Waters), *loc. cit.*, Aug. 1881.

80. STEGANOPORELLA MAGNILABRIS, Busk ('B. Mus. Cat.' p. 59), 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 265 = *Steganoporella elegans*,

Smitt, 'Flor. Bry.' p. 15, pl. iv., figs. 96 and 101 = *Escharellina* sp., D'Orb. (Smitt) = *Membranipora magnilabris*, Busk, 'Mar. Poly.' p. 62, pl. lxv., fig. 4.

81. STEGANOPORELLA MAGNILABRIS, Busk (Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 506, pl. xxii., figs. 7 and 7*a*, Waters = *Lepralia firma*, Reuss; *Biflustra crassa*, Haswell; *Vincularia neozelanica*, Busk; *Steganoporella magnilabris*, Hincks, MacGillivray.

Range.—Fossil: Mount Gambier & Victoria, Australia; Mt. Gambier, Busk. Living: Florida, Smitt.

82. STEGANOPORELLA ROZIERI, Aud.; var. *indica*, Hincks, 'Gen. Hist. Mar. Pol.,' 'Ann. Mag. Nat. Hist.' ser. v. vol. iv. p. 339, 8180; Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 505 = *Eschara ignobilis*, Reuss = *Vincularia Novæ Hollandiæ*, Haswell, *loc. cit.* p. 505 = *Vincularia steganoporides*, Goldstein.

Range.—Living: India and several other localities. Fossil: Miocene, Solingen.

83. STEGANOPORELLA PERFORATA, MacG.; var. *clausa*, Waters = *Membranipora*, ibid., 'Zool. of Victoria,' decade iii. and decade iv. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 505=? *Monoporella lepida*, Hincks.

Genus SETOSELLA, Hincks.

No record of as a fossil.

Family X. CRIBRILINIDÆ, Hincks.

'*Zoarium* adnate, forming an indefinite crust, or erect. *Zoœcia* having the front wall more or less fissured, or traversed by radiating furrows.'—Hincks, p. 182.

Genus CRIBRILINA, Gray.

Reptescharella, D'Orbigny; *Escharipora*, Smitt, 'Oefv. Kongl. Vet. Ak. Förhandl.' 1867, Bihang. *Cellepora*, (part) Fabr.; *Lepralia*, (part) Johnst., Busk.

Zoarium incrusting. *Zoœcia* contiguous, having the front more or less occupied by transverse or radiating punctured furrows; orifice semicircular or suborbicular.'—Hincks, *op. cit.*, p. 184.

84. CRIBRILINA RADIATA, Moll., Hincks, p. 185 = *Eschara radiata*, Moll, 'Seerinde,' 63, pl. iv., fig. 17 = *Lepralia innominata*, Couch, Busk, 'Crag,' p. 40, pl. iv. fig. 2 = *Lepralia innominata*, Manzoni, 'Pliocene Ital.' 1st Contr. 8, pl. ii., fig. 13 = *Lepralia multiradiata*, Reuss, 'Oberburg,' 31, pl. x., fig. 5, 'Palæon. St.' = *Lepralia scripta*, Rss. 'Sitzungsb. K. Akad. d. Wissen., pl. xv. f. 63 = *Lepralia scripta*, Rss., Manzoni, 'Suppl.' &c. 5, pl. i. fig. 6 = *Lepralia preliosa*, Rss., 'Bryoz. d. deutsch. Septarienth.' = *Lepralia calomorpha*, Rss., *loc. c.* 62, pl. xi. fig. 10 = *Lepralia raricostata*, Rss., 'Bry. Öst.-ungar.' p. 26, pl. i., fig. 8 = *Lepralia Endlicheri*, Rss., *loc. cit.* p. 31, pl. i., fig. 9 =? *Reptescharella pygmea*, D'Orb., 'Pal. Fr. Tert. Crét.' v. 468 = ? *Reptescharella radiata*, D'Orb., 'Pal. Fr. Tert. Crét.' v. 468 = *Cribrilina radiata*, *C. innominata*, Smitt, 'Flor. Bry.' = ? *Lepralia cribrilina*, Manzoni, 'Bri. di Castrocaro,' p. 27, pl. iii., fig. 40 = *Lepralia elegantissima*, Seguenza (*fide* Waters), 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 265 = *Lepralia megacephala*, Rss., 'Polyp.

d. Wien. Tertiar.' p. 83, pl. x. fig. 5. Smitt says these species should be placed very near to present one.—*Semiescharipora fragilis*, D'Orb., 'Pal. Ter. Crét.' v. p. 480; *Semiescharipora brevis*, D'Orb., 'Pal. Ter. Crét.' v. p. 485; *Semiescharipora ovalis*, D'Orb., p. 488 (*fide* Smitt, 'Bry. Florida,' &c.). Some of Reuss's species are described as *Cellepora*.

Range.—Eng. Chalk: Vine, 'B. Assoc. Rep.' 1883. Miocene: several localities in Austria and Hungary; Mount Gambier, Australia: Pliocene, Post-Pliocene. I have also in my collection a specimen similar to our own Cretaceous form, from the Yellow Limestone (Cretaceous), Timber Creek, N. America. Living: rather widely distributed.

85. Cribrilina punctata, Hassall (Hincks, p. 190) = *Lepralia* ibid., Hass., Johnst., Busk, 'Crag Pol.' 40, pl. iv., fig. 1.

Range.—Coralline Crag. Recent, very widely distributed.

86. Cribrilina annulata, Fabric. (Hincks, p. 193) = *Cellepora annulata*, Fabr. = *Reptescharella Heermannii*, Gabb & Horn, 'Monog. Polyz.' = *Escharipora annulata*, Fabr. (Smitt, 'Florid. Bry.').

Range.—Scotch Glacial deposits. Living: Brit. Seas; Florida (Smitt); Gabb & Horn's sp., Santa Barbara; Miocene (?).

87. Cribrilina figularis, Johnst. (not *C.*, *ibid.*; Smitt, Florid. Bry.). Allied forms, *Escharella Arge*, D'Orb. (See Hincks, p. 197) = *Lepralia Ungeri*, Reuss, 'Öst.-ungar.' Seems to be a connecting form between *C. figularis* and *C. radiata*. *Lepralia Haueri*, Reuss, closely allied to present form.

Range.—? Cretaceous, D'Orb. sp.; Miocene, Reuss sp.; Lower Coralline Crag (Bell).

88. Cribrilina terminata, Waters (*Hemeschara* form), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 326; *ibid.* vol. xxxviii., p. 507; *ibid.* vol. xxxix., p. 436, pl. xii. fig. 17.

Allied forms, *Lepralia scutulata*, Busk.

The marginal cells of the American Cretaceous *Eschara digitata*, Lonsd. have their surfaces punctured below the orifice in a very similar manner to *C. terminata*, Waters, only not so thickly. The other cells are quite plain.

Range.—S. W. Victoria; Bairnsdale (Gippsland); Muddy Creek, Australia.

89. Cribrilina dentipora, Waters (Bactridiiform), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 326, pl. xv. f. 33.

Range.—S.W. Victoria, Australia.

90. Cribrilina suggerens, Waters. (*Eschara* form), *op. cit.* vol. xxxvii., p. 327, pl. xvii. fig. 75.

'This is a most curious and instructive form, in which we are at the outset met by a difficulty as to its generic position; for, looking at the aperture, we find it might belong to *Cribrilina* or *Mucronella*. With the latter, however, in other respects there is little in common; but with *Cribrilina* we find the radiating character of the pores, and although no known species has such a bristling surface, yet in *C. Gattyæ*, *C. cribrosa*, Heller, *C. figularis*, &c. there is a row of slightly raised pores round the edge of the cribriform area.'—Waters.

Range.—S. W. Victoria, Australia.

91. Cribrilina tubulifera, Hincks. Waters, *op. cit.*, vol. xxxix., p. 436.

Range.—Living, Bass Straits, Hincks; Fossil, Muddy Creek, Australia.

92. CRIBRILINA MONOCEROS, Busk (non Reuss) = *Lepralia* ibid., Busk, 'Mar. Poly.' p. 72 = *Lepralia* ibid., MacGill., 'Zool. Vict,' decade iv. p. 32 = *Cribrilina*, Hincks, 'Proceed. Lit. & Phil. Soc. Liverpool,' April, 1881; 'Ann. Mag. Nat. Hist.,' July, 1881.

Range.—Living: Bass's Straits. Fossil: Bairnsdale (Gippsland).

Genus MEMBRANIPORELLA (part), Smitt.

Berenicea, (part) Flem.; *Lepralia*, (part) Johnston, Gray, Busk; *Membranipora*, (part) Smitt.

'*Zoarium* incrusting, or rising into free, foliaceous expansions, with a single layer of cells. *Zoœcia* closed in front by a number of flattened calcareous ribs more or less consolidated.'—Hincks, 199.

93. MEMBRANIPORELLA NITIDA, Johnst. (Hincks, p. 200) = *Escharoides* ibid., Milne-Ed. = *Berenicea* ibid., Flem.; *M. nitida*, Waters. 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 436; *Lepralia eximia*, Seguenza, 'Le Form. Terz. R. Accad. dei Lincei; (?) *Pliophlœa sagena*, Gabb & Horn, Monogr. (Cret. Bry. New Jersey). The authors give the following synonyms for this species = *Flustra sagena*, Morton, 'Synopsis,' p. 79, pl. 13, fig. 7; *Escharina* ibid., Lons. 'Quart. Jour. Geol. Soc.' vol. i. p. 71; *Reptescharinella* ibid. D'Orb, 'Pal. Fr.' v. p. 429.

Range.—(?) Cretaceous, Timber Creek, New Jer.; Waurn Ponds, Australia (Waters); Zanclean Calabria (Seg.). Living: Northern Seas; Capri, 225 fathoms (Waters); New Zealand (Hutton).

Family XI. MICROPORELLIDÆ, Hincks.

Celleporidæ, (part) Johnst.; *Membraniporidæ*, (part) Busk; *Porinidæ* (part) D'Orb.; *Eschariporidæ*, (part) Smitt.

'*Zoœcia* adnate and incrusting, or forming erect and foliated or dendroid zoaria; orifice more or less semicircular, with the lower margin entire; a semilunate or circular pore on the front wall.'—Hincks, p. 204.

This important family group is founded upon well-marked structural features, one of which is the 'semilunate or circular pore,' in the front wall, given in the diagnosis. Mr. Hincks indeed says, 'We do not know the physiological import of this definitely shaped opening . . . . but the character which is constant may be fairly accounted of considerable importance, and taken in combination with the form of the aperture is a good diagnostic mark,' (*l. c.* p. 205). Further particulars of this mark are given by Mr. Waters ('Quart. Jour. Geol. Soc.' vol. xxxvii., p. 313). He says, 'In studying both recent and fossil forms, I have often been impressed with the frequency with which open pores are replaced by avicularia, and think that it is a matter worthy of most careful examination.' Mr. Waters says, however, that the 'genus *Microporella* must be extended; for we are able to trace relationship from *M. violacea* with a round pore to the variety *fissa* with an elongated pore (fig. 73). Then we have *M. Yarranensis* with two or three denticulated pores in the depression, and, in this way on by *M. coscinopora* and var. *armata* to *M. symmetrica* (fig. 83).' The fossil *Microporellidæ* are well represented in the Australian deposits, and the necessarily reduced number of generic features in the group has increased the number of synonymous names; but in spite of this, the three genera which Mr. Hincks includes in the family, in his 'Brit. Marine Polyzoa,' are well marked and easily identified.

Genus MICROPORELLA, Hincks.

Eschara (part), Pallas; *Cellepora*, (part) Linn., Audouin; *Flustra*, (part) Aud.; *Berenicea*, (part) Flem.; *Lepralia*, (part) Johnst.; *Escharina*, (part) M.-Edw., Gray; *Herentia* (sp.), Gray; *Reptoporina*, (part) D'Orb.; *Porina* and *Porellina*, Smitt (non D'Orb.).

'*Zoarium* incrusting. *Zoœcia* with a semicircular aperture, the lower margin entire, and a semi-lunate or circular pore below it.'

94. MICROPORELLA CILIATA, Pallas (*Eschara* ibid., Pal.) = *Eschara vulgaris*, var. β, Moll., 'Seerinde,' 62, pl. iii. fig. 11 = *Berenicea utriculata*, Flem. 'Brit. Anm.' 533 = *Lepralia ciliata*, Johnst., Busk, Brit. M. C.; Crag Pol. 42, pl. vii. fig. 6 = *Reptoporellina subvulgaris*, D'Orb., 'Pal. Fr. Terr. Crét.' v. 477 = *Lepralia lunata*, MacGil., 'Tr. Phil. Inst. Victoria,' iv. 1860, p. 159 = *Cellapora crenilabris*, Rss., 'Foss. Poly. Wien. Tertiärb.' 88, pl. x. fig. 22 = *Cellipora pleuropora*, Rss. 'Foss. Poly. Wien. Tertiärb.' p. 86, pl. x. fig. 21 = *Lepralia utriculus*, Manzoni, 'Bry. Pliocene Ital.' = ? *Lepralia glabra*, Rss. smooth var., 'Foss. Bry. Öst.-ung.' 17, pl. iv. fig. 3.

Range.—English Coralline Crag; Middle Pliocene beds (Bell); Vienna Basin (Reuss); Italian Pliocene beds (Manzoni); Sicilian Pliocene, Bruccoli (Waters); Australian Miocene, Mt. Gambier (Waters). Living, widely distributed.

95. MICROPORELLA MALUSII, Aud. (*Cellepora* ibid.) = *Reptoporina* ib., D'Orb. 'Pal. Franç. Crét.' v. p. 443 = *Lepralia* ib., Busk, 'Crag Pol.' 53, pl. viii. fig. 3.

Range.—English Coralline Crag; Pliocene, Italy; Australia, fragments (Waters). Living, widely distributed.

96. MICROPORELLA IMPRESSA, Aud. (*Flustra* ib.) = *Lepralia pyriformis*, Busk, 'Crag Poly.' 51, pl. v. fig. 3.

Range.—Eng. Crag. Living: British seas, rather widely distributed, &c.

97. MICROPORELLA VIOLACEA, Johnst. = *Lepralia plagiopora*, Busk, 'Crag Pol.' p. 44, pl. iv. fig. 5; *Lepralia violacea*, 'Crag Pol.' 43, pl. iv. fig. 3. Manzoni, 'Brioz. Plioc. Ital.' 1st Contrib. 5, pl. i. fig. 9; *Lepralia diversipora*, Reuss, 'Foram. Anthoz. u. Bryoz. d. Deutsch.'

98. MICROPORELLA VIOLACEA, var. *fissa*, Hincks. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 329.

Range.—Eng. Crag.; Ital. Pliocene; S.W. Victoria, Australia, Mt. Gambier.

99. MICROPORELLA FERREA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 330, pl. xvii. p. 72. Mt. Gambier.

99.* MICROPORELLA FERREA, var. *perforata*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 267, pl. viii. fig. 4. Mt. Gambier.

100. MICROPORELLA ELEVATA, T. Wood, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 267, pl. vii. fig. 63–64; pl. xviii. fig. 90. Mount Gambier. = *Eschara* ibid., T. Wood.

101. MICROPORELLA YARRAENSIS, Waters, (*l. c.*, vol. xxxvii., p. 331), pl. xv. figs. 27–28.

102. MICROPORELLA COSCINOPORA, Reuss, var. *armata*, Waters (*l. c.*, vol. xxxvii., p. 331), pl. xv. fig. 25. Mt. Gambier.

103. MICROPORELLA ÆNIGMATICA, Waters (*l. c.* vol. xxxvii., p. 331), pl. xv. figs. 29–30. Mt. Gambier.

104. MICROPORELLA SYMMETRICA, Waters (*l. c.* vol. xxxvii., p. 331), pl. xviii. fig. 83. Mt. Gambier.

105. MICROPORELLA CLAVATA, Stol. (*l. c.* vol. xxxvii., pl. xviii. fig. 84 = *Flustrella*, ibid., Stol. 'Foss. Bry. Orak. Bay,' p. 139. Mt. Gambier (?) *Eschara tetrastoma*, Reuss, 'Sitz. Ak. W. Wien,' 1864. Mt. Gambier.

106. MICROPORELLA MACROPORA, Stol. (Lepralia forma). (Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 267) = *Lepralia* ibid., Stol. 'Olig. Bry.'

Range.—New species: Waters, Mt. Gambier, Victoria (S.W.); Bairnsdale, Australia.

107. MICROPORELLA DECORATA, Reuss (*Cellepora* id.), Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 508, pl. xxii. fig. 1 = *Cellepora* ibid., Rss. 'Foss. Pol. Wien. Tert.' p. 89, pl. x. fig. 25 = *Lepralia* ibid., Manzoni, 'Bry. Foss. 2nd Cont. Bry. Castrocaro' = *Lepralia* ibid. Seguenza = *Lepralia Stori*, Rss. 'Bry. Öst.-ung.' = *Lepralia formosa* (?), Seguenza.

Range.—Miocene, Hungary; Australia Bairnsdale; Pliocene, Castrocaro (Manzoni). Living, Madeira (30 fath.).

108. MICROPORELLA CELLULOSA MacGil. (forma ADEONA), Waters 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 437 = *Dictyopora* ibid., Mac G., 'Trans. Roy. Soc. Vic.' 1868 = *Adeona* ibid., Kirchenpauer.

Range.—Fossil: Muddy Creek, Australia (Waters). Living: Queenscliffe.

109. MICROPORELLA INTROVERSA, Waters, *loc. cit.*, vol. xxxviii., pl. ix. figs. 33–34. This would be *Diporula*, Hincks.

Range.—Mt. Gambier, South Australia.

Genus DIPORULA, Hincks.

Distinguished from *Microporella* by the structure of the orifice. The genus is founded upon a single species, *Diporula* (Eschara) *verrucosa*, Peach. Mr. Hincks cites as a synonym *E. lunaris*, Waters.

110. DIPORULA LUNARIS, Waters, 'Bryoz. from Pliocene of Bruccolo, Sicily,' 'Trans. Manchester Geol. Soc.' 1878 = ? *Porellina labiata*, Roemer—'I believe this is the same,' Waters.

Range.—Living: Sicilian Pliocene, Waters; Oberoligocän, Lattorf, Roemer.

Genus CHORIZOPORA, Hincks.

Flustra, sp. Audouin; *Lepralia*, sp. Johnst. and Busk; *Mollia*, pt., D'Orb.

'*Zoœcia* more or less distant, connected by a tubular network; the orifice semicircular, with the inferior margin entire; the special pore wanting.'—Hincks, p. 222.

This peculiar genus is founded upon the Flustra Brongniartii of Audouin. In his description of Lepralia Brongniartii, Aud. ('Bay of Nap. Bry,' p. 35, 'Ann. M. N. Hist.') Mr. Waters says the 'connections between the zoœcia are short tubes as shown in Savigny's fig. . . . This is interesting as showing the first step towards more widely separated cells, like *Diachoris*: and Hutton calls a form closely allied to this *Diachoris Buskii.*' It is very evident that the tubular processes cannot be relied upon as generic guides; both in the genus *Chorizopora* and also in *Diachoris* as now understood these tubular processes vary considerably, as has already been pointed out by Mr. Waters in the description of the species *D. patellaria*, var *multijuncta* (Bry. Bay Nap.).

111. CHORIZOPORA BRONGNIARTII, Aud. = *Lepralia* ibid. Busk, 'Crag Poly.' 46, pl. vi. fig. i.; Manzoni, 'Bry. Foss. Ital.' 2nd cont. 7, pl. ii. fig. 9 = *Mollia tuberculata* and *Brongniartii*, D'Orb. 'Pal. Franç. Terr. Crét.' = ? *Reptescharallinella rhomboidalis*, D'Orb. = *Lepralia capitata*, Rss. 'Bry. d. Öst.-ung.' 21, pl. iv. fig. 7.

Range.—Coralline Crag; Pliocene, Volterra and Castrocaro (Manzoni); Austro-Hungarian Miocene (Reuss). Living, widely distributed in Brit. seas.

Family MICROPORELLIDÆ.

Genus MONOPORELLA.

General character.—Zoœcia destitute of a membranous area or aperture, and of raised margins; orifice arched above, with the lower lip entire; no special pores.

This group is formed for species with a Microporellidan orifice, but destitute of the median pore, which is so striking a character of the genus Microporella. It is difficult to believe that this structure has no special significance; it is at least a much better clue to affinity than mode of growth. If this be so, the Microporellidan form from which it is absent may well be set apart as a distinct group.[1]

Family XII. MONOPORELLIDÆ.

Monoporella, Hincks.

Provisionally at least it will be better to keep the genus Monoporella apart from the Microporellidæ. If (as seems probable) the special pore of the latter is represented by the oral sinus of the Myriozoidæ, Microporella will have closer affinity with such forms as Schizoporella than with the present.

As yet the species of Monoporella described are but few, and we have hardly material for a thorough study of the type.—'Ann. & Mag. Nat. Hist.' ser. 5 vol. ix., p. 123.

M. lepida
M. nodulifera } 'Ann. & Mag. Nat. Hist.,' Feb. 1882, Hincks.
M. albicans

112. MONOPORELLA CRASSICAULES, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 270, pl. viii. fig. 23.

113. MONOPORELLA CRASSATINA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 270. pl. viii. fig. 23.

114. MONOPORELLA HEBETATA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 271, pl. vii. fig. 11.

[1] Smitt's genus Escharipora (as far as I understand it) is founded for Microporellidan forms with more than a single pore. But the physiological significance is the same, whether there be one or many, and the distinction seems to be unimportant; so also are differences in the shape of the pore.—*Ann. & Mag. Nat. Hist.* July, 1881.

115. MONOPORELLA OBLONGA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 271, pl. vii. fig. 9.

Range.—Miocene, Australia (Waters).

116. MONOPORELLA SEXANGULARIS, Goldf. = *Eschara* ibid., Hagenow, 'Maestr. Kreid,' p. 81, pl. x. figs, 345 = *Eschara Clarkei*, T. Woods, 'On some Tert. Australian Polyzoa,' &c. = *Monoporella sexangularis*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix. p. 435.

Range. — Cretaceous, Maestricht (Hagenow); Miocene, Australia (Waters).

117. MONOPORELLA ALBICANS, Hincks, 'Contrib. towards Gen. Hist. of Mar. Poly.,' 'Ann. Mag. Nat. Hist.' Feb. 1882, ser. 5, vol. ix. p. 123, pl. v. figs. 5, 5a, 5b = *Cellepora albicans*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 512.

Range.—Miocene, Bairnsdale, Australia (Waters); Living, Australian seas (Hincks).

In certain remarks on the above species Mr. Waters says (*loc. cit.* p. 512), 'I have already pointed out that *Cellepora sardonica*, Waters ("Bay of Nap. Bry.," A. M. N. H. March 1879, p. 196); *C. Yarraensis*, W.; *C. intermedia*, MacG; *C. compressa*, Busk; and *C. fossa*, Hasw., should be formed into a sub-genus; and the present form should be added to the list. I am not, however, inclined to think that they will ultimately find their place with *Monoporella*, Hincks.' These forms, as Mr. Waters is inclined to leave them with *Cellepora* provisionally, will be found further on. This form after due consideration I place in the genus *Monoporella*. Mr. Hincks describes other forms besides the one given, but of which I have no fossil record. *Monoporella* was originally placed as *Haploporella* in the family *Microporellidæ*.

Family XIII. PORINIDÆ (part), D'Orbigny.

Membraniporidæ, (part) Busk; *Escharoporidæ*, (part) Smitt.

'*Zoarium* incrusting, or erect and ramified. *Zoœcia* with a raised tubular or subtubular orifice, and frequently a special pore on the front wall.'—Hincks, p. 226.

In the absence of the special pore, and also the ovicell, it would be very easy to mistake fossil specimens of *Porina tubulosa* for *Diastopora*, or even *Bidiastopora*—but the special characters ought to be sufficient to keep the genera distinct; and although I have met with fossil specimens, which I place fearlessly with *Diastopora*, yet in some of the zoœcia there are faintly indicative structural peculiarities that cannot be accepted as normal features of Cyclostomatous Polyzoa. These, however, should be closely studied and noted. In some of the *Porinidæ* described by Mr. Waters, the characters are still very difficult to understand or identify; yet, notwithstanding the apparent anomaly in his synonyms, I think that we cannot but be thankful to him for the labours he has bestowed upon the group, especially so when we look over synonymous genera given below from Hincks.

Genus PORINA, D'Orbigny.

Eschara, (part) auctt.; *Bidiastopora*, (part) D'Orb.; *Pustulipora*, (part) Sars; *Lepralia*, (part) Busk; *Onchopora*, (part) Busk; *Quadri-*

cellaria, Sars. (not D'Orb.); *Anarthropora*, (part) Smitt; *Tessaradonia* (part), Norman; *Cylindroporella*, sp. Hincks.

'*Zoœcia* tubular or subtubular above, with a terminal circular orifice; a median pore on the front wall. *Zoarium* incrusting,[1] or erect and ramose.'—Hincks, p. 227.

118. Porina tubulosa, Norman = *Lepralia tubulosa*, Norman—see Hincks, p. 230.

Range.—Scotch Glacial deposits (Geikie); Palæolithic, A. Bell. Living, Shetland.

119. Porina coronata, Reuss (*Cellaria* ibid., Rss.); Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 333, pl. xvi. fig. 571 = *Cellaria coronata*, Rss., 'Foss. Polyp. des Wien. Tert.' p. 62, pl. viii. fig. 3 = *Eschara conferta*, Rss., *loc. cit.* p. 71, pl. viii. fig. 32 = *Acropora coronata*, Rss., 'Foss. Anth. & Bry. d. S. von Crosara' = *Spiroporina vertebralis*, Stol. 'Foss. Bry. Orak.' p. 106 = *Spiroporina vertebralis*, T. Woods, 'Cor. & Bry. Neozoic Period,' p. 23 = *Porina Dieffenbachiana*, Stol. (*loc. cit.* p. 135) = *Porina Dieffenbachiana*, T. Wood (*loc. cit.* p. 135) = *Eschara Buskii*, T. Wood, 'On some Tert. Aust. Poly.' = *Pustulopora angulata*, T. Wood, 'Tert. Aust. Poly.' 1876, p. 150 = *Myriozoum australiense*, Haswell, 'On some Aust. Poly.'

Range.—Foss.: Bartonian; Val di Lonti; Montecchio Maggiore, Vienna; Hutchinson Quarry and Oamaru, New Zealand (Lower Eocene of New Zealand Geologists); Mount Gambier, S.W. Victoria, Australia. Living: Queensland.

120. Porina clypeata, Waters; Waters, *op. cit.* vol. xxxvii., p. 332, pl. xvii. fig. 67.

Range.—Foss.: S. W. Victoria; Mt. Gambier.

121. Porina ? columnata, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 334, pl. xviii. fig. 88.

Probably related to *Eschara heterostoma*, Rss.; *Eschara duplicata*, Rss. For interesting particulars see paper as above.

Range. S. W. Victoria, Australia.

122. Porina larvalis, MacGill.; Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 269, pl. viii. fig. 19 (fig. bad) = *Lepralia* ibid., MacG. 'Nat. Hist. of Vict.,' decade iv. p. 30.

Range.—Fossil: Bairnsdale, Mt. Gambier (Waters). Living: Victoria and Bondy Bay, New South Wales.

Genus Celleporella, Gray.

See Hincks, p. 413. (No fossil species recorded.)

Genus Anarthropora, (part) Smitt.

Hincks, p. 232. (No fossil species recorded.)

Genus Lagenipora, Hincks.

Hincks, p. 235. (No fossil species recorded.)

Family XIV. Myriozoidæ, (part) Smitt.

Celleporidæ, (part) Johnston; *Porinidæ*, (part) D'Orb.; *Membraniporidæ*, (part) Busk.

[1] In the British species.

'*Zoarium* incrusting, or rising into foliaceous expansions, or dendroid. *Zoœcia* calcareous, destitute of a membranous area and raised margins; orifice with a sinus on the lower lip.'—Hincks, p. 237.

Genus Schizoporella, Hincks.

Lepralia, (part) Johnst. and Busk; *Escharina* and *Reptoporina*, (part) D'Orb.; *Escharella*, *Mollia*, *Hippothoa*, (part) Smitt.

'*Zoœcia* with a semicircular or suborbicular orifice, the inferior margin with a central sinus. Avicularia usually lateral, sometimes median, with an acute, or rounded, or spatulate mandible, occasionally wanting. *Zoarium* incrusting or forming foliaceous expansions.'—Hincks, p. 237.

123. Schizoporella unicornis, Johnst. (see Hincks, p. 238) = *Lepralia*, ibid. Johnst., Busk, 'Crag Pol.' p. 45, pl. v. fig. 4 = *Lepralia spinifera*, var. *unicornis*, Manzoni, 'Bry. Plioc. Ital.' Prima Contrib. p. 7, pl. xi. fig. 11 = *Lepralia ansata*, Johnst., Reuss, 'Bry. Öst.-ung.' pl. i. p. 18, pl. vi. fig. 12 = *Lepralia ansata*, Manzoni, 'Bryz. Foss. It.' Contrib. iii. p. 9 = *Lepralia tetragona*, Rss. 'Foss. Polyp. d. Wiener Tert.' p. 78, pl. ix. fig. 19, forma *unicornis*, Manz. 'Bry. Foss. Plioc.' Contr. iii. = *Lepralia ansata*, var. *tetragona* and var. *porosa*, Reuss. 'Öst.-ungar.' = *Reptoporina tetragona*, D'Orb. 'Pal. Fr. Ter. Crét.' v. 442.

Range.—Form *unicornis*, Cor. Crag, Vienna Basin, Austro-Hung. Miocene; Italian Pliocene; Scotch Glacial; Palæolithic. Form *ansata*, Cor. Crag; Vienna Basin; Ital. Pliocene; Palæolithic.

124. Schizoporella vulgaris, Moll. (*Eschara*) = *Cellepora otophora*, Reuss, 'Polyp. d. Wien. Tert.' p. 90 = *Lepralia cognata*, Rss. 'Bry. d. deutsch.' p. 62 = *Lepralia intermedia*, Rss. 'Bry. d. Öst.-ung.' p. 269 = ? *Lepralia tumida*, Manz. 'Bryozoa di Castro.' p. 25.

Range.—Vienna Basin, Rss.; Aust.-Hung.; Pliocene dep. Bruccoli. Living.

125. Schizoporella linearis, Hassall = *Lepralia tenella*, Rss. 'Bry. d. Öst.-ung.' p. 23.

This species in a living state varies very much, and it will be well to refer to both Mr. Hincks, 'Brit. Mar. Poly.' and Mr. Waters's paper on Bry. Bay Nap., before describing new fossil species or varieties.

Range.—Austro-Hung. Miocene; Pliocene beds, Calabria; Australia (Waters).

126. Schizoporella biaperta, Michelin (*Eschara*) = *Lepralia* ibid. Busk, 'Crag P.' p. 47; Manzoni, 'Castrocaro,' p. 21 = *Reptoporina* ibid., D'Orb. 'Pal. Fr. Ter. Crét.'

Range.—English Crag; Castrocaro; Miocene, Doué, France. Form *eschariformis*, Sicil. Plioc. Bruccoli (Waters).

127. Schizoporella auriculata, Hassall: Foss. Australia, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 273.

Var. leontiniensis, Waters, 'Bry. Pliocene, Bruccoli;' Waters, 'Manchester Geol. Soc. Trans.' vol. xiv., p. 468, 1878.

Range.—Sicilian Pliocene.

128. Schizoporella sinuosa, Busk (see Hincks).

Range.—Canadian Post-Pliocene, Dawson. Living.

129. Schizoporella cruenta, Norman = *Lepralia violacea* var. *cruenta*, Busk (Scotch Glacial).

130. SCHIZOPORELLA HYALINA, Linnæus = *Cellepora* and *Lepralia* of authors.

Range.—Scotch Glacial: Post-Pliocene, Canada; Coralline and Red Crag. Living, very widely distributed.

131. SCHIZOPORELLA VENUSTA, Norman ?= *Lepralia obvia*, Manz. 'Castrocaro.'

Range.—Scotch Glacial; ? Pliocene, Manzoni.

132. SCHIZOPORELLA VIGILANS, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 328, pl. xiv. fig. 13.

133. SCHIZOPORELLA PHYMATOPORA, Rss. (*Eschara* ibid.), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 328, pl. xv. fig. 31, 32.

134. SCHIZOPORELLA VENTRICOSA, ? Hass. (*Onchopora* ibid.), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 328.

135. SCHIZOPORELLA FENESTRATA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 339.

136. SCHIZOPORELLA SUBMERSA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 340, pl. xviii. fig. 85.

137. SCHIZOPORELLA CONSERVATA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 340, pl. xviii. fig. 81.

138. SCHIZOPORELLA SPIROPORINA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 340.

139. SCHIZOPORELLA EXCUBANS, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 341, pl. xvi. fig. 56; pl. xviii. fig. 80.

140. SCHIZOPORELLA AMPHORA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 341.

141. SCHIZOPORELLA AUSTRALIS, T. Woods, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 341, pl. xiv. fig. 15 = *Tetraplaria* ibid. T. Woods.

142. SCHIZOPORELLA CECILII, Aud. (*Flustra* ibid.), 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 272.

143. SCHIZOPORELLA CORNUTA, Gabb and Horn, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 272, pl. vii. fig. 5 = *Reptescharellina cornuta*, G. & H. 'Foss. Pol. of Second and Tert.'

144. SCHIZOPORELLA BOMBYCINA, Waters (*op. cit.* p. 274, Waters), pl. ix. fig. 36.

145. SCHIZOPORELLA MARGINIPORA, Reuss (*op. cit.* p. 274, Waters), pl. vii. fig. 2 = *Cellepora* ibid. Rss. 'Foss. Polyp. Wien. Tert.' = *Reptescharellina prolifera*, Gabb & Horn (*op. cit.*).

146. SCHIZOPORELLA ACUMINATA, Hincks (*op. cit.* p. 274, Waters).

147. SCHIZOPORELLA FILIFORMIS, Waters (*Vincularia* forma), *op. cit.* p. 274, Waters, pl. vii. fig. 12.

148. SCHIZOPORELLA SCHIZOSTOMA, MacG. (*Lepralia* ibid.), *op. cit.* p. 274; Waters, and vol. xxxix. p. 439.

Range.—The whole of the above seventeen species of *Schizoporella* are given on the faith of Mr. A. W. Waters. They are nearly all Australian fossil forms, one or two doubtfully related to European and American forms. Very full particulars—especially of the new species—are given by Mr. Waters in the various published papers already quoted.

Genus MASTIGOPHORA, Hincks.

'*Zoœcia* with a semicircular orifice, the inferior margin straight, with a central sinus: furnished with lateral vibracula. *Zoarium* incrusting.' —Hincks, p. 278.

149. Mastigophora Dutertrei, Aud. (*Flustra* ibid)=*Lepralia Woodiana* Busk, 'Crag Poly.' p. 42, pl. vii., figs. 1 and 3=*Lepralia aurita*, Reuss, 'Bryoz. d. deutsch. Septarien.' p. 62=*Lepralia otophora*, Manzoni, 'Castrocaro,' p. 23 (non *L. otophora*, Rss.).

Range.—Cor. Crag, Mitteloligocän (Rss.), Older Pliocene, Castrocaro. Living.

Genus Rhynchopora, Hincks.[1]

No fossil species recorded. See Hincks, 'Brit. Mar. Poly.' p. 385.

Genus Schizotheca, Hincks, p. 283.

No record of fossil species.

Genus Hippothoa, Lamouroux.

Catenicella, (part) Blainv.; ? *Terebripora*, D'Orb.; *Mollia*, (part) Smitt.

'*Zoœcia* distant, caudate, connected with one another by a slender prolongation of the lower extremity, so as to form linear series; branches given off from the sides of the cells; orifice subterminal, suborbicular, with the lower margin sinuated or produced. *Zoarium* adherent.'—Hincks, p. 286.

150. Hippothoa divaricata, Lamx=*H. patagonica*, Busk, 'Crag,' p. 24, pl. i. fig. 5; *H. longicaudia*, Fischer=*H. patagonica*, Busk.

Range.—Pliocene, Castrocaro, rare (Manzoni); Scotch Glacial; Palæolithic; var. *patagonica*, Cor. Crag; Hippurite Limestone, St. Grégoire (Michelin).

151. Hippothoa expansa, Dawson (see Hincks for description, *op. cit.* p. 291). 'The species is distinguished from *H. divaricata* by its large size.'—Hincks.

Range.—Post-Pliocene, Beaufort and Rivière-du-Loup, Canada (Dawson). Living, Shetland.

152. Hippothoa flagellum, Manzoni, 'Bryoz. Foss. Ital.' 4th Contrib. 6, p. 1, f. 4.

Range.—Pliocene, Calabria; Castrocaro (Manzoni).

Family XV. Escharidæ, (part) Smitt.

This is by far the most important family group founded by the Rev. Thomas Hincks in his work on the 'Brit. Marine Polyzoa,' and the description of the genera and species occupies over 100 pages of the work. So far as the different genera have been worked, the grouping appears to be perfectly natural; but at the same time, as our knowledge increases of the foreign Recent as well as Fossil forms, some of the genera might require modification. Under present circumstances it is best to adopt the family as it is.

'*Zoarium* calcareous, incrusting, or erect and lamellate, or ramose. *Zoœcia* without a membranous area, or raised margins: (α) with a simple primary aperture, horseshoe-shaped, or semielliptical, or suborbicular; or (β) with an elevated secondary orifice inclosing an avicularium; or (γ) with a primary orifice having a dentate lower margin, and a secondary orifice channelled in front or entire; or (δ), with the

[1] This genus is wrongly placed among the *Escharidæ*. It belongs to the family *Myriozoidæ*.

lower margin elevated into a mucro; in all cases destitute of a true sinus and special pores.'—Hincks, p. 295.

Mr. Hincks gives (p. 296) a brief synopsis of this group, made up of three divisions:—

I. Species with a simple primary orifice. Genera: *Lepralia*, *Umbonula*.[1]

II. Species with a secondary orifice differing in form from the primary. Genera: *Porella*, *Escharoides*, *Smittia*, *Phylactella*.

III. Species with a mucronate elevation of the peristome. Genera: *Mucronella*, *Palmicellaria*, *Rhynchopora*.[2]

I. With a simple primary orifice only.

Genus Lepralia, Johnston (part).

'*Zoœcia* usually ovate, with the orifice more or less horseshoe-shaped, arched above, contracted at the sides, and with the lower margin entire and generally slightly curved outwards. *Zoarium* incrusting, or rising into foliated expansions, composed of one or two layers of cells.'—P. 297.

153. Lepralia Pallasiana, Moll. (*Eschara*). Busk, 'Crag Poly.' pl. ix. fig. 7; Waters, 'Bruccoli Paper.'

Range.—Pliocene: Bruccoli, Sicily, Crag. Living: Scandinavia, British.

154. Lepralia foliacea, Ellis and Sol.; Manzoni, 'Brioz. Foss. Ital.' 4th Contr. p. 18, pl. i. f. 4; pl. iv. f. 24. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 268, pl. vii. fig. 3. 'There is a slight difference in the placement of the avicularia in the Australian form.'—See paper by Mr. Waters.

Range.—Bairnsdale, Australia; Italian and Sicilian Pliocene; Bruccoli (Waters). Living, various localities.

155. Lepralia pertusa, Esper (*Cellepora*).

Range.—Fossil: Scotch Glacial; Palæolithic (A. Bell); Australia (Waters).

156. Lepralia adpressa, Busk=*Lepralia lata*, Manzoni, 'Bri. Plio. Ital.' 1st Contr., pl. iii. f. 2.

Range.—Fossil: Italian Pliocene, Manzoni. Living.

157. Lepralia hippopus, Smitt.

Range.—Post-Pliocene, Cañada (Dawson). Living.

158. Lepralia edax, Busk (*Cellepora*, ibid.), 'Crag Polyzoa,' p. 59, pl. ix. fig. 6, pl. xxii. fig. 3 = *Cumulipora angulata*, V. Munst., Rss. 'Septarien.' p. 63, pl. viii. fig. 12=*L. edax*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 270.

Range.—Fossil: Australia, Mt. Gambier; Sellingen (Reuss.); Crag (Busk). Living.

159. Lepralia corrugata, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 335, pl. xvii. fig. 60. S. W. Victoria.

160. Lepralia monilifera, M.-Ed., var. *armata*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 335, pl. xv. fig. 24. S. W. Victoria.

161. Lepralia spatulata, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 335, pl. xviii. fig. 87. S. W. Victoria.

162. Lepralia cleidostoma, Smitt, var. *rotunda*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 335, pl. xviii. fig. 92. S. W. Victoria.

[1] *Umbonella* in text, pp. 296 and 316.

[2] The genus *Rhynchopora* is not given by Mr. Hincks in the introduction. I have, however, included it: see p. 3.

163. LEPRALIA BURLINGTONIENSIS, Waters (Vincularia forma), 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 270, pl. vii. f. 6. Bairnsdale.
164. LEPRALIA DEPRESSA, Busk, var., 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 509.
165. LEPRALIA BAIRNSDALEI, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 509.
166. LEPRALIA GIPPSLANDII, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 509, pl. xxii. f. 12.

Range.—The whole of the above are fossil species and varieties, described by Mr. Waters as occurring in his 'Australian Miocene' ? Material.

Genus UMBONULA, Hincks (see Brit. M.P. p. 316).

167. UMBONULA VERRUCOSA, Esper (? *Cellepora* ibid.).

Range.—Scotch Glacial; Palæolithic (Bell). Living.

II. With a raised secondary orifice.

Genus PORELLA, Gray.

'*Zoœcia* with a primary orifice, semicircular; secondary (or adult) orifice elongate, inversely sub-triangular or horseshoe-shaped, inclosing an avicularium usually with a rounded mandible. *Zoarium* incrusting or erect; foliaceous, with a single layer of cells, or ramose.'—Hincks, p. 320.

168. PORELLA CONCINNA, Busk (*Lepralia* ibid.) = *Lepralia Belli*, Dawson 'Rep. Geo. Surv. Canada.' *Porella concinni*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 271.

Range. — Scotch Glacial; Palæolithic; Post-Pliocene, Canada; Miocene? Mt. Gambier, Australia (Waters).

169. PORELLA MINUTA, Norman (*Lepralia* ibid.) = ?*Lepralia chilopora*, Manzoni, 'Castrocaro,' 32, pl. iv. f. 51.

Range.—Older Pliocene, Castrocaro (Manzoni), 'If I am right in the identification' (Hincks). Living: only a few British localities—Shetland, Hastings (Jelly).

170. PORELLA EMENDATA, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 336, pl. xvii. fig. 69.
171. PORELLA DENTICULATA, Stol. (Waters), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 936, pl. xvii. fig. 70 = *Flustrella* ibid. (Stol.), 'Foss. Bry. Orak.' p. 188, pl. xx. fig. 2.
172. PORELLA MARSUPIUM, MacG. (Waters), *op. cit.* vol. xxxix., p. 437 = *Lepralia* ibid., MacG. 'Trans. Roy. Soc. Vict.' 1868.

Range.—Miocene, Australia (Waters); MacGillivray.

Genus ESCHAROIDES, Smitt.

No fossil record. See Hincks, 'Brit. M. Pol.' p. 336.

Genus SMITTIA, Hincks.

'*Zoœcia* with the primary orifice suborbicular, the lower margin entire and dentate; peristome elevated, and forming a secondary orifice, which is channelled in front; generally an avicularium below the sinus. *Zoarium* either incrusting, or erect and foliaceous, the cells in a single or double layer.'—Hincks, p. 340.

173. Smittia Landsborvii, Johnst.; *Lepralia* ibid. See Hincks for minute particulars, pp. 341–346.

174. Var. *crystallina*, Norman.

Range.—Geikie records the variety as occurring in Scotch Glacial beds. Living.

175. Smittia reticulata, Mac G. (*Lepralia* ibid.); Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii.; Hincks, 'Brit. Mar. Pol.' p. 346, pl. xlviii. figs. 1–5.

Range.—Fossil: Bairnsdale, Australia. Living: Northern Seas, Brit., Australia.

176. Smittia cheilostoma, Manzoni = *Lepralia* ibid., 'Bry. Foss.' 3rd contrib. p. 13, pl. iv. fig. 22.

Range.—Italian Pliocene. Living, abundant, South coast.

177. Smittia trispinosa, Johnst. = *Discopora* ibid., Johnst.; see Hincks, p. 353 = *S. trispinosa*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 272, pl. viii. fig. 20.

Range.—Miocene, Australia (Waters, Mt. Gambier); Post-Pliocene, Canada (Dawson). Living: Very widely distributed.

178. Smittia centralis, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 337. S. W. Victoria.

179. Smittia centralis, var. *lævigata*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 337, pl. xiv. figs. 7 and 8. S. W. Victoria.

180. Smittia Tatei, T. Woods. (*Eschara* ibid. T. W.) 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 337, pl. xvii. fig. 65. Mt. Gambier = *Eschara porrecta*, T. Wood, 'On some Tert. Aust. Pol.'

181. Smittia anceps, MacG. (*Lepralia* ibid.) Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 337, pl. xviii. fig. 94.

182. Smittia bi-incisa, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 272, pl. vii. fig. 1.

Range.—Miocene, Australia (Waters).

183. Smittia seriata, Reuss = *Lepralia* ibid. Reuss, 'Die Foss. Bry. des. Öst.-ung.' p. 32, pl. ii. fig. 12 = *Smittia* ibid. Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 272, pl. viii. fig. 17.

Range.—Miocene, Baden (Rss.); Australia, Mt. Gambier, Waters.

184. Smittia Napieri, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 438, pl. xii. fig. 14.

Range.—Miocene, Napier; New Zealand; Waurn Ponds, Busk.

185. Smittia turrita, Smitt = *Lepralia* ibid., Sm., 'Floridan Bry.' p. 65, pl. xi. figs. 226–228 = *S. turrita*, Sm., Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 438.

Range.—Miocene, Australia. Living, Florida.

Genus Phylactella, Hincks.

Lepralia sp., auctt. *Alisidota* sp., Busk.

'*Zoœcia* with the primary orifice more or less semicircular, the lower margin usually dentate; peristome much elevated, not produced or channelled in front. No avicularia. *Zoarium* incrusting.'—Hincks, p. 356.

185*a*. *Phylactella collaris*, Norman (*Lepralia* ibid.) = *Smittia collaris* var., Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 438, pl. xii. fig. 10.

Mr. A. W. Waters, in his remarks on *Smittia collaris*, Nor., given above, says: 'I have always found the greatest difficulty in distinguishing between *Phylactella* and *Smittia*, and have always expressed my doubts as to the advisability of using the shape of the peristome as a generic character; and the present form, which is closely allied to, if not identical with, *P. collaris*, Norman, has decided me to only use the name *Smittia* for what are looked upon as belonging to these two genera.'

Range.—Miocene, Australia, Waurn Ponds and Waurn Quarry (Waters). Living, Brit. localities.

186. PHYLACTELLA LABROSA, Busk = *Alysidata* ibid., 'Crag Pol.' p. 26, pl. xxii. fig. 7.

Range.—Red Crag. Living, several Brit. localities.

III. With a mucronate peristome.

Genus MUCRONELLA, Hincks.

'*Zoœcia* with a suborbicular or semicircular orifice; the peristome elevated in front into a more or less prominent mucro. *Zoarium* incrusting.'—Hincks, p. 360.

187. MUCRONELLA PEACHII, Johnst. = *Lepralia* ibid., Busk, 'Crag Pol,' p. 48, pl. v. figs. 6, 7, 8; pl. vi. fig. 4.

Range.—Coralline Crag, abundant; Mid. Pliocene beds, Suffolk Crag; Upper Pliocene; Palæolithic (A. Bell); Scotch Glacial (Geikie).

188. MUCRONELLA VENTRICOSA, Hassall = *Lepralia* ibid., Busk, 'Crag Pol.' p. 49, pl. vi. figs. 3 and 6 = *Lepralia* ibid., *arrecta*, Rss. 'Bry. Öst.-ungar.' p. 24, pl. ii. fig. 11.

Range.—Coralline Crag; Aus. Mid. Pliocene, Palæolithic (Bell); Miocene, Austro-Hung. (Reuss). Living, rather widely distributed.

189. MUCRONELLA VARIOLOSA, Johnst. = *Lepralia* ibid., Busk, 'Crag Pol.' p. 48, pl. iv. fig. 6 (? fig. 8), and pl. viii. fig. 8 = *Lepralia serrulata*, Rss., 'Bry. Öst.-ung.' p. 27, pl. ii. figs. 2 and 3 = *Lepralia tenera*, Rss., ibid. p. 27, pl. ii. fig. 4.

Range.—Miocene, Austro-Hungary (Reuss); Mid. Pliocene; Coralline and Red Crag. Living: Northern Seas.

190. ? MUCRONELLA MICROSTOMA, Norman (Hincks, p. 370). Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 265.

Range.—Doubtfully, Australia, Mt. Gambier. Living, Shetland.

191. MUCRONELLA COCCINEA, Johnst. (Hincks, p. 271) = *Lepralia mamillata*, Busk, 'Crag Pol.' p. 46, pl. vi. fig. 5 = *Lepralia mamillata*, Manzoni, 2nd Cont. p. 6, pl. ii. fig. 8 = *Lepralia pteropora*, Reuss, 'Pol. Wien. T.' p. 81. pl. ix. fig. 26 = *Lepralia pteropora*, Manzoni, 'Bry. Foss. Ital.' 3rd Cont. p. 1, fig. 3 = *Distans escharellina*, ibid., D'Orb., 'Pal. Franç;' *Lepralia peregrina*, Manzoni, *loc. cit.* p. 6, pl. i. fig. 5 = ? *Lepralia fulgurans*, Manzoni, *loc. cit.* p. 7, pl. i. fig. 6; *Lepralia quadricornuta*, Dawson, 'Canad. Naturalist,' 1857; *Lepralia resupinata*, Manzoni, 'Castrocaro,' p. 20, pl. ii. fig. 26; *Lepralia resupinata*, Waters, 'Bry. Bruccoli,' *loc. cit.* p. 474; *Mucronella coccinea*, Johnst., Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 266.

Range.—Fossil: Eocene; Miocene, Europe; Miocene, Australia, Mt. Gambier; Pliocene, Crag; Quaternary, Livorno, Manzoni. Living.

192. MUCRONELLA MUCRONATA, Smitt = *Escharipora* ibid., 'Floridan Bry.' p. 24, pl. v. figs. 113–115 = ? *Eschara Liversidgii*, T.

Woods, 'Tert. Aust. Pol.' 1876, p. 3 = *M. mucronata*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 328, p. xvii. fig. 66.

Range.—Miocene, Australia. Living: Florida (Smitt).

193. MUCRONELLA DUPLICATA, Waters (*Vincularia* form), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 328, pl. xvi. fig. 54.

194. MUCRONELLA ELEGANS, MacG. (var. ?), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 329, pl. xviii. fig. 91 = ? *Eschara elegans*, MacG., 'Aust. Poly. Trans. R. Soc.' Victoria.

195. MUCRONELLA NITIDA, Verrill = *Discopora* ibid., Ver., 'Amer. Journ. Sc.' vol. ix. p. 415, pl. vii. fig. 3, 1875 = *Lepralia reticulata*, var. *inæqualis*, Waters, 'Bry. of Naples' = *Mucronella nitida*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 507.

Range.—Miocene, Australia. Living, *M. elegans* and *nitida*.

196. MUCRONELLA POROSA, Hincks, Waters, 'Quart. Jour. Geol. Soc.' (Addendum, p. 512) vol. xxxviii.: Hincks, 'General Hist. of Mar. Polyzoa;' 'Ann. M. Nat. Hist.' ser. 5, vol. viii. p. 124, pl. i. fig. 4.

Range.—Fossil: S.W. Victoria, Australia. Living: Curtis Il., Singapore, Tasmania.

Genus PALMICELLARIA, Alder.

'*Zoœcia* with the primary orifice orbicular, or ranging from semicircular to semielliptical; the peristome elevated around it, so as to form a secondary orifice, and carried out in front into a projecting palmate or mucronate process with an avicularium on its inner aspect. *Zoarium* erect and ramose, or lamellate.'—Hincks, p. 378.

197. PALMICELLARIA SKENEI, Ell. and Sol. (*Millepora* ibid.) = *Lepralia bicornis*, 'Crag Pol.' p. 47, pl. viii. figs. 6 and 7; 'Brit. Mar. Poly.' p. 380 = *P. Skenei*, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 511.

Range.—Fossil: Crag (Mr. Waters puts ?); Bairnsdale, Australia (Waters). Living: Northern Seas.

Genus RETEPORA, Imperato.

See Hincks, *op. cit.*, for special details, pp. 388 to 397.

'*Zoœcia* disposed on the front surface of an erect and ramose zoarium, the branches of which usually inosculate and form a reticulate expansion; orifice semicircular or semielliptical, with a prominent rostrum on the lower margin, bearing an avicularium. *Zoarium* adherent by means of an incrusting base, composed in great part of aborted cells; avicularia developed on both the back and front of the zoarium.'—Hincks, p. 388 (*op. cit.*).

198. RETEPORA BEANIANA, King ('B. M. Pol.' p. 391), ibid. Busk, 'Crag Pol.' p. 75, pl. xii. figs. 2, 5, 6, and 7; Waters, 'Quart. Jour. Geol. Soc.' vol. xxxix., p. 439. But Mr. Waters doubts whether the species described by Stoliczka is really *R. Beaniana*. = ? *Lepralia lobata*, Busk, 'Crag Pol.' p. 50, pl. vi. fig. 7; pl. xxii. fig. 4, the young state.

Range.—Fossil: Coralline and Red Crag; Miocene, Australia; Waters. Living.

199. RETEPORA COUCHII, Hincks (*op. cit.*, p. 395) = *R. cellulosa*, var. *Beaniana*, Manzoni, 'Bry. Foss. Ital.' 4th Contrb. p. 19, pl. v. fig. 26.

Range.—Italian Pliocene beds, Manzoni. Living.

200. Retepora marsupiata, Smitt ('Floridan Bryozoa') = *Philodophora labiata*, Gabb & Horn, 'Polyzoa of Second and Tert. Form. of N. America,' p. 138, pl. xix. fig. 21; Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 342, pl. xv. figs. 34–36 figs. 59–61, 76, 77.

Range.—Miocene, S. Barbara, Amer. (G. & H.); Mt Gambier, Australia (Waters). Living: Floridan seas (Smitt); Teneriffe (Busk).

201. Retepora rimata, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 343, pl. xvi. figs. 48, 35.

202. Retepora deserta, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxviii., p. 511.

Range—S.W. Victoria; Mt. Gambier, *R. rimata*; Bairnsdale, *R. deserta.*

Genus Cellepora, (part) Fabricius.

Celleporaria, Lamk.: Reuss, D'Orb. (for branched species). *Spongites*, Oken: *Reptocelleporaria* (sp.), D'Orb. (for incrusting species).

'*Zoœcia* arceolate, erect or sub-erect, heaped together, or irregularly disposed; the orifice terminal, with one or more ascending rostra in connection with it, bearing avicularia. *Zoarium* incrusting, often composed of many layers of cells, or erect and ramose.'—Hincks, p. 398.

203. Cellepora pumicosa, Linnæus. (See Hincks, *op. cit.*, p. 399.) ? Manzoni, 'Ital. Plioc. Foss.'

Range.—Scotch Glacial (Geikie); Ital. Pliocene ? (Manzoni); *C. pumicosa*, Busk (non Linn.); Australia (Waters, *op. cit.*, vol. xxxviii., p. 514). Living, generally distributed.

204. Cellepora ramulosa, Linn. (Hincks, p. 401, *op. cit.*); Busk, 'Crag Poly.' p. 58, pl. ix. fig. 2; Manzoni, 'Bri. Foss.' 4th Contr. p. 12, pl. v. figs. 29, 29′, pl. vi. figs. 30, 30′, 30″.

Range.—Coral Crag; Ital. Pliocene. Living, widely distributed.

205. Cellepora tubigera, Busk, 'Crag Polyzoa,' p. 60, pl. ix. figs. 8 & 10; Manzoni, 'Bri. Foss.' 4th Contr., p. 14, pl. iv. fig. 25 (?).

Range.—Coral Crag; ? Ital. Pliocene (Manzoni). Living.

206. Cellepora Costazii, Aud. (Hincks, *op. cit.* p. 411) = *Cellepora Hassallii*, 'Brit. Mus. Cat.;' Manzoni, 'Bri.' 4th Contr. p. 17, pl. iv. fig. 22.

Range.—Italian Pliocene (Manzoni). Living.

207. Cellepora yarraensis, Waters, 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 343. See 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 512, pl. xxii. fig. 8.

208. Cellepora fossa, Haswell (Waters), 'Quart. Jour. Geol. Soc.' vol. xxxvii., p. 343, pl. xviii. fig 89 = *Sphæropora*, ibid., Hass., 'On some Poly. from the Queensland Coast.'

Range.—Miocene, Australia (Waters), and Mt. Gambier. Living (*C. fossa*): Holborn Is., Queensland.

Sub-order II. Cyclostomata, Busk.

Cyclostomata, Smitt; *Tubuleporina*, Milne-Ed., Johnst.; *Auloporina* and *Myrioporina*, (part) Ehrenb.; *Cerioporina*, (part) Bronn; *Centrifuginea*, (part) D'Orbigny.

'*Zoœcia* tubular, with a plain inoperculate orifice; *marsupia* and appendicular organs wanting.'—Hincks, p. 139.

Group I. Radicellata, D'Orbigny, Smitt.

Articulata s. radiata, Busk, 'Crag Polyzoa.'

'*Zoarium* erect, articulated, attached by radical tubes.'

Family I. Crisiidæ, Johnston.

'*Zoarium* dendroid, calcareous, composed of segments, united by corneous joints. *Zoœcia* tubular, disposed in one or two series.'—Hincks, p. 417.

Genus Unicrisia, D'Orb.

Type *Unicrisia vindobonensis*, D'Orb.

I am not familiar, otherwise than by figure, with D'Orbigny's species, but the form described and figured by Reuss in his 'Val di Lonti Bryozoa,' is present also in the Bryozoa material from Montecchio Maggiore, North Italy, though not given in the lists of the author. The *zoarium* is uniserial, but unlike any other uniserial *Crisia* known to me. The *zoœcia* are borne upon a kind of stolon, out of which the cells are developed, and these are pyriform; the proximal part of the cell contracting and the distal protruding from the stolon.

1. Unicrisia tenerrima, Reuss = ? *Unicrisia vindobonensis*, D'Orb., 'Palæontol. Ter. Crét.' = *Crisia vindobonensis*, Reuss, 'Foss. Pol. d. Wien. Tert.'

Range.—Miocene, Val di Lonti; Montecchio Maggiore, N. Italy.

Genus Crisia, (part) Lamouroux.

'*Zoœcia* in a single series, or in two alternate series.'—Hincks, p. 418.

I have no knowledge of Fossil *Crisia* of the type *Crisia cornuta*, Linn. The only unicellular form known to me is the one already described, and this is so unlike any *Crisia* known to occur in a recent state, that I place it in the group out of deference to Reuss and D'Orbigny, and because the fragments are too small to allow of proper location in this or in any other group. The following, however, are true *Crisiæ* but I am not certain that all the identifications of authors are correct. Anyone who has studied this genus in large masses must be convinced that the characters upon which species are founded vary considerably. These characters are, for the most part, the number of cells to each internode and the positions from which the branches arise. Thus we find that *C. eburnea*,[1] *C. denticulata*, *C. acropora*, *C. eburneo-denticulata*, and *C. margaritacea* have, so far as features are concerned, a common likeness. In *C. elongata* and *C. sinclarensis* we have another special feature, especially so in the crowded state of the minute foramina of the cells. In *C. fistulosa*, *C. tubulosa*, and *C. Holdsworthii*, we have different characters again; while in *C. Edwardsiana* and *C. conferta* we have two additional types of *zoœcia* and also *zoarium*. In a fossil state, it would be difficult indeed to distinguish specific characters in the first group, but not so difficult with the other groups. In the following list, then, so far as I have a personal knowledge of the forms, I will distinguish the first as Group α. The others are sufficiently characteristic to allow of proper identification in the fossil state.

[1] See *Brit. Mus. Catalogue*, pt. iii.; 'Marine Polyzoa,' Busk, and plates.

Group *a*.

2. CRISIA EBURNEA, Linn. 3. CRISIA DENTICULATA, Lamk. = *Crisia subæqualis*, Reuss, 'Paläont. Stud.' = *Crisia gracilis*, Roemer, 'Norddeutsch. Tert. &c.' p. 23, tab. iii. 3 = *Crisia*, undescribed, 'Australian Bryozoa' = *Crisia*, undescribed, 'Australian Bryozoa,' *C. elongata* type = *Crisia denticulata*? Busk, 'Crag Polyz.' p. 93, pl. i. fig. 8.

Range.—Scotch Glacial; Post-Pliocene, Montreal (Dawson); Suffolk Crag, Palæolithic (Bell); Miocene, Australia, undescribed,[1] but in my cabinet; Austro-Hungarian Miocene, Reuss. I see no reason for separating from the above group the North Dutch species of Roemer, or the North Italy species of Reuss.

4. CRISIA FISTULOSA, Heller (non Busk), 'Bry. Bay of Naples, Ann. Mag. Nat. Hist.' Ap. 1869, p. 268 = *C. Haueri*, Rss., 'Foss. Polyz. des W. Tertb.' p. 54, pl. vii. fig. 22–24 = ? *C. eburnea*, Manzoni, 'Bri. Foss. del Mioc. Aust.-Ungh.' p. 3, pl. i. fig. 1.

Range.—Miocene, Nassdorf; Berchtoldsdorf and Wieliczka, Pliocene; Rhodes (M.). Living, Naples.

5. CRISIA ELONGATA var. *angustata*, Waters, 'Bry. Bay Nap.' *loc. cit.*, p. 269, pl. xxiii. fig. 4 = ? *C. Edwardsii*, Reuss, 'Die Polyp. W. T.' p. 53, pl. vii. fig. 20 = ? *C. Edwardsii*, Manz. 'I Bri. Foss. Aust. ed Ungh.' The above are the suggested identifications by Mr. Waters.

Range.—Miocene, Austro-Hung. Living, Naples.

I have a fragment of a species with ovicell like *C. conferta*, Busk ('Brit. Mus. Catalogue,' pl. vi. A, pt. iii. p. 7), among my material from Montecchio Maggiore. I would be glad if local students would search for and describe the form.

The following are given by Reuss in his 'Foss. Pol. des W.' as occurring in the Marine Limestone of Nussdorf and Eisenstadt.

Crisia Edwardsii, Reuss; *C. Hornesii*, R.; *C. Haueri*,[2] Rss.; *Crisidia vindobonensis* (Unicrisia).

Group II. INCRUSTATA, D'Orbigny.

'Centrifugènes empalées à cellules *non* operculées,' D'Orb. (pars); 'Inarticulatæ seu adfixæ,' Busk, 'Crag Pol.'; INCRUSTA, D'Orb., Smitt.

Zoarium continuous, calcareous, not divided by corneous joints, or furnished with radicle tubes; erect and attached by a contracted base, or recumbent and immediately adnate, either wholly or in part.

In my last 'Brit. Assoc. Report on Foss. Polyzoa' (Southport, 1883), I felt compelled to found the Family Stomatoporidæ for the inclusion of peculiar Palæozoic and Mæsozoic forms. In this grouping I took *Stomatopora* as the type of the family. The Recent *Stomatoporæ* are, however, so multiform in habit that it seems to me unwise to increase the difficulties by placing in the way of the student any ill-digested or unnatural associations. But the case may be stated thus: the Stomatoporæ of the older rocks differ in many points from those existing in our present seas. The simple forms such as *S. granulata*, Edw., agree with

[1] Since this was written Mr. Waters has sent his promised paper on the Australian Cyclostomata to the Geol. Soc. (read June, 1884), and it will be found in vol. xl. *Quart. Jour. Geol. Soc.* (G. R. V.)

[2] *C. Haueri*, Rss.; similar to *C. eburnea* Lamx., Rss.

many of the Cretaceous and Jurassic species in their unicellular character, and *Stomatopora major*, except in the want of fenestration, seem to be allied to forms described by Prof. Nicholson from the Cincinnati rocks of America, but my own uniserial forms differ from the Jurassic.[1]

Family II. TUBULIPORIDÆ.

Zoarium entirely adherent, or more or less free and erect, multiform, often linear, or flabellate or lobate, sometimes cylindrical. *Zoœcia* tubular, disposed in contiguous series, or in single lines. *Oœcium* an inflation of the surface of the zoarium at certain points or a modified cell.

In Busk's 'Crag Polyzoa,' p. 91, the Tubuliporidæ include the three genera—*Mesenteripora*, Blainv., *Tubulipora*, Lamk., and *Alecto* (Stomatopora) Lamx. In the 'III. Brit. Mus. Catalogue of Polyzoa,' p. 23, *Alecto*, *Stomatopora* and *Tubulipora* only are included. The *Mesenteripora* is relegated to the Diastoporidæ. In Mr. Hincks' 'Brit. Marine Polyzoa,' the Tubuliporidæ include the genera—

STOMATOPORA, Bronn.
TUBULIPORA, Lamk.
IDMONEA, Lamx.
ENTALOPHORA, Lamx.
DIASTOPORA, (part) Lamx.

Genus STOMATOPORA, Bronn.

1821, *Alecto*,[2] Lamx.; 1825, *Stomatopora*, Bronn.; 1826, *Aulopora*, Goldfuss (part).

Zoarium repent, wholly adnate, or free at the extremities, or giving off erect processes, simple or branched; branches more or less ligulate. *Zoœcia* in great part immersed, arranged in a single series or in several, which take a linear direction or are very slightly divergent.—Busk, 'Brit. Mus. Cat. III.' p. 23; Hincks, 'Brit. Mar. Polyzoa,' p. 424.

Of my own knowledge I have but little to furnish respecting Tertiary *Stomatopora* below the 'Crag.' My continental material, both Eocene and Miocene, has only yielded to me a few very minute fragments of two species. In his work on the 'Bryozoa of Castrocaro' (Pliocene), Manzoni describes three species of *Stomatopora* (Alecto) as found by him. One species of very frequent occurrence is named by him *Alecto Castrocarensis*, Manzoni. It is a very fine example of this type. The large and peculiar character of the cells is noted by the author ('Brioz. Castro.' p. 40, pl. vi. figs. 71, 71′). The *zoœcia* are granulose and punctate, but except that he speaks of the grand dimensions of the cells we are left in entire ignorance of their natural size. Besides this beautiful form Manzoni describes and figures two other *Stomatoporæ*—*S.* (*Alecto*) *repens*,[3] Wood, and *S.* (*Alecto*) *parăsita*,[4] Heller.

In the 'Crag Polyzoa' (p. 112, pl. xx. figs. 5, 8, and ibid. figs. 6, 7) Mr. Busk describes and figures *A. repens*, S. Wood, and *A. dilatans*, W. Thomson. I cannot regard—so far as I may be allowed to express an opinion by comparing the figures in the absence of specimens of Manzoni's type—the *A. repens* of Busk, and the *A. repens* of Manzoni as one and the same species. The Crag specimens in my cabinet show very well the characters of Busk's species, but none of the cell characters of Manzoni's.

[1] See 'Silurian Uniserial Stomatoporæ and Wenlock Polyzoa' (mihi), *Quart. Jour. Geol. Soc.*, Aug. 1881, Feb. 1882.

[2] Name previously used for a group of Echinoderms by Leach (1814).

[3] Ibid. tav. vi. fig. 72.

[4] Tav. vii. fig. 69

In his 'Bryozoa of the Bay of Naples' (p. 273, *op. cit.* Ap. 1879), Mr. Waters associates with *A. repens*, Wood, the *Diastopora echinata*, Rss., and *D. repens*, Smitt, and describes, but does not figure, a variety of *A. repens*, Wood, as *A. repens*, var. *vitriensis* (habitat on *Terebratula vitrea*). Mr. Hincks, however ('Brit. Mar. Polyzoa,' p. 427), gives the following synonymy: *Stomatopora major*, Johnston = *Tubulipora repens*, S. V. Wood = *Alecto repens*, Busk, 'Crag Polyzoa,' pl. 112, fig. 8 (not fig. 5).

6. Stomatopora granulata, M.-Edw., Hincks, p. 425, pl. lvii. figs. 1, 2; Busk, 'Brit. Mus. Cat. III.' p. 23, pl. xxxii. fig. 1 = *S. granulata*, D'Orb; *S. incrassata*, D'Orb., 'Pal. Fr.' = ? *Alecto parasita*, Heller, 'Bry. Adr.' p. 40, pl. iii. fig. 10 = ? *Alecto parasita*, Manzoni, 'Castrocaro,' p. 41, pl. vii. fig. 69 = ? *Stomatopora minima*, Roemer, 'Bry.' woodcut, p. 22, pl. iii. fig. 2.

Range.—Hincks says, 'Grès vert inférieur, France; Norddeut. Tert. Oligocän' (Roemer, *S. minima*); Castrocaro (Manzoni). Living: Adriatic and Brit. Seas.

7. Stomatopora rugulosa, Rss.; *Aulopora* ibid. Rss. 'Foss. Pol. des Wiener Tert.' Marine Limest.
8. Stomatopora divaricata, Rss.; *Aulopora*, ibid. Rss. 'Foss. Pol. des Wiener Tert.' Marine Limest.
9. Stomatopora regularis, Gabb & Horn; *Alecto* ibid., G. & H. 'Mon. Foss. Pol.' Cretaceous, New Jersey.

I give the above on the authority of the authors rather than suppress the names.

10. Stomatopora major, Johnst.; Hincks, 'Brit. M. Pol.' p. 427, pl. lviii. and pl. lxi. fig. 1 = ? *Tubulipora repens*, S. Wood; *Alecto* ibid., Busk, 'Crag Poly.' p. 112, pl. xx. fig. 8 (not 5) = *Tubulipora fimbriata*, ? Michelin (Busk, *loc. cit.* p. 112) = *Idmonea ramosa*, D'Orb. p. 632, figs. 1, 2 (Busk, *loc. cit.* p. 112); Waters, 'Bry. Bay Naples,' *loc. cit.* p. 273, as *Alecto repens*, Wood. Syn. Waters, *Diastopora echinata*, Rss. 'Foss. Polyp. des W. T.' p. 52, pl. vii. figs. 14, 15; *Diastopora repens*, Smitt, 'Krit. Fört.' p. 395, 1866.

Range.—Miocene, Eisenstadt (Rss.); Pliocene, Crag, Castrocaro (Manzoni—as *S. major*, Hks.), Coralline and Red Crag. Living: Several localities, Brit. Seas; Naples.

11. Stomatopora dilatans, Johnst.; Hincks, 'B. M. Poly.' p. 420, pl. lvii. figs. 3, 3a = *Alecto* ibid., 'Crag Polyz.' p. 112 (*A. dilatans*, W. Thomson, pl. xx. figs. 6, 7) = ? *Alecto repens*, Manzoni, 'Castrocaro,' p. vi. fig. 72 (Hincks) = (Syn. Busk) *Diastopora echinata*, Rss.; *Idmonea divaricata* ?, *I. depressa* (?), *I. cenomana* (?), *I. elegans* (?), D'Orb. Compare the synonymy of *S. major* and *S. dilatans*. Hincks gives ? *Proboscina ramosa* = *Idmonea cenomana*—as syn. of *Stomatopora expansa*, Hincks, 'Brit. M. Poly.' p. 432, pl. lxii. fig. 1.

Range.—English Crag (Busk); Miocene and Pliocene (remains for closer comparison). Living, Brit. Seas.

12. Stomatopora incrassata, Smitt (sub-genus *Proboscina*, Smitt), Hincks, 'Brit. M. Poly.' p. 436, pl. lix. figs. 2, 3 = *Filisparsa* ibid., D'Orb. 'Pal. Fr.' p. 817. For other synonymy see Busk, 'B. M. Cat.' pl. iii. p. 24. In a fossil state it is almost impossible to correlate, with any degree of positive exactness, these and recent forms. The relationship which these synonyms are

supposed to indicate are only in a certain sense correct. The older forms may, upon examination, give characters not found in recent species—and *vice versâ*. Thus Smitt ('Scandinavian Bry.') gives Busk's *Alecto repens* as *Diastopora* ibid., with the following additional synonyms—*Proboscinia dichotoma*, D'Orb.; *P. Toucasiana*, D'Orb.

Range.—(?)

Genus TUBULIPORA, Lamarck.

Ceriopora, (pt.) Hagenow; *Phalangella* (sp.), Gray; *Obelia* (sp.), Lamx.; *Reptotubigera*, D'Orb.

Zoarium adnate or decumbent or suberect, forming a variously shaped expansion, either entire or lobate, or branched. *Zoœcia* tubular, partially free and ascending, arranged in divergent series.—Hincks, p. 443; Busk, 'Cyclostomata,' 'Brit. Mus. Cat.' pl. iii. p. 24; 'Crag Polyzoa,' 110. For additional synonyms, Busk, 'Cyclos,' 'B. Mus. Cat.'

This genus I referred to briefly in my 4th Brit. Assoc. Report on Fossil Polyzoa, as being one of those genera very poorly represented, if at all, below the Tertiary rocks. After carefully studying some very fine forms of the *Tubulipora*, found amongst the Crag Polyzoa, and comparing these with recent forms, I can fully endorse the remarks on the genus made by the Rev. T. Hincks ('Brit. Marine Polyzoa,' p. 443), that the colony of *Tubulipora* originates in a discoid body, and that the after development from this primary stage is by a 'second cell,' usually bent in the opposite direction; 'followed by an increasing number of series which diverge more or less on each side. In some cases a simple flabellate crust is thus formed; in others it divides into lobes, which again subdivide.' Although in some respects *Tubulipora* may resemble, on the one hand *Diastopora*, and on the other *Stomatopora*, there is a distinct facial character in the group which, under present circumstances at least, keeps the genera distinct. It would be folly, however, not to recognise that in the Mesozoic rocks some of the *Diastopora* preserve the flabellate character until the colony is considerably advanced, but these, instead of following the line of colonial development as found in *Tubulipora*, ultimately assume the normal discoid habit and not the branching and rebranching of typical *Tubulipora*. The beautiful species described as *Tubulipora flabellaris*, (?) Fal. (sp.) by Mr. Busk in 'Crag Polyzoa,' p. iii., and figured pl. xviii. fig. 3, pl. xx. fig. 9, is given by Mr. Hincks as *T. fimbria*, Lamk. ('Brit. Mar. Polyzoa,' p. 448). I have before me a very fine example of Busk's species figured in pl. xx. fig. 9, 'Crag Polyzoa,' and I can therefore accept the strictures of Mr. Hincks, when he remarks (p. 449) that *T. fimbria* being distinguished by its flat, fan-shaped zoarium, differs from the zoarium of *T. flabellaris*, in 'being horizontal and destitute of the very tall sub-erect extremities.' The cells are not arranged in series, or at all connected together. There is, however, an element of doubt in identifying the Crag form with the recent *T. fimbria*, for the reason that I have been unable to trace the 'transversely wrinkled' aspects referred to by Mr. Hincks. I shall not therefore differ from Mr. Hincks in his general appreciation of the types accepted by him, but follow him in his identifications, in the hope that further study will throw some light at least upon the doubtful points referred to.

13. TUBULIPORA FLABELLARIS, Fab., Hincks, 'Brit. Mar. Polyzoa,' p. 446 (Post-Pliocene Glacial deposits); Synon. = *T. phalangea*, Busk, 'Crag Pol.' p. iii. fig. 6, pl. xviii. (Coralline Crag) = *T. flabellaris* (Manzoni) = *Diastopora plumula*, Reuss ('Miocene d'Austria,' Manzoni).

14. TUBULIPORA FIMBRIA, Lamk., Hincks, 'Brit. Mar. Pol.' p. 448 = *T. flabellaris*, Busk, 'Crag Pol.' p. iii. pl. xvii.; fig. 3, pl. xx. fig. 9 (similar range in Time) = ? *Proboscina latifolia*, D'Orb. 'Pal. Fr. Terr. Crét.' p. 847 (? Cretaceous).

It will be seen by the above that the recent origin of this peculiar form is somewhat established insomuch as reliable observation and study reduce the *Tubulipora* to two well-marked types, both of which are recent. The figure of *T. flabellaris* given by Manzoni in 'Bryozoa of Castrocaro,' pl. vi. fig. 73, and briefly described in p. 43 of the same work, is identified as the same Northern form, fully described by Smitt, 'Kritisk Förteckn. öfver Skand. Hafs-Bryozoer,' p. 401, tab. ix. fig. 6–8, and with Busk's figs. and references previously given. It will be seen, however, that this is referred to *T. fimbria* by Mr. Hincks. Notwithstanding the above, I give below a list of *Tubulipora* at present accessible to me.

15. TUBULIPORA PARASITICA, Hagenow, 'Die Bryoz. der Mästrich. Kreid.' &c. tab. i. fig. 1.

Range.—Up. Chalk, Maestricht.

16. TUBULIPORA TRIFARIA, Roemer, 'Polyp. Nord-deutsch. Tert. Geb.' p. 22, tab. iii. fig. 2.

17. TUBULIPORA ECHINATA, Von Münst. (Cellepora), Goldf. 'Petrefac.' tab. xxxvi., fig. 14; Roemer, *loc. cit.* p. 22. *Diastopora echinata*, Rss. 'Foss. Polyp. d. W. Tertiärb.

Range.—Roemer gives Oligocän von Solingen; for Goldf. sp. Oberoligocän; Goldf. cites Tert. Merg. Astrupp.

It will be seen from the above, against which I place (?), that Roemer identifies the *Cellepora echinata*, Goldf., as *Tubulipora*, whilst Jules Haime in his 'Jurassic Bryozoa' speaks of the same species as being an example of *Proboscina*, and remarks that it is well placed between *Stomatopora* and *Idmonea*. In all probability, judging from the brief diagnosis given by Goldfuss, 'repens, ramosa, cellulis tubulosis, ostiolis orbicularibus erectis,' Roemer is more correct in the identification.

18. TUBULIPORA PHALANGEA, Couch (see note), Busk, 'Crag Poly.' p. iii. pl. xviii. fig. 6 (*T. palmata*, Wood).

19. TUBULIPORA FLABELLARIS, (?) Fab. (sp.), Busk, 'Crag Poly.' p. iii. pl. xviii. fig. 3, pl. xx. fig. 9 = *Discopora palmata*, Reuss = *Diastopora vassiacensis*, D'Orb. 'Ter. Crét.' p. dcxxxv. p. 12 and 13 = *Diastopora plumula*, Reuss, 'Foss. Poly. Wien. Tertiarb.' p. 51, pl. vii. fig. 11.

Range.—Miocene ? Rss.; Cor. Crag, Busk; Living.

As *Phalangella*, Gray (*Tubulipora* in this Report), Smitt in his Scandinavian Bryozoa gives the following species and synonymy:—

20 TUBULIPORA PALMATA, Wood (sub-genus *Phalangella*, Gray) = *T. palmata*; Wood, Busk = *Alecto dilatans*, Busk, 'Crag Pol.' p. 112.

21. TUBULIPORA FIMBRIA, Lamk. = *Proboscina serpens*, D'Orb. 'Pal. Fr.' *l.c.* p. 847 = *Tubulipora flabellaria*, Busk, 'Crag Pol.' p. iii.

22. TUBULIPORA FLABELLARIS, Fab., *Tubulipora verrucaria*, D'Orb. 'Pal. Fr.' *l.c.* p. 832 = *Tubulipora phalangea*, Busk, 'Cr. Pol.' p. iii.

Genus IDMONEA, Lamouroux.

Idmonea, Lamx., Blainville, Milne-Ed., Johnston, Reuss, D'Orbigny (part), Busk.; *Retepora*, (pt.) Goldfuss, Lamk.; *Diastopora*, (pt.) Michelin, *Tubulipora*, (pt.) Lamk.; *Crisina*, (pt.) D'Orb., Smitt; *Tubulipora*, subgenus *Idmonea*, Smitt.

'*Zoarium* erect and ramose, or (rarely) adnate; branches usually triangular. *Zoœcia* tubular, disposed on the front of the branches, ranging in parallel transverse or oblique rows on each side of a mesial line.'—See Hincks, p. 450; Busk, 'Crag Polyzoa,' p. 104.

This peculiar genus seems to have originated in early Mesozoic times, but the species described by Lamouroux as *I. triquetra*, as occurring in the Jurassic rocks, especially in this country, is far less specialised than those forms found in the Cretaceous rocks of Maestricht, and in the Faxoe Limestone of Denmark. The unusual character of some of the species described by Goldfuss as *Retepora clathrata* and *R. disticha*, induced Hagenow to break up the forms grouped together by Goldfuss, out of which several new species were founded, described and figured. I do not say, after having studied the Faxoe material, that Hagenow was wrong in his redistribution, but I think that even he has given us more species than were needed or that the doubtful character of some of the forms warranted, but his beautiful figures have materially assisted the student in mastering the details of the group. Yet it seems to me a rather invidious practice, in the present state of our knowledge, to criticise unfairly the labours of other authors on this peculiar group of fossil forms. It is not a mere matter of opinion as to whether this and that form are identical, because unless there is a sufficiency of material to connect by intermediate links form and form, mere opinion in this direction is useless. I have hundreds of specimens of Reuss's *Idmonea gracillima* from the Montecchio Maggiore beds, and it is quite possible to erect two or more species out of the various specimens accordingly as we accept the young or the matured stages as types. As I have been able to trace this form from a single elongated cell on each side of the mesial line up to four and five cells on each side of the mesial line, I can only say that mere growth is a fallacious factor in the determination of a species. In the enumeration of the following I shall take into consideration other special features, leaving the number of cells in the branch for workers to deal with separately, if they so desire. I shall take the species as I find them in the works of authors accessible to me. As my friend Mr. A. W. Waters has gone over the Tertiary species for his work on the Bryozoa of the Bay of Naples, I shall take his references to fossil species as work accomplished, because he has had a fuller access to foreign works than I could possibly obtain.

Before passing on to the numerous fossil forms described by authors it may be well to dispose of the two recent species which are now pretty well known to zoologists.

23. IDMONEA ATLANTICA, Forbes, MS. See Busk, 'Cyclostomata;' Waters, 'Bay of Naples Bryozoa;' Hincks, 'Brit. Mar. Polyzoa.'

'*Zoarium* irregularly branched, branches triangular, cells one, four, five in each series, the, innermost the longest, dorsal surface of branch not perforate' (Busk); 'dorsal surface, lineated and minutely punctate' (Hincks); peristome entire . . . . The large tubular cells, mode of arrangement, triangular branches, and entire peristome are good features in this species.

The abundance of specimens of this species in the Garvel Park deposits have enabled me to study the form in all its varying features. It is a peculiarly Northern type, whereas the *Idmonea radians*, Lamarck, its nearest ally, is as peculiarly Southern. The Fossil specimens from the Garvel Park beds are, I have no doubt, closely related to, if not identical with, the *I. radians* of Beneden; and besides this, Mr. Busk and Mr. Hincks give as synonyms, though doubtfully, *I. coronopis*, Def., and *I. angustata*, D'Orb., as well. Mr. Waters ('Bay of Naples Bryozoa,' *op. cit.* p. 269) remarks of the *I. gracillima* of Reuss, 'that specimens in his possession, from Val di Lonti, correspond with recent *I. atlantica*.

It is very possible that if the various specimens of this beautiful species were isolated, or found in different localities even of the same age as the Glacial deposits, they may be characterised as different species, but mingling with such abundance in these beds, all the gradations of variations may be traced, and it seems to me impossible to separate them. With regard to the *I. gracillima* of Reuss from the Miocene beds of Val di Lonti, and also from the Montecchio Maggiore beds of Northern Italy, although specimens resemble, in some cases closely so, recent *Idmonea atlantica*, I should rather hesitate to put the one as a synonym of the other. It may be possible to establish a connection between the *I. gracillima*, Reuss (non Busk, 'Cyclostomata,' p. 14), and some of the still undescribed Cretaceous species, and it may also be possible to show gradations of type from *I. gracillima* to *I. atlantica*.

24. Idmonea serpens, Linnæus = *Tubipora* ibid., Linn., 'Syst. Nat.' ed. 12, 1271. *Tubulipora* ibid., Flem., Couch, Johnst., Busk. *Idmonea serpens*, Van. Ben., Smitt (sub-genus), Hincks. (See for references, p. 453, 'Brit. Mar. Polyzoa,' vol. i. 1880.)

This species, as a fossil, has a far more limited range than the above. I have specimens in the young state from the Glacial Beds of Scotland. A specimen, figured by Manzoni ('Bryozoa of Castrocaro,' p. 43, fig. 78, tav. vi.), Mr. Hincks accepts, on the authority—Pliocene, Castrocaro (Manzoni); Sicilian Pliocene (Waters). In his synonyms, Mr. Hincks also refers to this species—*Tubulipora transversa*, Lamk., and *Idmonea* ibid., Milne-Edw. and D'Orb. In my own investigations I have not been able to place *Idmonea serpens*—type accepted by Hincks, Manzoni, and Waters—below the Pliocene beds.

For fuller particulars, see Busk, 'Cyclostomata, Brit. Mus. Cat.' pl. iii. pp. 25–26; and Hincks, 'Brit. Mar. Poly.' (*loc. cit.* p. 453).

25. Idmonea triquetra, Lamx. (author's) ('Jura formation,' Ranville). Brit. locality, Juras. rocks under London—Professor Judd's material.

Though not abundant, I have a few specimens of this species from the material referred to by Professor Judd. The species is evidently founded upon its peculiar triangular character rather than any special features in the cells. After a careful study of the British specimens, the following results have been obtained, which I give rather as a description than as a diagnosis. I. *Zoarium* triangular, *zoœcia* arranged in lines—sometimes flattened, some lines slightly produced; the flattened cells are 'Lepralia'-like, with a semicircular orifice, with the area punctured; the produced cells are tubular, occasionally passing off into the Lepralia-like form of a cell. The general features are that of *Idmonea*, but the cell characters are abnormal, and one would incline to place the one form in two different genera. The same feature is noticeable in some of the cells of *Terebellaria*. Mr. Busk, in remarking on *I. fenestrata* ('Crag Poly.' p. 105), says that his species approaches 'in some respects the *I. triquetra*, Lamx., as well as a recent species met with in South Africa, which, if not identical with the Caen fossil, is undistinguishable from it.' The form referred to by Busk is before me, and there is certainly a likeness between the Jurassic and the Recent form, but the Recent form has the advantage of being more highly specialised and also larger in both the cells and in the size of the zoarium. Mr. Busk, however, says that the branches of *I. triquetra* are very much thicker than the Recent form. This difference of opinion may arise from difference in size of fragments, but anyhow I cannot regard the *I. fenestrata*, Busk, or the *I. fenestrata* (Busk), Smitt, 'Scand. Bryozoa,' as being one and the same species. This being the earliest record that I have of *Idmonea*, I think it would be unwise not to keep the species separate. It will be well, however, if students will direct their attention to the several features referred to.

Goldfuss, in his 'Petrefacta,' describes and figures what he gives as five species of *Retepora*—*R. cancellata*, G.; *R. clathrata*, G., and R. *lichenoides*, G.; *R. truncata* and *R. disticha*—all from the Chalk. It is very evident that Goldfuss neglected to sort out his species, and the consequence is that we have an assemblage of forms anything but satisfactory; consequently the labour of Hagenow on the group is all the more appreciable, because he worked from fresh material, and, from what I understand from his text, with full access to the type species of Goldfuss. I also have been able to study the Faxoe Limestone material, already referred to; and if I offer any remarks upon the species of Hagenow, it must be understood that I do so with specimens before me which seem to be the same or of near the same horizon as those of Hagenow's Maestricht beds. To prevent a repetition of Hagenow's and Goldfuss's works, I shall give the reference to the plate and fig. only of the two authors.

26. Idmonea maculata, Hag., H. Tab. II., fig. 3.
27. Idmonea clathrata, Goldfuss (*Retepora*), H. Tab. II. fig. 2; Gold., 'Pet.' Tab. IX. figs. 12 *c* and *d*.
28. Idmonea verriculata, Goldfuss (*Retepora*), H. Tab. II. fig. 5; Gold., 'Pet.' Tab. XXXVI. fig. 19 *b*.
29. Idmonea lichenoides, Goldfuss (*Retepora*), H. Tab. II. fig. 6; Gold., 'Pet.' Tab. XXXVI., fig. 13 *a* and *b*.
30. Idmonea cancellata, Goldfuss (*Retepora*), H. Tab. II. fig. 7 = *Idmonea* ibid., Rss.
31. Idmonea macilenta, Hag. (*Retepora*), H. Tab. II. fig. 4.
32. Idmonea disticha, Goldf. (*Retepora*), H. Tab. II. fig. 8; Goldf., 'Pet.' Tab. IX. figs. 15 *c*, *d* = *Retepora* ibid., Goldf., Lamx., Blainv. = ? *Retepora*, Michelin, Reuss.
33. Idmonea pseudo-disticha, Hag., H. Tab. II. fig. 9; Gold. 'Pet.' Tab. IX. fig. 15 *a–b* = *R. disticha*, G., in part.
34. Idmonea dorsata, Hag., H. Tab. II. fig. 10; Goldf., 'Pet.' Tab. IX. figs. 15 *g* & *n* = *Retepora disticha*, G., in part.
35. Idmonea geometrica, Hag., H. Tab. II. fig. 11.
36. Idmonea sulcata, „ „ „ 12.

37. Idmonea lineata, Hag., H. Tab. II. fig. 13; Goldf., 'Pet.' Tab. IX. figs. 15 *c, f.* = *Retepora disticha*, G., in part.
38. Idmonea gibbosa, Hag., H. Tab. II. fig. 14.
39. Idmonea geniculata, Hag., H. Tab. III. fig. 5; Goldf., 'Pet.' Tab. IX. fig. 12 *e, f* = *Retepora clathrata*, G., in part.
40. Idmonea tetrasticha, Hag., H. Tab. IV. fig. 3.

Some of these Hagenow describes as found in the Maestricht and Falkenberg beds. I cannot give the range of the species other than that given by the author. In my Faxoe material I have several *Idmoneæ*, and it would be quite possible out of the varied forms to construct a number of species, but I should be inclined to place the majority in three species only of those described above—*I. dorsata*, *I. lineata*, or *I. pseudo-disticha*.

Sub-genus Truncatula, Hagenow.

Out of the *Retepora truncata*, Goldfuss—with other species as allies—Hagenow constructs the sub-genus *Truncatula*. Although the facial character at first sight appears to be like *Idmonea*, a closer study of the form shows certain features altogether different. The more prominent are these:—(1) On the different sides of the mesial line the cells are clustered together and not separate. This appears to be a normal feature. (2) The reverse of one species at least—*R. truncata*—is very peculiarly striated, or, speaking with more exactness, the lines of striæ seems to be the line markings of the individual cells seen through a very delicate membrane which covers the reverse. It this be a correct description, founded upon observation of a limited number of specimens from the Faxoe Limestone material, then I cannot see the necessity for retaining the sub-generic term.

41. Truncatula filix, Hagenow, tab. iii. fig. 4.
42. Truncatula truncata, Goldf., Hag. tab. iii. fig. 2. Goldf., 'Pet.' tab. ix. fig. 14. = *Retepora* ibid., Goldf.; Lamk.; Milne-Ed. = *Idmonea* ibid., Blainv.
43. Truncatula repens, Hag., tab. iii. fig 1.

Range.—Hagenow cites Maestricht and Falkenberg.

I have several lists of fossils from the Cretaceous beds of America, and a fine suite of fossils as well, many of which are undescribed as yet. Taking the order of the strata as given by Lyell, Emmons, and others, as Upper Cretaceous, the following species of *Idmoneæ* correspond to some extent with the *Idmoneæ* already given from Hagenow and Goldfuss.

Idmonea contortilis, Lonsdale, 'Quart. Jour. Geol. Soc.' vol. i. p. 68 = *Crisisina* and *Idmonea* ibid., D'Orb., 'Pal. Fr.' vol. ii. and vol. v.

Locality.—Timber Creek, New Jersey.

The Tertiary *Idmoneæ*, both of Europe and America, are of a very special character, and the facies of the several species would afford valuable details for the study of the Palæontology of the group. There is a slight difference between some of the American and European forms; but there is a wide difference in the facies of others. I know of no American Tertiary *Idmoneæ* similar in character to those described by Reuss from the North Italian deposits. The localities are those given by the several authors.

44. Idmonea maxillaris, Lonsdale, 'Quart. Jour. Geol. Soc.' vol i. p. 523 = *Crisisina* ibid., D'Orb, Prod. 2, p. 397 = *Idmonea* ibid.

Gabb and Horn, 'Mon. Foss. Poly. Sec. and Tert. Formations,' N. America.

Locality.—Eocene (G. and H.), S. Carolina.

45.—IDMONEA COMMISCENS, Lonsdale, *loc. cit.*, p. 524=*Crisisina* ibid., D'Orb.

Locality.—Eocene; Rock's Bridge.

46. IDMONEA CALIFORNICA, Gabb and Horn, *loc. cit.*

Locality.—Miocene (G. and H.), Santa Barbara, California.

47. IDMONEA CARINATA, Roemer,[1] Reuss, 'Foss. Pol. des Wiener Tert.-beck.' Marine Limestone.

48. IDMONEA PERTUSA, Reuss, 'Foss. Pol. des Wiener Tert.-beck.' Marine Limestone.

49. IDMONEA COMPRESSA, Reuss (*op. cit.*). Marine Limestone.

Range.—From the Tophaceous Chalk of Maestricht to Eocene.

50. IDMONEA FORAMINOSA, Rss., (*Crissina*) Stoliczka, 'Oligocene Bry. from Latdorf.'

51. IDMONEA GIEBELI, Stol., (*Tubigera*) Stoliczka, 'Oligocene Bry. from Latdorf.'

52. IDMONEA *DELICATULA, Busk, Stoliczka, 'Oligocene Bry. from Latdorf.'

53. IDMONEA TENUISULCA, Rss., Stoliczka, 'Oligocene Bry. from Latdorf.'

54. IDMONEA HORNESII, Stol., Stoliczka, 'Oligocene Bry. from Latdorf.'

55. IDMONEA RETICULATA, Reuss, 'Palæont. Stud. Tert. der Alpen,' pl. xxxiv. fig. 13.

56. IDMONEA GRACILLIMA, Reuss, 'Palæont. Stud. Tert. der Alpen,' pl. xxxv. fig. 1–2.

57. IDMONEA CONCAVA, Reuss, 'Palæont. Stud. Tert. der Alpen,' pl. xxxv. figs. 3–4.

Localities.—Val di Lonti; Montecchio Maggiore, N. Italy.

58. IDMONEA PUNCTATA, D'Orb., sp.=*Laterocava*, D'Orb., pl. dcclxxii. figs. 11–12. Busk, 'Crag Pol.' pl. xv. fig. 5; pl. xvi. fig. 3.

Range.—Cretaceous (D'Orb.); Crag (Busk).

59. IDMONEA FENESTRATA, Busk, 'Crag Pol.' p. 105, pl. xv. fig. 6.
60. IDMONEA *DELICATULA, ,, ,, ,, p. 106, pl. xv. fig. 8.
61. IDMONEA INTRICARIA ,, ,, ,, p. 106, pl. xv. fig. 7.

Range.—Coralline Crag (Sutton).

Genus ENTALOPHORA, Lamx.

=*Pustulopora*, (pt.) Blainv., M.-Edw., Lamk., Busk; *Spiropora*, Lamx., J. Haime.

'*Zoarium* erect and ramose, rising from a more or less expanded base, composed of decumbent tubes; branches cylindrical. *Zoœcia* tubular, opening on all sides of the branches.'

I have already in my former Reports on Fossil Polyzoa, 1882 and 1883, given the history of this group, both as *Entalophora* and *Spiropora*, in strata of the Mesozoic and Palæozoic ages. All that remains for the present report are the species described in the Upper Cretaceous and Tert. rocks of America and Europe. I cannot however furnish, from my own knowledge, a very detailed list; excepting a few of the species described

[1] 'Quite agreeing with the specimens from the *Maestricht* beds of Fauquemont' (Roemer).

by Reuss, Gabb and Horn, and Roemer. The list is therefore, for the present, a compilation rather than the result of special work, and it may in the future have to be modified. The recent species are very few, and their range is limited. In the British seas only one is recorded; in the Mediterranean Mr. Waters records three species, and as these have fossil representatives as well as recent, I give Mr. Waters's list first—'Bry. Bay Naples,' 'Ann. Mag. Nat. Hist.' 1879.

62. ENTALOPHORA PROBOSCIDEA, Forbes. See Busk, 'Cyclostomata,' p. 21, pl. xvii. A right fig.=*E. attenuata*, Rss., 'Die Foss. Anth. und Bry.' p. 74, pl. xxxvi. figs. 1–2.

Range.—Miocene, Val di Lonti. Living: Shetland; Bay of Naples, common; Madeira.

63. ENTALOPHORA DEFLEXA, Couch=*Pustulopora clavata*, Busk, 'Crag Poly.' p. 107, pl. xvii. fig. 1.

Range.—Pliocene; Crag. Living.

64. ENTALOPHORA RUGOSA, D'Orb=*E. rugosa*, 'Pal. Franç.' p. 795=*Pustulopora rugulosa*, Manz., 'I Brioz. Foss. del Mioc. d'Aust.'=*Pustulopora rugosa*, Waters, 'Bry. from Pliocene of Bruccoli.'

Range.—Chalk; Miocene; Pliocene; Bruccoli. Living, Naples.

The following are the identifications of Busk, 'Crag Polyzoa,' pp. 107–108:—

65. ENTALOPHORA CLAVATA, Busk=*Pustulopora* ibid., Busk, 'Crag Pol.' p. 107, pl. xvii. fig. 1=*Pustulopora gracilis*, M.-Ed.=*Pustulopora Roemeri*, D'Orb.; Michelin. *Entalophora linearis*, D'Orb.

66. ENTALOPHORA PALMATA, Busk=*Pustulopora* ibid., Busk, 'Crag Pol.' p. 108, pl. xviii. fig. 2.

67. ENTALOPHORA SUBVERTICILLATA, Busk = *Pustulophora* ibid., Busk, 'Crag Pol.' p. 108, pl. xviii. fig. 1.

Range.—Coralline Crag.

Genus DIASTOPORA, (part) Lamx.

Berenicea, Lamx; *Mesenteripora*, Blainv., Busk (for foliaceous bilaminate forms). *Discosparsa*, D'Orb.

'*Zoarium* adnate and crustaceous, or foliaceous, usually discoid or flabellate, less commonly irregular in form. *Zœcia* tubular, with an elliptical or subcircular orifice, crowded, longitudinally arranged, in great part immersed.'—Hincks, 'Brit. Mar. Pol.' p. 457.

The Diastoporæ of the Tertiary rocks, even as defined above, which include the foliaceous forms, are not abundant. So many different forms have been included in the group that it is difficult from the lists to say which are true Diastoporæ and which are not. The following, however, are the identifications of two of our best workers on Recent and Tertiary species; so the synonyms may be relied on as being tolerably correct.

68. DIASTOPORA LATOMARGINATA, D'Orb., 'Pal. Franç.' p. 827, pl. 758, figs. 10–12, Waters, 'Bry. Bay Nap.' 'Ann. Mag. Nat. Hist.' 1879, p. 272 = ? *Diastopora sparsa*, Manzoni, 'Foss. Bri. d'Aust. ed Ung.'

69. DIASTOPORA FLABELLUM, Reuss, Waters, *op. cit.* p. 273 = Reuss, 'Die Foss. Polyp. der Wiener Tertb.'=*Diastopora* ibid., Manzoni (Pliocene) = *Diastopora simplex*, Busk (non D'Orb.), 'Crag Poly.' p. 113.

70. DIASTOPORA PATINA, Lamarck (Hincks, p. 458) = *Discosparsa marginata* (proliferous form), 'Pal. Fr. Terr. Crét.' v. 822.

71. DIASTOPORA OBELIA, Johnst. (Hincks, p. 462), Post-Pliocene of Canada (Dawson).

72. DIASTOPORA SUBORBICULARIS, Hincks (Hincks, p. 464) = *D. simplex*, Busk, 'Crag Poly.' 113, pl. xx. fig. 10, not *Discosparsa simplex* of D'Orb (Hincks) = ? *D. flabellum*, Reuss (Hincks).

The following are the identifications and descriptions of the different authors.

73. DIASTOPORA LINEATA, Gabb and Horn (Cretaceous), 'Approaches *D. regularis*, D'Orb.' (G. & H. *op. cit.*).

74. DIASTOPORA DISCIFORMIS, Hagenow (Cretaceous), *op. cit.* pl. i. fig. 7.

74* DIASTOPORA DISCIFORMIS, Goldf, Up. Oligocene, Roemer, 'Polyp. Nord. d. Tert. Geb.'

75. DIASTOPORA MINIMA, Reuss, 'Marine Limestone, Nussdorf.' 'Foss. Pol. d. W. Tert.'

76. DIASTOPORA ROTULA, Reuss, 'Marine Limestone, Eisenstadt,' 'Foss. Pol. d. W. Tert.'

77. DIASTOPORA SPARSA, Reuss, 'Marine Limestone, Eisenstadt,' 'Foss. Pol. d. W. Tert.'

78. DIASTOPORA FLABELLUM, Reuss, 'Marine Limestone, Eisenstadt,' 'Foss. Pol. d. W. Tert.'

Two other species are given by Reuss—*D. plumula*, Rss., and *D. echinata*, Goldf. These have already been referred to *Tubulipora*.

79. DIASTOPORA PATINA, Lamk.; Pliocene, Castrocaro, Manzoni, 'Bri. di Castrocaro,' p. 44.

80. DIASTOPORA STRIATA, J. Haime; Pliocene, Castrocaro, Manzoni, 'Bri. di Castrocaro,' p. 44.

81. DIASTOPORA EXPANSA, Manzoni; Pliocene, Castrocaro, Manzoni, 'Bri. di Castrocaro,' p. 45.

82. DIASTOPORA MEANDRINA, S. Wood, 'Crag;' Busk, 'Crag Pol.' p. 109 = *Mesenteripora* ibid., Busk, pl. xvii. fig. 2; pl. xviii. fig. 4; pl. xx. fig. 2 = *D. Eudesiana*, M.-Edw. (?) = *Ditaxia compressa*, (?) Goldf., Hagenow = *Mesenteripora neocomiensis*, D'Orb. 'Ter. Crét.'

The following synonyms of this species are given by Smitt, 'Scandinavian Bryozoa':—

Ceriopora compressa, Goldf.; *Polytrema*, D'Orb.; *Ditaxia*, Hag.; *Mesenteripora*, D'Orb.; *Bidiastopora Michelina*, D'Orb.; *Mesenteripora*, ibid., D'Orb.; *Bidastopora* and *Mesenteripora Eudesiana*, D'Orb.

Family III. HORNERIDÆ, Smitt.

'*Zoœcia* opening on one side only of a ramose *zoarium*, never adnate and repent.'

The family HORNERIDÆ, as defined by the Rev. T. Hincks, is capable of very wide extension, and can be made to include the Polyporidæ ('Brit. Assoc. Rep. Foss. Poly.' 1883), in which I have placed the *Polypora* and *Phyllopora* of the Palæozoic Rocks. It may seem, however, a very questionable proceeding to include so many apparently diversified forms in one family group, especially as we have no gradational links by which we can unite the Polypora of the Palæozoic with the well-defined *Hornera* of the Tertiary Rocks. But, irrespective of the peculiarity, I see no sufficient reason for keeping the group separate if we are to accept Mr. Hincks's diagnosis. The same remarks may apply to the

Thamniscidæ as well. It is when we come to study the various genera that would, in all probability, form a natural group, that several doubts arise as to the wisdom of this arrangement.[1]

In his definition of *Hornera* ('Brit. Mar. Pol.' p. 467), Mr. Hincks says that the *zoœcia* are tubular, and this is well shown in the figure of *H. lichenoides*, fig. i. pl. 67, 'Brit. Mar. Pol.,' and also in *H. violacea*, fig. 6 of the same plate. Then, again, it is said that the '*oœcium* (*gonœcium*) is a distinct chamber—not a mere inflation of the surface of the zoarium, placed dorsally or in front.' These are elements of structure that indicate distinct characters, and though I have not been able to detect the *gonœcium* in any of the specimens found in the Crag, or in the Miocene described by Reuss, the tubular zoœcia are, in many respects, similar to recent forms described by Mr. Busk ('Cyclostomata') and Mr. Hincks. Then, again, the characteristic cell orifice, with its waving lines surrounding it—given by Mr. Busk ('Cyclostomata,' pl. xx. fig. 3)—is entirely unlike any cell-orifice known to me in any of the species of the genera named as found in the Palæozoic rocks. I do not, however, set so much value upon the 'wavy anastomosing ridges' indicated by Mr. Hincks in his diagnosis of his genus *Hornera*; nevertheless they are peculiar, and may merit some consideration in our definition of species. In the *Polypora* of the Carboniferous rocks there are wavy lines which seem to be merely ornamentations of the surface, yet these, too, may be analogous with the wavy ridges of the *Hornera* of more recent times. The Messrs Young, of Glasgow, in their joint paper On New Carboniferous Polyzoa ('Ann. Mag. Nat. Hist.' May, 1875), describe as new a species which they provisionally name *Thamniscus ? Rankini*, Y. & Y. pl. ix. *bis*, and in their remarks (*loc. cit.* p. 336) they say, 'The generic position of the fossil is uncertain . . . . Meanwhile, though strongly disposed to regard the fossil as a true *Hornera* or a member of a closely allied genus, we think it safer to leave it in the Palæozoic genus *Thamniscus*.' This species is certainly (superficially considered) more closely allied to *Hornera* than any Palæozoic species known to me; yet it, too, lacks the peculiar cell orifices, though partaking somewhat of the tubular cell structure of true *Hornera*. In the Mesozoic rocks—excepting a few doubtful forms in the Upper Chalk—I know of no *Hornera* or allies of the genus.

In his 'Crag Polyzoa' (p. 95), Mr. Busk says, 'Several fossil forms of *Hornera* have been noticed, and some of them figured; but from the want of precision in the details of the figures, and in the absence of any determinate specific characters in the descriptions, it is extremely difficult to arrive at any satisfactory conclusion respecting them. The best figures are those contained in Milne-Edwards's excellent memoir on the Crisiæ, &c.; but even these are by no means sufficiently precise to convey a correct idea of the specific differences or resemblances.' This cannot be said of the species figured by Mr. Busk in his 'Crag Polyzoa,' and I feel confident that I cannot do better than follow him in his synopsis of fossil forms.

In characterising one of his forms in the 'Bay of Naples Bryozoa,' Mr. Waters draws attention to the very beautiful species which he names *Filisparsa tubulosa*, Busk. This is, in all probability, a variety of the *Hornera violacea*, var. *tubulosa*, Busk; but, as Mr. Waters points out ('Bay Nap.

[1] Exception to this association has been taken by Mr. Ulrich in his contribution to the *Cincin. Journ. Nat. Hist.* April 1884, and, according to his views, rightly so.

Bry.,' 'Ann. Mag. Nat. Hist.' April, 1879, p. 275), after inspecting a Northern *H. violacea* from the cabinet of Rev. A. M. Norman, there is 'hardly anything in common' with the two forms. He also remarks that 'the genus *Filisparsa* is, as pointed out by D'Orbigny, intermediate between *Hornera* and *Idmonea*. . . . I am, however, somewhat in doubt as to whether the genus will permanently stand' (*loc. cit.* p. 275). Of this I am not so certain. *Filisparsa tubulosa*, Busk and Waters, and *F. varians*, Reuss, are neither *Idmonea* nor *Hornera*, and it seems to me to be far preferable to characterise an intermediate form by a generic name, rather than simplify too much our generic nomenclature. If, however, it can be found that, in dealing with fragments of species of the genus *Hornera*, the differences in character arise from differences of growth —like the *Fenestella* of the Carboniferous rocks, then these remarks will have no weight; but so far as I have been able to study species of the genus *Hornera* and *Filisparsa* they appear to me as distinct.

There are a few fossil species of *Hornera* found in material from several localities in Australia, especially the Yarra Yarra district, but as these have not as yet been described it would appear rather invidious to anticipate Mr. Waters's work, the completion of which—Cyclostomatous Forms—has been promised by him.[1]

Before concluding these remarks, it may be well to refer the student to Mr. Hincks' matured opinion of the genus *Hornera* (*loc. cit.* p. 467), because he includes in the one genus the true typical *Hornera* with its 'wavy anastomosing ridges,' and the tubular *H. violacea*, Sars, which is destitute of the characteristic 'fibrous crust' found in *H. lichenoides*, Linnæus.

Genus HORNERA, Lamouroux.

= *Retepora*, (pt.) Goldfuss; *Siphodictum*, Lonsdale.

Zoarium erect, ramose, sometimes reticulate. *Zoœcia* tubular, opening on one side only of the branches, disposed in longitudinal series, the celluliferous surface often traversed by wavy anastomising ridges. *Oœcium* a distinct chamber, not a mere irregular inflation of the surface of the *zoarium*, placed dorsally or in front.

The care with which Mr. Hincks has drawn up the above diagnosis ought to satisfy the ordinary critical student of Fossil Polyzoa, but the most valuable element of structure is the peculiar *oœcium*. In the absence of this, there are other elements which may serve as a guide and a check to overhasty identification. In his work on the 'Bryozoa of the Maestricht Beds,' &c., Hagenow gave a synopsis of the whole of the then known *Hornera*, ranging from the Recent to the Upper Silurian. In the last formation the *Hornera crassa*,[2] Lonsdale, is the sole representative; excepting this no true *Hornera* is given by the author below the 'Kreide-formation.' I reproduce below Hagenow's list, because in his work he only describes and figures one species. There are several *Hornera* described by Reuss and Busk, and there are still many undescribed forms among the Australian Polyzoa of Mr. A. W. Waters, and also in my own cabinet.

B. Tertiarformation.

83. HORNERA HIPPOLYTA, Defrance.
84. ,, GRACILIS, Philippi.

[1] See remarks *ante*. [2] This is not a *Hornera*, but a *Thamniscus*.

85. HORNERA BISERIATA, Philippi.
86. „ AFFINIS, Milne-Ed.
87. „ STRIATA, „
88. „ ANDEGAVENSIS, Michelin.
89. „ BILOBA, Reuss.
90. „ VERRUCOSA, Reuss.
91. „ SERIATOPORA, „
92. „ RADIANS, Defrance (non Lamx.).
93. „ CRISPA, „
94. „ ELEGANS „
95. „ DECIPIENS, Eichwald.

C. Kreideformation.

96. HORNERA LANGETHALI, Hagenow.
97. „ OCULATA „
98. „ COMPRESSA „
99. „ TRIGONOPORA „
100. „ TUBULIFERA „
101. „ (IDMONEA) CONTORTILIS, Lonsd.
102. „ CARINATA, Reuss.

In the same synopsis, Hagenow gives a list of eight species of *Idmonea* as belonging to his stage B, and twenty-seven belonging to the stage C, and only one, *I. triquetra*, Lamx., in the stage D or the Juraformation.

Mr. Busk's list ('Crag Polyzoa') is valuable on account of the care with which he has worked the known species for comparison and identification of the fossil forms described by him as found among his Crag Polyzoa. Busk describes eleven species, some of which he considers to be new, others are referable to forms previously described by authors; these are given under the two divisions—

FENESTRATÆ and RAMOSÆ.

103. HORNERA INFUNDIBULATA, Busk (C. Crag), 'Crag Poly.' p. 97, pl. xiv. fig. 1.
104. HORNERA RETEPORACEA, M.-Edw., „ „ p. 98, pl. xiv. fig. 2.
105. HORNERA CANALICULATA, Busk, „ „ „ pl. xiv. fig. 3.
106. HORNERA RHIPIS, Busk, „ „ p. 99, pl. xiv. fig. 4.
107. HORNERA HUMILIS, Busk, „ „ p. 100, pl. xiv. figs. 5 and 6.
108. HORNERA PERTUSA, Busk, „ „ p. 101, pl. xiv. fig. 7.
109. HORNERA HIPPOLYTA (?), Defrance. „ „ „ pl. xiv. figs. 8–9 = *H. Hippolyta*, *hippolythus*, M.-Edw. and Defrance.
110. HORNERA LUNATA, Busk (C. Crag), 'Crag Poly.' p. 102, pl. xvi. fig. 4.
111. HORNERA FRONDICULATA, Lamx. (C. Crag), 'Crag Poly.' p. 102, pl. xv. figs. 1–2, pl. xvi. fig. 6 = *Retepora frondiculata*, Lamx. = *Millepora tubipora*, Ellis & Sol. = *Millepora lichenoides*, Linn., Pallas, Esper = *Hornera affinis*, M.-Ed. = *Hornera andegavensis*, Michelin.

112. HORNERA STRIATA, M.-Edwards (C. Crag) 'Crag Poly.' p. 103, pl. xv. fig. 3; pl. xvi. fig. 5 = *Hornera striata*, M.-Edw., Michelin.
113. HORNERA RHOMBOIDALIS (C. Crag), 'Crag Poly.' p. 104, pl. xv. fig. 4.

The following forms Mr. Busk was unable to identify with the Crag forms (pp. 96–97) :—

114. HORNERA FLABELLIFORMIS, Blainv. = *Retepora* ibid., Blainv., Michelin, 'Icon. Zooph.' p. 314 = ? *Hornera Ferussacii*, Mich. ? Eocene; Miocene.
115. HORNERA SCOBINOSA, Michelin = *Retepora* ibid., Mich. *l. c.* p. 316; Miocene.
116. HORNERA AFFINIS, M.-Edw. Upper Tert. of Sicily.
117. " LÆVIS, " *l. c.* p. 20. Miocene, Dap.

Stoliczka gives the following list of *Hornera* in his 'Oligocene Bryozoa, from Latdorf.'

118. HORNERA HIPPOLYTA, Def. = *Hornera gracilis*, Philippi.
119. " RETEPORACEA, M.-Ed. = " *subannulata*, Philippi.
120. " VERRUCOSA, Reuss = " *seriatopora*, Reuss.
121. " POROSA, Stol. =

Under the family name of *Idmonidæ*, Professor Reuss describes and figures in his 'Bryozoa, Palæon. Stud. über die älteren Tertiär. der Alpen,' the following species of *Hornera*. Some of the species seem to be widely distributed in the Alpine Tertiaries, but are most abundant in the Val di Lonti and Montecchio Maggiore material.

122. HORNERA CONCATENATA, Reuss; *op. cit.* pl. 35, figs. 5 and 6.
123. " TRABECULARIS, " " " fig. 7 = ? *H. hippolithus*, Def.
124. " ASPERULA, " " " figs. 8 and 9.
125. " SERRATA, " " " figs. 10 and 11.
126. " D'ACHIARDII, " " " fig. 12.

Prof. Roemer, in his Monograph of the 'Polyparien des Norddeutsch. Tert.-Gebirges,' gives the following list of five *Hornera* as found in the Lower, and one in the Upper Oligocene :—

127. HORNERA BIPUNCTATA, Roemer, *op. cit.* p. 23, Tab. III. fig. 4. Lower Oligocene.
128. HORNERA SULCOPUNCTATA, Roemer, *op. cit.* p. 23, Tab. III. fig. 5. Lower Oligocene.
129. HORNERA TORTUOSA, Roemer, *op. cit.* p. 23, Tab. III. fig. 6. Lower Oligocene.
130. HORNERA NITENS, Roemer, *op. cit.* p. 23, Tab. III. fig. 7. Lower Oligocene.
131. HORNERA LAMELLOSA, Roemer, *op. cit.* p. 24, Tab. III. fig. 8. Lower Oligocene.
132. HORNERA GRACILIS, Philippi, Beiträge, Tab. I. figs. 7, 8, 9. Upper Oligocene.

Family IV. LICHENOPORIDÆ, Smitt.

= *Discoporidæ*, Busk, 'Brit. Cyclop.'; *Discoporellidæ*, Busk, 'Mus. Cat.' pt. iii.; *Caveidæ*, (part) D'Orb.; *Tubigeridæ*, (part) D'Orb.

'*Zoarium* discoid, simple or composite, adnate, or partially free and stipitate. *Zoœcia* tubular, erect or suberect, disposed in more or less distinct series, which radiate from a free central area; the intermediate surface cancellated or porous.'—Hincks, p. 471.

Whether this family will remain intact as we get a more perfect knowledge of the structure of the fossil forms below the Tertiary rocks, I am, at present, unable to say. It would be unwise to displace the Tertiary forms that would naturally fall under this head, and the few Mesozoic species known to me may also find a resting-place here, for unless we knew more of the structure of the Jurassic species it would be also unwise to disturb the placement of these; but when we come to the few disc-like forms of the Palæozoic rocks, we meet with peculiarities of structure unknown to me in the more recent *Lichenoporidæ*. Three species are described in the 'Silurian System' as *Discopora*, and figured in Plate 15 of that work (figs. 21, 22, 23); these are named:—

Discopora antiqua, Milne-Ed. ? = *Cellepora antiqua*, Goldf.
Membranipora ,, Blainv.
,, *squamata*, Lonsdale
,, ? *favosa* ,, = *Cellepora favosa*, Goldf.

Within the last few years the affinities of these forms have been the subject of a good deal of controversy. Dr. Gustav Lindstrom ('Ann. Mag. Nat. Hist.' Ser. 4, vol. xviii. p. 5 and sequel), in speaking of the development of *Monticulipora petropolitana*, Pander, says that—'It begins . . . . as a Bryozoon, as a *Discoporella*, or, as what Hall has termed *Ceramopora imbricata* ('Pal. N. Y.' vol. ii., p. 169, pl. xl., figs. 1*a*–1*i*). There can be no doubt that this is closely allied to the recent *Discoporella*. (See Fr. Smitt, 'Ofv. Vet. Akad. Forb. 1866,' p. 476, pl. xi. fig. 4).' This opinion has been contested by Prof. Nicholson in his work on the 'Tabulate Corals,' p. 283, wherein he says—'I have endeavoured to give a faithful account of the views Dr. Lindstrom has published as to the development of the *Monticulipora*, and upon which he, in large part, bases his view that the fossils of this genus are really Polyzoa.' Since the publication of the works 'Monticuliporidæ' and 'Tabulate Corals' of Prof. Nicholson, Mr. John Young, of Glasgow, has 'discovered specimens of another Bryozoon, or Polyzoon, as I prefer to name it . . . . that is closely allied to the Silurian *Ceramopora*, and which I have been enabled to follow clearly in all its stages of growth until it becomes a true *Monticulipora*' ('On the Identity of Ceramopora megastoma,' &c., 'Ann. Mag. Nat. Hist.' Dec. 1882). The stages through which this form passes before it assumes the *Monticulipora* form are similar to, or probably the same as, the stages indicated by Dr. Lindstrom—the *Fistulipora* and *Thecostegates* stages. Mr. John Young, however (*loc. cit.* p. 430), does not commit himself to give an opinion on 'the vexed question as to the zoological position of the organisms showing these changes, but only states that, as regards the Carboniferous form, one of two things seems certain, viz., that if *Fistulipora minor* (M'Coy) be held to be a tabulated coral of the *Monticuliporidæ* group, then *Ceramo*-

pora megastoma (M'Coy), is only its younger stage; and if, on the other hand, the latter form be held to be a Polyzoon, then its later stage is only a further development of Polyzoal life, and *Fistulipora minor*, and the other forms indicated in Dr. Lindstrom's paper in the "Annals," must of necessity be removed from the Tabulate Corals.'

It is impossible to gainsay the logic of Mr. John Young, however we may be inclined to controvert the views of those who still hold the Polyzoal affinity of Silurian *Discopora*. I do not, however, speak without a full knowledge of the whole of the forms previously referred to, and at present it would be better to defer any positive opinion in the face of the really honest work of Dr. Lindstrom, Smitt, Prof. A. Nicholson, or Mr. John Young. Yet I cannot forbear remarking that, so far as I can rely upon my own work, I cannot speak in favour of the views of those who hold the belief that any natural affinity exists between the *Discopora* of the Silurian rocks, and the *Discoporella* of present seas. In this review, then, I must except the Palæozoic forms altogether, and I would prefer, for the present, to leave also the Mesozoic as well.

Genus LICHENOPORA, Defranc.

'*Zoarium* discoid, raised, simple, or composed of many confluent disks, entirely adnate, or partially free, and sometimes stipitate, developed on a thin lamina, which usually forms a border round it. *Zoœcia* distinct or connate in single radiating lines, or multiserial.'—Hincks, p. 472.

133. LICHENOPORA HISPIDA, Flem. (Hincks, p. 473) = *Discoporella hispida*, Gray; Busk, 'Crag Pol.' p. 115. *Discocavea* (*Lichenopora*) *aculeata*, D'Orb. ?*Heteroporella radiata*, Busk, 'Crag Pol.' p. 127, pl. xix. fig. 2.

Range.—?Cor. Crag (S. Wood); Scotch Glacial Deposits (Geikie); Post-Pliocene, Canada (Dawson). Living.

134. LICHENOPORA RADIATA, Aud. (Hincks, p. 476) = *Discoporella* sp., Manzoni, 'Bry. du Plioc. de Rhodes.'

Range.—Pliocene; Rhodes (Manz.); Bruccoli, Sicily (Waters). Living.

135. LICHENOPORA VERRUCARIA, Linn. Fabr. (Hincks, p. 478) = *Discocavea* and *Unicavea*, D'Orb. 'This in many respects resembles *D. radiata*. It is not the *Discoporella verrucaria* of Manzoni ('Bry. Foss. Ital.' 4th Contr. pl. vi. fig. 33), which may be *Diastopora flabellum*, Rss.' (Waters, 'Bry. Bay of Naples,' p. 271).

Range.—Living. Fossil (?).

136. LICHENOPORA CRASSIUSCULA, Smitt (Scand. Bryoz.) = *Tubulipora Grignonensis*, Busk, 'Crag Pol.' p. 116.

Range.—Crag (Busk). Living, Northern Seas.

137. LICHENOPORA REGULARIS, D'Orb. (Hincks, p. 479); D'Orb. 'Pal. Fr.'

Range.—French Cretaceous beds. Living, Shetland.

Genus DOMOPORA, D'Orbigny.

Domopora, D'Orb., 1874, 'Prod. de Pal.,' Busk; *Defrancia*, (part) Reuss, Hagenow, Sars, Manzoni; *Ceriopora*, (part) Goldfuss; *Stellipora*, (part) Hagenow.

'*Zoarium* massive, cylindrical or mammiform, simple or lobed, formed of a number of subcolonies superimposed one upon the other; the whole surface porous. *Zoœcia* disposed in radiating lines, consisting of one or more series, on the free extremity of the stem or lobes.'—Hincks, p. 481.

138. Domopora stellata, Goldf.; Hincks, p. 481; Goldf. 'Petrefac.' i. p. 39, pl. xxx. fig. 12 = *Stellepora stellata*, Hag. 'Bry. Maest.' p. 44 = *Defrancia stellata*, Reuss, 'Foss. Pol. Wien. T.' 37, pl. vi. fig. 2; Manzoni, 'Bri. Foss. Mioc. d'Aust.'

Range.—'In stratis arenoso-margaceis,' Westphaliæ (Goldf.); Austro-Hung. (Manzoni); Vienna Basin (Reuss).

139. Defrancia disticha, Hagenow (*α* with smooth interspaces), Tab. IV. fig. 1.

140. Defrancia Michelini, " " " " Tab. IV. fig. 5.

141. Defrancia cochloidea, " " " " Tab. IV. fig. 8.

142. Defrancia diadema, Goldf. (*β* with porous interspaces, Hag.), Tab. IV. fig. 23 = *Ceriopora* ibid., Goldf.

143. Defrancia reticulata, Hag. (*β* with porous interspaces, Hag.), Tab. IV. fig. 4.

144. Defrancia cariosa, " " " " Tab. IV. fig. 6.

145. Defrancia sellula, " " " " Tab. IV. fig. 7.

Range.—The first and fourth of Hagenow's species are found both at Maestricht and Falkenberg, the rest are Maestricht. Busk, 'Brit. Mus. Cat.' pt. iii. p. 35, gives *D. truncata*, Jameson, as a Recent Northern form, and he gives *Ceriopora stellata*, Goldf., as a synonym.

This is the end of the classification of the Cyclostomata, so far as Mr. Hincks gives any details. But Mr. Busk, in his 'Ill. Brit. Mus. Catalogue,' admits the following.

Family VI. Frondiporidæ, Smitt.

= *Fasciculineæ* and *Fascigeridæ*, D'Orb.; *Frondiporidæ* and *Corymboporidæ*, Smitt; *Cerioporidæ*, Busk; *Cerioporina*, Hagenow.

'*Zoarium* massive, stipitate, simple or lobed, or ramose. *Zoœcia* connate, aggregated into fasciculi, and continuous throughout the length of the fasciculus, at the extremity of which only they open; walls of cells porous; no intermediate pores or cancelli.'

Fasciculipora, sp., are found in the Jurassic strata, and Frondipora also are probably as old as the Chalk; but in this Report I can give no details respecting the species.

Part II.—*Historical Labours on the Group.*

Cretaceous Polyzoa (Pt. ii. Foreign Species).

See Cretaceous Polyzoa (Pt. i. Brit. Species), Brit. Assoc. Rep. Foss. Polyz. (mihi), 1883.

It is impossible at the present time, and with our present knowledge, to comprehend the full meaning of the grouping of the Fossil Polyzoa by the older naturalists. The genera were few in number and not always well defined, so that the history of any special group is, comparatively speaking, the history of advancing knowledge—not, however, based upon structure, but upon external form only. Then, again, the form and habit of an individual type served as a pretext for founding new genera and new species, without, in many cases, the least regard to structural peculiarities. I do not put this down as a reproach, but rather as one of the primary reasons why these time-honoured naturalists are disregarded by younger workers. For myself, I have no desire to ignore the help of early investigators, and I wish particularly, in this division of my Report, to give as full a history of the grouping of Fossil Polyzoa, together with as full an account of the species, as possible. I do this in the interest of two different classes of workers. In the first place, I desire to give—beginning with Goldfuss—the Palæontological history of the Polyzoa, ranging from the Cretaceous beds to the highest beds of the Tertiary; and, in the second, to place in the hands of fellow students a full history of species described by the successive workers also from the time of Goldfuss to the present, giving, as far as I am able, the modern classificatory name. This part of my Report may appear, to all but the two sets of workers named above, a tedious piece of labour. But when it is remembered that many of the works, papers, or monographs of the earlier workers are at the present day inaccessible—or almost inaccessible except to those who reside in the vicinity of large libraries—the tediousness will be more apparent than real. I think it will be admitted by all, that the whole of the lists of species of Polyzoa must be accepted by the Palæontologist—unless by carefully working over the old work many of the early names are reduced to synonyms. In many cases I know that this is their ultimate destiny. Until new students, then, are content to work along the lines fully elaborated—from the consecutive labours of the Rev. Thomas Hincks and Mr. A. W. Waters—in the earlier part of the present Report—confused and ill-digested compilation must follow. I have been asked, over and over again, why not work along the lines laid down by D'Orbigny in his grouping of the Polyzoa; or if not, give my reasons for neglecting him. I have no wish to do either. So far as D'Orbigny gave to us original work I am proud, and even glad, to follow him in his groupings; but I do not believe that a dozen men exist who can adopt his method with any satisfaction to themselves. Professor Roemer adopted D'Orbigny's classification for his work on the Norddeutsch Bryozoa; and so have the Messrs. Gabb and Horn for their monograph of the Secondary and Tertiary Polyzoa of North America; and a pretty full digest of D'Orbigny's system is given in M. Pictet's work on Palæontology, and also a goodly number of figures to illustrate the many divisions.

In one of Professor Smitt's elaborate papers—'Floridan and Scandinavian Bryozoa'—the author has given identifications and probable relationships of his own with some of D'Orbigny's genera and species, and I have availed myself of Smitt's valuable lists for the sake of synonymy alone. With regard to Hagenow, Reuss, Manzoni, Busk, Waters, and some few others, I think that no two opinions can exist as to the value of their special labours, and the very full list given from these authors will, I think, be fully appreciated by the working student at least. It may be well now to explain the principle by which I have been guided in compiling this part of my Report. In every case in dealing with an author's work I have not disturbed his grouping or arrangement—except where it was necessary to break up the list for the purpose of giving a stratigraphical arrangement. In an opposite column I have given, where I could, the modern and, to me, more acceptable names; otherwise the work is practically that of the author named.

At first I only intended to give the history and classification of Cyclostomatous Polyzoa, leaving for future work, or for others, the history, &c., of Cheilostomatous forms; not because I had no desire for the complete task, but because of the limited time for the continuous application necessary for the success of the Report. In making my wants known to my ever constant friend—Miss E. C. Jelly—her answer was prompt and welcome: 'The Cheilostomata *must* be done, and you can command my services to any extent in the work.' Of her labours I have gladly availed myself, and I owe to her the compilation of many of the elaborate lists given below; the arrangement, however, is my own.

It must not be supposed that what follows are mere barren names, which are easily written and as easily passed over. I have a fine suite of the Faxöe Limestone Polyzoa—almost equivalent to those of the Maestricht beds—and also of the Cretaceous rocks of America, and whenever I have made remarks on an author's work, I have only done so after a study of the species in my possession. The same remark will apply to the Australian forms described by Mr. Waters, and many of the species described in the works of Roemer, Reuss, and Manzoni. Of the Crag Polyzoa and Post-Tertiary species, I may say that it was the study of these forms that gave to me my first and longing desire to make myself as fully acquainted as possible with the whole of our Fossil, as with our Recent Polyzoa, and, thanks to Miss E. C. Jelly and to Miss Gatty, my desire to a large extent has been gratified for Recent and Fossil forms. I am greatly indebted to Professor Roemer of Breslau, and to Mr. J. M. Nickles of Cincinnati, for material from Cretaceous and Tertiary horizons which have been of great advantage to me in my varied labours on these Reports.

For reasons that may be easily understood, I place Smitt's list as a preface to this part of my Report, rather than in the first part, where it ought to be placed. In it the student will find the fullest synonymy that I have yet met with from D'Orbigny, and this in itself is a fitting introduction to the works of Roemer and the Messrs. Gabb and Horn.

F. A. Smitt, 'Floridan Bryozoa,' 1872–3 (Cheilostomata).—F. A. Smitt, 'Scandinavian Bryozoa,' 1864–68 (Cheilostomata), and Cyclostomata.

In the above works of Professor Smitt, we have not only the author's systematic arrangement of genera and species, but a most elaborate synonymy, and the two works are evidently amongst the finest of original memoirs ever offered to the scientific public on this special group of animals. I have not thought it in any way necessary to alter or disarrange the text of the author.

Scandinavian CHEILOSTOMATA.

CHEILOSTOMATA.

Sub-order CELLULARINA.

1. AETEA ANGUINA, Linn.; ibid, D'Orb. 'Pal. Fr. Terr. Crét.' v. p. 41.
2. „ „ (α) forma *spathulata*
3. „ „ (β) „ *recta* = *Stomatopora gallica*, (?) D'Orb. *l. c.* p. 836.

EUCRATEA, Lamx. = *Catenaria*, D'Orb. *l. c.* p. 43.

4. CELLULARIA TERNATA, Sol. (*Menipea* & *Scrupocellaria*, Hincks).
5. ,, (*a*) forma *ternata* = *Menipea* ibid. D'Orb. *l. c.* p. 47.
6. ,, REPTANS, Linn. = *Cellularia*, D'Orb. *l. c.* p. 50.
7. ,, SCRUPOSA, ,, ,, ,, ,,
8. GEMELLARIA LORICATA, ,, = *Gemellaria*, ,, *l. c.* p. 46.
9. BICELLARIA CILIATA ,, = *Cellularia*, ,, ,, p. 49.
10. BUGULA AVICULARIA, ,, = *Ornithopora* ,, ,, p. 322.
11. ,, forma *flabellata* = *Ornithoporina avicularia*, D'Orb. *l. c.* p. 322.
12. BUGULA forma *fastigiata* = *Acamarchis*, D'Orb. *l. c.* p. 324.
13. ,, MURRAYANA, Sm. = *Ornithoporina dilata*, D'Orb. *l. c.* p. 323.

Sub-order FLUSTRINA.

14. FLUSTRA MEMBRANACEA, Linn. = *Reptoflustra telacea*, D'Orb. *l. c.* p. 328.
15. FLUSTRA SECURIFRONS, Pall. = Ibid. D'Orb. *l. c.* p. 55.
16. ,, PAPYREA ,, = *Semiflustrata carbasea*, D'Orb. *l. c.* p. 326.
17. FLUSTRA FOLIACEA, Linn. = *Eschara* ibid. D'Orb. *l. c.* p. 55.
18. CELLARIA FISTULOSA, Linn. = *Cellaria salicornia*, D'Orb. *l. c.* p. 28. (See *ante* for synonyms, Hincks & Reuss.)
19. MEMBRANIPORA LINEATA, Linn., forma *craticula*, Alder = *Reptoflustrella arctica*, D'Orb. *l. c.* p. 571.
20. MEMBRANIPORA forma *lineata* = *Reptelectrina* ibid. D'Orb. *l. c.* p. 334 = *Membranipora sedecimdentata*, D'Orb. *l. c.* p. 542.
21. MEMBRANIPORA forma *Sophiæ*, Busk = *Reptoflustrina arctica*, D'Orb. *l. c.* p. 582.
22. MEMBRANIPORA forma *americana*, D'Orb. = *Reptoflustrella* ibid. D'Orb. *l. c.* p. 571.
23. MEMBRANIPORA ARCTICA, D'Orb. = *Semiflustrellaria* ibid. D'Orb. MS.
24. MEMBRANIPORA FLEMINGII, Busk, forma *trifolium* = *M. trifolium*, 'B. Crag Pol.' p. 32 = *M. Pouilletii*, 'B. Crag Pol.' p. 32.
25. MEMBRANIPORA PILOSA, Linn. (typica) = *Reptelectrina pilosa*, D'Orb. 'Pal. Fr. Ter. C.' v. p. 334 = *Reptelectrina dentata*, D'Orb. *l. c.* p. 334 = *Electrina lamellosa* and *cylindrica*, D'Orb. *l. c.* p. 188.
26. MEMBRANIPORA forma *monostachys*, Busk = *Flustrellaria pustulosa*, (?) D'Orb. *l. c.* p. 526.
27. MEMBRANIPORA forma *catenularia*, Jameson (non *Hippothoa catenularia*, D'Orb. 'Pal. Fran.') = *Pyripora ramosa*, D'Orb. *l. c.* p. 539.
28. MEMBRANIPORA forma *membranacea*, Müll. = ibid., D'Orb. *l. c.* p. 542.

Sub-order ESCHARINA.

Family ESCHARIPORIDÆ.

ESCHARIPORA, D'Orb.

29. ,, PUNCTATA, Hass. ('Crag Poly.' p. 40).
30. ,, ANNULATA, Fabr. = *Repteschareila Heermannii*, Gabb & Horn = *Cribrillina*, Hincks.

Porina, D'Orb.

31. „ Mallusii, Aud. = *Repteporina* ibid., D'Orb. 'Pal. Fr. T. C.' v. *l. c.* p. 443 = *Repteporina hexagona*, D'Orb. 'Pal. Fr. T. C.' v. *l. c.* p. 444.
32. Porina ciliata, Ball (*Lepralia* ibid., 'Crag Pol.' p. 42) = *Pyriflustrella arctica*, D'Orb. *l. c.* p. 570.

Escharella, D'Orb.

33. Escharella Legentilii, Aud. = *Cellepora* ibid., D'Orb. (*op. cit.*) *l. c.* 401 = *Reptoporina*, D'Orb. = *Reptescharella simulata*, D'Orb. *l. c.* p. 465.
34. Escharella Jacotina, Aud. = *Reptescharella Jacotina*, D'Orb. *l. c.* p. 465 = *Semieschara lamellosa*, D'Orb. *l. c.* p. 366.
35. Escharella linearis (forma typica) = *Semiporina pulchella*, D'Orb. *l. c.* 440 = *Semiescharellina oblonga*, D'Orb. *l. c.* p. 450.
36. Escharella linearis forma *biaperta* = *Reptoporina biaperta*, D'Orb. *l. c.* p. 442.

Mollia, Lamx.

37. „ hyalina.
38. „ „ forma *divaricata*, Lamx. = *Hippothoa divaricata*, D'Orb. 'P. F. T. C.' v. p. 383 = *Hippothoa catenularia*, D'Orb. 'P. F. T. C.' v. p. 383 = *Hippothoa Savignyana*, D'Orb. 'P. F. T. C.' v. p. 383 = *Hippothoa borealis*, D'Orb. 'P. F. T. C.' v. p. 384 = *Hippothoa mediterranea*, D'Orb. 'P. F. T. C.' v. p. 384 = *Hippothoa Robertina*, D'Orb. 'P. F. T. C.' v. p. 384 = *Hippothoa patagonica*, Busk, 'Crag Pol.' p. 24.

Myriozoum.

39. „ crustaceum, Sm. = (?) *Eschara incisa*, M.-Edw., Michelin = *Eschara incisa*, D'Orb., Busk, 'Crag Pol.'
40. Myriozoum subgracilis, D'Orb. = *Eschara incisa*, D'Orb. 'Pal. F. T. C.' *l. c.* p. 662.

Escharidæ.

41. Lepralia hippopus, Sm. = (?) *Eschara Deshayesii*, M.-Edw.
42. „ cervicornis, Pall. = ibid. D'Orb. 'P. F. T. C.' *l. c.* p. 344.
43. Lepralia elegantula, D'Orb. = ibid. D'Orb. 'P. F. T. C.' *l. c.* p. 101.

Escharoides, M.-Edw.

44. „ Sarsii, Sm. = (?) *Eschara lobata*, D'Orb. *l. c.* p. 101 = (?) *Eschara grandipora*, D'Orb. *l. c.* p. 345.

Family Discoporidæ.

45. Discopora coccinea, Abbildg. = *Lepralia variolosa*, (pars) *L. Peachii*; *L. ventricosa*, Busk, 'Crag Polyz., pp. 48 and 49.
46. Discopora forma *ovalis*, Hass. = *L. variolosa*, (pars) Busk, 'Crag Polyz.' p. 48.
47. Discopora Skenii, Sol. = *L. bicornis*, Busk, 'Crag Polyz.' p. 47.

Sub-order CELLEPORINA.

Family CELLEPORIDÆ.

48. CELLEPORA RAMULOSA, Linn., forma *tuberosa* = *Reptocelleporaria tuberosa*, D'Orb. 'P. F. T. C.' XI. (pars) p. 428 = *Cellepora tubigera*, Busk, 'Crag Pol.' p. 60.
 Forma *ramulosa* = ibid. Busk, 'Crag Pol.' p. 58.
49. CELLEPORARIA INCRASSATA, Linn. = Ibid. D'Orb. 'P. F. T. C.' v. p. 419.

Family RETEPORIDÆ.

50. RETEPORA CELLULOSA, Linn., forma *notopachys* (*a*, forma *typica*) = *Retepora notopachys*, Busk, 'Crag Pol.' p. 76.

Floridan CHEILOSTOMATA.

51. MEMBRANIPORA CANARIENSIS, B., 'Sm. Fl.' pl. ii. f. 10 = *Cupularia* ibid., Busk, 'Cr. Pol.' p. 87.
52. MEMBRANIPORELLA AGASSIZII, Sm., 'Sm. Fl.' pl. ii. f. 11. Compare *Escharipora filiformis*, D'Orb. *l. c.* p. 232.
53. CUPULARIA UMBELLATA, Def., 'Sm. Fl.' pl. ii. f. 14 = ibid. 'Bri. Plio. Ital.,' Manzoni, 1869, p. 26 = ? *Discoporella Bermudiana*, D'Orb. 'P. F. T. C.' p. 474 = ? *Discoporella denticulata*, Gabb & Horn.
54. CUPULARIA DOMA, D'Orb., 'Sm. Fl.' pl. ii. f. 15. *Discoflustrella* ibid., D'Orb. *l. c.* p. 561.
55. STEGANOPORELLA[1] ELEGANS, M.-Edw., 'Fl. Bry.' pl. ii. f. 15= *Escharellina*, D'Orb. 'P. F. T. C.' v. p. 448.
55*. STEGANOPORELLA ROZIERI, Aud., 'Fl. Bry.' pl. ii. f. 16=*Repteschar-ellina*, D'Orb. 'P. F. T. C.' v. p. 453.
56. BIFLUSTRA LACROIXII, 'Fl. Bry.' pl. ii. f. 18=*Biflustra* and *Reptoflustra* ibid., D'Orb.
57. BIFLUSTRA DENTICULATA, 'Fl. Bry.' pl. ii. f. 18=?*Membranipora tuberculata*, Busk, 'C. P.' p. 30=*Reptoflustra*, D'Orb., 'P. F. T. C.' v. pp. 328–329.
58. BIFLUSTRA SAVARTII, 'Fl. Bry.' pl. ii. f. 20= *Membranipora*, D'Orb. *l. c.*, p. 542=?*Flustrellaria tubulosa*, D'Orb., *l. c.*, p. 532= ?*Membranipora Ligeriensis*, D'Orb., *l. c.*, p. 550=?*Membranipora Savartii*, Busk, 'Crag Pol.' p. 31=?*Biflustra delicatula*, Busk, 'Crag Pol.' p. 72.
59. CRIBRILINA RADIATA, Moll, 'Fl. Bry.' pl. ii. f. 22, 'Very near to the present species, and its allies must be placed,' *Semiescharipora fragilis*, D'Orb. 'P. F. T. C.' v. p. 480 = *Semiescharipora brevis*, D'Orb. 'P. F. T. C.' v. p. 485 = *Semiescharipora ovalis*, D'Orb. 'P. F. T. C.' v. p. 488.
60. CRIBRILINA INNOMINATA, Couch, 'Fl. Bry.' pl. ii. f. 22=*Lepralia*, ibid., Busk, 'C. P.' p. 40=?*Reptescharella pygmæa*, D'Orb., *l. c.*, p. 468.
61. PORELLINA CILIATA (see *Microporella*, Hincks), 'Fl. Bry.' pl. ii. f. 26=*Reptoporellina subvulgaris*, D'Orb., *l. c.*, p. 477.
62. PORINA VIOLACEA (see *Microporella*, Hincks), 'Fl. Bry.' pl. ii. f. 30 =*Lepralia* ibid., Busk, 'C. P.' p. 43.
63. PORINA PLAGIOPORA, 'Fl. Bry.' pl. ii. f. 30=*Lepralia* ibid., Busk, 'C. P.' p. 44.

[1] *Steginoporella*, Sm.

64. Mamillopora cupula, Sm., 'Fl. Bry.' pl. ii. f. 32=?*Conescharellina*, D'Orb., *l. c.*, p. 446.
65. Gemillipora eburnea, Sm., 'Fl. Bry.' pl. ii. f. 35=?*Hippothoa elegans*, D'Orb., *l. c.*, p. 384.
66. Hippothoa Isabellina, D'Orb., 'Fl. Bry.' pl. ii. f. 44=*Reptoporina*, D'Orb.=?*Schizoporella unicornis*, Hincks.
67. Escharella sanguinea, Sm.=?*Cellepora subtorquata*, D'Orb., *l. c.*, p. 399 (*Schizoporella*, Hincks).
68. Escharella pertusa, Esper = *Cellepora*, D'Orb. (*Lepralia*, Hincks).
69. Escharella Audouinii=*Cellepora*, D'Orb.; *C. Audouinii*, D'Orb. =?*C. ovoidea* and *C. subovoidea*, 'Pal. Fr. T. C.' p. 402 (*Lepralia*, Hincks).
70. Lepralia inornata=*Cellepora* ibid., Gabb and Horn.
71. Lepralia edax, Busk=*Cellepora edax*, Busk, 'Crag Pol.' p. 59.
72. Retepora marsupiata=?*Phidolopora labiata*, Gabb & Horn.
73. Discopora albirostris (forma typica)=*Cellepora ceratomorpha*, Rss., 'Fos. Pol. W. T.' p. 80= ?*Cellepora cuculina*, Mich. 'Icon. Zoo.' p. 324.

In giving these lists of *Cheilostomata* from the Floridan and Scandinavian Bryozoa of Professor Smitt, I have not thought it necessary to curtail any of the synonyms, or alter into the more modern genera any of the forms described by the author. The student will see at a glance how very different Smitt's and Hincks's genera are, and how readily the latter author has adopted from Smitt the generic terms that could be adopted with safety. It will be for those who take up the study of either Recent or Fossil Polyzoa to arrange their species after any author whomsoever they may choose to follow. I believe, however, that for the first time, both Palæontologists and those who take up the examination of Recent or living forms, have been, by the publication of the present Report, put in possession of lists which will facilitate research and prove advantageous to future scientific exposition.

Smitt: Cyclostomata (Scandinavian).

Tribe Infundibulata, Gervais. Order Cyclostomata, Busk (=*Centrifugina*, D'Orb.).

Sub-order Radicellata, D'Orb. (=*Articulata*, Busk).

Family Crisieæ: Les Crisies (M.-Edw.)=*Crisiadæ*, D'Orb.

Crisia, Lamx. (=*Crisia*, *Unicrisia*, *Bicrisia*, *Crisidea*, *Filicrisia*, D'Orb.).

1. Crisia cornuta, Linn.=*Filicrisia*, D'Orb. 'Pal. Fr. Terr. Crét.' v. p. 604.
2. Crisia β cornuta=*Crisidia*, D'Orb. 'Pal. Fr. Terr. Crét.' v. 653.
3. Crisia eburnea. Linn.=*Crisia*, D'Orb. " " " " " 598.
4. Crisia denticulata, Linn., *Crisia*, D'Orb., 'Pal. Fr. Terr. Crét.' v., p. 599, and Busk, 'C. P.' p. 93.

Sub-order Incrustata (= *Inarticulata*, Busk).

I. Tubulinea, D'Orb. Family Diastoporidæ.

Diastopora, Lamx.; M.-Edw.

5. Diastopora repens=*Alecto*, Busk, 'Crag Pol.' p. 112=*Proboscina dichotoma*, D'Orb. 'P. F. T. Crét.' v. p. 847=*Proboscina Toucasiana*, D'Orb. (?) *l. c.*, p. 856.

6. Diastopora simplex, Busk, 'Crag Pol.' p. 113—(non D'Orb.).
7. Diastopora hyalina (α), *D. obelia*, Johnst.=*Berenicea prominens*, D'Orb. *l. c.*, p. 862.
8. Diastopora hyalina (β), *latomarginata*, D'Orb.=*Diastopora* ibid., D'Orb. *l. c.*, p. 827.
9. Diastopora patina (β) forma typica=*Discosparsa marginata*, D'Orb. *l. c.*, p. 822=*Reptomultisparsa congesta*, D'Orb. (?) *l. c.*, p. 878.
10. Diastopora patina (γ) forma *radiata*=*Radiotubigera*, D'Orb. sp. ?= *Patinella proligera*, Busk, 'Crag P.' p. 104.

Mesenteripora, Blainv.

11. Mesenteripora meandrina, Wood; D'Orb.=*Ceriopora compressa*, Goldf. 'Petr.' vol. i., p. 37=*Polytrema*, D'Orb., 'Prod. Pal. Strat.' vol. ii., p. 279=*Ditaxia*, Hagenow, 'Bry. Mäst. Kreid.' p. 50=*Bidiastopora* and *Mesenteripora Michelini*, D'Orb., 'Prod. P. S.'=*Bidiastopora* and *Mesenteripora Eudesiana*, D'Orb.= *Mesenteripora meandrina* Busk, 'Crag Pol.' p. 109=*Mesenteripora neocomiensis*, D'Orb. 'Pal. F. T. C.' p. 808.

Family Tubuliporidæ.

Tubulipora, Lamx. Sub-genus Idmonea, Lamx.

12. Tubulipora atlantica, Forbes, forma *erecta*=*Idmonea coronopus*, D'Orb. 'Pal. Fr.' *l. c.*, p. 729=*Idmonea angustata*, D'Orb. 'Pal. Fr.' *l. c.*, p. 731.
13. Tubulifora fenestrata (Busk?) (*Idmonea*) 'Crag Pol.' p. 105.
14. Tubulifora serpens, forma *erecta*=*Idmonea dilatata*, D'Orb. 'Pal. Fr. T. Crét.' p. 731.
15. Tubulipora serpens, forma *serpens* = *Reptotubigera tubulifera*, D'Orb. 'Pal. Fr. T. Crét.' p. 752=*Reptotubigera confluens*, D'Orb. 'Pal. Fr. T. Crét.' p. 752.

(Sub-genus Phalangella, Gray.)

16. Tubulipora palmata, Wood=*Tubulipora* ibid. Zooph. Crag 'Ann. Mag. Nat. Hist.' xiii. p. 14=*Alecto dilatans*, Busk, 'Crag Pol.' p. 102.
17. Tubulipora fimbria, Lam. = *Proboscina serpens*, D'Orb. 'Pal. Fr. T. C.' p. 847 = *Tubulipora flabellaris*, Busk, 'Crag P.' p. 111.
18. Tubulipora flabellaris, Fab. = *Tubulipora vernicaria*, D'Orb. 'P. Fr. T. C.' v. p. 832=*Tubulipora phalangea*, Busk, 'Crag Pol.' p. 111.

Sub-genus Proboscina, Aud.

19. Tubulipora incrassata, D'Orb., forma *erecta*=*Filesparsa incrassata*, D'Orb. 'Pal. Fr. T. C.' p. 817=*Filesparsa tubigera*, D'Orb., ibid.
20. Tubulipora incrassata, D'Orb., forma *serpens* = *Stomatopora*, D'Orb. (?) ibid. p. 386=*Stomatopora incrassata*, D'Orb. (?) ibid. =*Stomatopora recticulata*, D'Orb. (?) ibid. p. 841=*Proboscina serpens*, D'Orb., 'Pal. Fr.' *l. c.*, p. 847.
21. Tubulipora penicillata, Fabr.=*Defrancia striatula*, Busk, 'Crag Pol.' p. 117.

Family Horneridæ.

Hornera, Lamx.

22. Hornera lichenoides, Linn.=*Hornera borealis*, Busk, 'Crag Pol.' pp. 95 and 103.

Family Lichenoporidæ.

Discoporella, Gray.

23. Discoporella verrucaria, Linn., Fabr.=*Discocavea*, D'Orb. 'Pal. Fr. T. Crét.' v. p. 958=*Unicavea convexa*, D'Orb. 'Pal. Fr. T. Crét.' v. p. 972.

24. Discoporella crassiuscula, Sm.=*Tubulipora Grignonensis*, Busk Crag Pol.' p. 116 (*non* M.-Edw.)=*Defrancia rugosa*, Busk (?) *l. c.*, p. 118.

25. Discoporella hispida (Flem.) = *Lichenopora mediterranea*, Mich. 'Icon. Zoo.' p. 68=*Unicavea*, D'Orb., 'Pal. F. T. C.' p. 971=*Discocavea aculeata*, D'Orb., 'Pal. Fr.' *l. c.*, p. 958=*Heteroporella radiata*, Busk, 'Crag Pol.' p. 127.

II. Fasciculinea, D'Orb. Family Frondiporidæ.

Frondipora, Blainv.

26. Frondipora (α) reticulata, Linn.=*Frondipora* ibid., D'Orb., 'Pal. Fr. T. C.' v. p. 677.

Frondipora (β) reticulata, Linn.=*Frondipora verrucosa*, D'Orb., 'Pal. Fr. T. C.' v. p. 678.

Family Corymboporidæ.

Corymbopora, Mich.

27. Corymbopora fungiformis, Sm. = *Fungella prolifera*, Hag. (?) 'Mäst. Kreid.' p. 37=*Fasciculipora*, D'Orb. 'Pal. Fr. T. C.' v. p. 668=*Fungella quadriceps*, Busk (?), 'Crag Pol.' p. 119.

Defrancia, Bronn.

28. Defrancia lucernaria, Sav.=*Discofascigera cupula*, D'Orb. (?) *l. c.*, p. 675.

I would strongly advise the student of Fossil Cyclostomata to compare the species named, if in his power to do so, or contrast at least the lists given in this report from Hincks, Busk, Hagenow, and Reuss. It will be seen what different estimates are given of Zoarial characters by the different authors. The multiplication of species is unavoidable if we take into consideration habit only. In Smitt's list given above, the author certainly deserves the thanks of workers for his endeavour to combine leading facial characters in his simple Family arrangements, and I think I may venture to say that Smitt's Generic combination embraces all, or nearly all, the structural features that may be found in the study of this peculiar sub-order of the Polyzoa. It may be, however, quite possible to give simplicity of arrangement too wide a scope. (See Hincks and Busk on the Cyclostomata).

Dr. August Goldfuss, 'Petrefacta Germaniæ,' 1826.

The 'Zoophytorum Reliquiæ' of Goldfuss were classed under forty-five genera, and the genera Eschara, Cellepora, Retepora, and Ceriopora—

all that concerns us in the present Report—are placed after the numbers 14, 15, 16, and 20 in his cosmopolite list. It is useless to reproduce the definitions of these genera as given by Goldfuss, for the very simple reason that these names now used are much more restricted, and, comparatively speaking, have a different meaning. With regard to the use of the generic name *Ceriopora*, I may say that authors differ in opinion as to the necessity of its further retention. Generally speaking I agree with those who desire the suppression of the word ; still, there are some forms given by Hagenow, which will be referred to further on, that may conveniently retain the name, but the genus CERIOPORA, Goldfuss, embraces many typical forms that have been handed over to at least five distinct genera. The Cretaceous RETEPORA of Goldfuss, and also the CELLEPORA and ESCHARA, are also placed in hostile relationship, which will be more apparent when I review the labours of Hagenow. I cannot attempt any suggestive arrangement of Goldfuss's genera and species, because by so doing I should anticipate work that will be done further on. I merely take the lists given by him as found in the Maestricht beds, and the Cretaceous rocks of Essen.

CHEILOSTOMATA, Busk.

Genus ESCHARA, Lamarck.

Type E. FOLIACEA, Lamarck. LEPRALIA FOLIACEA, Hincks.

'Nearly stony, and not flexible, with depressed lamellary fragile expansions, extremely porous interiorly, entire or divided; cells of the polypi arranged in fives on both sides.' [1]

1. ESCHARA CYCLOSTOMA, Goldfuss, 'Petrefac,' Tab. VIII., fig. 9, Maestricht.
2. ESCHARA PYRIFORMIS, ,, ,, ,, ,, 10, Maestricht.
3. ESCHARA STIGMATOPHORA, ,, ,, ,, ,, 11, Maestricht.
4. ESCHARA SEXANGULARIS, ,, ,, ,, ,, 12, Maestricht.
5. ESCHARA CANCELLATA, ,, ,, ,, ,, 13, Maestricht.
6. ESCHARA ARACHNOIDEA, ,, ,, ,, ,, 14, Maestricht.
7. ESCHARA DICHOTOMA, ,, ,, ,, ,, 15, Maestricht.
8. ESCHARA STRIATA, ,, ,, ,, ,, 16, Maestricht.
9. ESCHARA FILOGRANA, ,, ,, ,, ,, 17, Maestricht.
10. ESCHARA DISTICHA, ,, ,, ,, ,, 18, Maestricht.
11. ESCHARA SUBSTRIATA, Münst., ,, Tab. XXXVI. ,, 9, Tert. Merg. Astrupp.
12. ESCHARA CELLEPORACEA, Münst., ,, ,, ,, 10, Tert. Merg. Astrupp.

[1] Brown's *Zoologist's Text-Book*, p. 566, ed. 1833.

Genus Cellepora, Linn.

= *Cellepora* and *Discopora*, Lamk.

Discopora, Lamarck, is now only a synonym of *Membranipora*, Blainville.

1. Cellepora ornata, Goldfuss; 'Petrefac.' Tab. IX. fig. 1, Maestricht.
2. Cellepora Hippocrepis, " " " " 3, Maestricht.
3. Cellepora Velamen, " " " " 4, Maestricht.
4. Cellepora dentata, " " " " 5, Maestricht.
5. Cellepora crustulenta, " " " " 6, Maestricht.
6. Cellepora bipunctata, " " " " 7, Maestricht.
7. Cellepora escharoides, " " Tab. XII. " 3, Cret. Rocks, Essen.
8. Cellepora urceolaris, " " Tab. IX. " 2, Tert. Merg. Astrupp.
9. Cellepora annulata, Münst., " Tab. XXXVI. " 11, Tert. Merg. Astrupp.
10. Cellepora tristoma, Goldfuss, " " " 12, Tert. Merg. Astrupp.

Cyclostomata, Busk.

1. Ceriopora micropora, Goldfuss, 'Petrefac.' Tab. X. fig. 4, Maestricht, Essen.
2. Ceriopora cryptopora, " (Heteropora); 'Petrefac.' Tab. X. fig. 3, Maestricht.
3. Ceriopora anomatopora, " " " " fig. 5, Maestricht.
4. Ceriopora dichotoma, " " " " fig. 9, Maestricht.
5. Ceriopora verticillata, " (Entalophora); " Tab. XI. fig. 1, Maestricht.
6. Ceriopora pustulosa, " " " " fig. 3, Maestricht.
7. Ceriopora gracilis, " " " Tab. X. fig. 11, Maestricht, Essen.
8. Ceriopora milleporacea, Goldfuss, " Tab. X. fig. 10, Maestricht, Astrupp.
9. Ceriopora madreporacea, Goldfuss, " Tab. XI. fig. 12, Maestricht.
10. Ceriopora tubiporacea, " " " fig. 13, Maestricht.
11. Ceriopora compressa, Goldfuss (Diastopora), " " fig. 4, Maestricht.
12. Ceriopora disciformis, " " " " Tab. XXXVII. fig. 4, Maestricht, Astrupp.

13. Ceriopora spiralis, fig. 2, Maestricht, 'Petrefac.' Tab. XI.
14. Ceriopora variabilis, Münst. ,,
Tab. XXXVII. fig. 6, Maestricht, Astrupp.
15. Ceriopora venosa, Goldfuss, ,,
Tab. XXXI. fig. 2, Maestricht.
— Ceriopora venosa, Goldfuss, ,, Tab. X.
fig. 7, Maestricht.
16. Ceriopora polymorpha, ,, ,,
Tab. XXX. fig. 11, Essen.
17. Ceriopora spongites, ,, ,, Tab. X.
fig. 14, Maestricht, Essen.
18. Ceriopora stellata, Goldfuss, ,,
Tab. XXXI. fig. 1, Essen.
19. Ceriopora Diadema, Goldfuss, ,,
Tab. XXXIX. fig. 12, Essen.
— Tab. XXXVII. fig. 3. ,,
20. Ceriopora mitra, Goldfuss, ,,
Tab. XXX. fig. 13.
21. Ceriopora cribrosa. ,, ,, Tab. X.
fig. 16.

1. Retepora clathrata, Goldf. (Idmonea) ,, Tab. IX.
fig. 12, Maestricht.
2. Retepora lichenoides, ,, ,, ,, ,,
fig. 13, Maestricht.
3. Retepora truncata, ,, ,, ,, ,,
fig. 14, Maestricht.
4. Retepora disticha, ,, ,, ,, ,,
fig. 15, Maestricht.
5. Retepora cancellata, ,, ,, ,,
Tab. XXXVI. fig. 17, Maestricht.

'Maestricht Beds,' Hagenow.

The most systematic work that has yet been published on the Cretaceous Bryozoa (or Polyzoa) is that of Frederick V. Hagenow—'Die Bryozeen der Mästrichter Kreidebildung,' 12 plates, 1851. In this monograph the writer figures and describes about 200 species of Polyzoa, many of which are new, others are re-described, from Goldfuss chiefly; and, as Hagenow had access to the original specimens of Goldfuss, I think we may pretty safely rely upon his judgment in the redistribution of types. The classification of the author is very simple. For a portion of the Cyclostomata, Busk, Hagenow adopted the division A, Tubuliporina, Milne-Edwards; for another portion he adopted Bronn's division B, Cerioporina. His division C, Salpingina embraces only two doubtful genera—*Escharites*, Röm., and *Inversaria*, Hag.—which in one sense may be considered as passage forms; still it is very doubtful whether some of the Salpingina do not belong rather to the Cyclostomata than to the Cheilostomata. The group D, Urceolata, Hag., are Cheilostomatous. Except that I shall begin with the latter groups—C and D—first, I shall not otherwise disturb the arrangement of the author; but I have not thought it necessary to load my text with reference to all the plates, especially as the species are numbered.

Sub-order Cheilostomata, Busk.

D. Urceolata, Hagenow.

Polypiaria membranacea, Blainville; *Thallopodia*, Ehrenberg.

Vincularia, Def. = *Glauconome*, (pars) Goldf.

1. V. areolata,	Hagenow,	Tab. VI.	fig.	12.
2. V. bella	,,	,,	,,	13.
3. V. canalifera	,,	,,	,,	14.
4. V. procera	,,	,,	,,	15.
5. V. Goldfussii	,,	(*Cellaria*).		

Eschara, Lamarck.

A. Truncatæ. B. Ramosæ.

a. Interminatæ.—In this division the cells are not bounded by distinct walls, and so far as I have been able to study species of the division it is certain that in the grouping there are a number of variations of cell character that would amply repay the special labour that could be bestowed upon them. This can be done, however, only by those who have access to material from the Maestricht beds. My own knowledge is derived from the Faxoe Limestone species, which are nearly akin to those of Hagenow.

Eschara, Lamk.

1. E. pusilla, H.
2. E. quinquepunctata, H.
3. E. variabilis, H.
4. E. goniostoma, H.
5. E. vicinalis, H.
6. E. coronata, H.
7. E. Kleini, H.
8. E. Jussieui, H.
9. E. Rondeleti, H.
10. E. filograna, Goldf.
11. E. foveolata, H.
12. E. Peyssonelli, H.
13. E. semistellata, H.
14. E. Desmaresti, H.
15. E. polystoma, H.
16. E. Peroni, H.
17. E. Defrancia, H.
18. E. Boryana, H.
19. E. Archiaci, H.
20. E. Verneuili, H.

β. Terminatæ.—In this division the cells are bounded by distinct walls—a rather unnatural grouping, and, like the others, many types of genera are mingled together.

21. E. striata, Goldf.
22. E. rhombea, H.
23. E. Savignyana, H.
24. E. scindulata, H.
25. E. ichnoidea, H.
26. E. Edwardsiana, H.
27. E. arachnoidea, Goldf.
28. E. cancellata, H.
29. E. Cuvieri, H.
30. E. Lesueuri, H.
31. E. Mülleri, H.
32. E. microstoma, H.
33. E. Lamourouxii, H.
34. E. stigmatophora, Goldf
35. E. Lamarcki, H.
36. E. Audouini, H.
37. E. pyriformis, Goldf.
38. E. cyclostoma, ,,
39. E. dipunctata sp. Goldf. = *Cellepora* ibid., Goldf. = *Membranipora* ibid., Blainv. = *Discopora* ibid., Lamk. = *Marginaria* ibid., Röm.
40. E. nana, H.
41. E. Ellisi, H.
42. E. Solandri, H.
43. E. detrita, H.
44. E. lepida, H.
45. E. Nysti, H.
46. E. dichotoma, Goldf.

47. E. Blainvillei, H.
48. E. papyracea, H.
49. E. propinqua, H.
50. E. sexangularis, Goldf.
51. E. Esperi, H.
52. E. Quoziana, Bosquet in litt.
53. E. Gaunardi, Bosquet in litt.
54. E. pavonia, H.

Genus Siphonella, Hag.

There are only three species described by the author; they are delicate and beautiful forms, and I have similar, if not identical species from Faxoe, Denmark.

1. S. cylindrica, H., Tab. VI. fig. 5.
2. S. subcompressa, H. „ 6.
3. S. elegans, H. „ 7.

Genus Cellepora (Goldf.), Hag.

With this group many diverse forms are placed, some of which have been redistributed by authors, and many others will have to be. Hagenow himself seems to have been puzzled as to how a natural division could be arranged, and failing this he gave the following synonymy of the genus:—

1. Cellepora, Fabr., Lamk., 1816.
2. Celleporaria, Lamx., 1821.
3. Diastopora, „ 1821. = *Rosacilla*, Röm. 1841.
4. Berenicea, Lamx. 1821.
5. Escharoides, M.-Ed. 1836.
6. Escharina, „ 1836.
7. Discopora, Lamk. (non Roemer) 1816.
8. Discopora, Roemer 1841.
9. Marginaria, „ 1841.
10. Membranipora, Blainv. 1834.
11. Cellulipora, D'Orb. 1850.

1. C. subinflata, H.
2. C. (Escharoides) pusilla, „
3. C. „ pinguis, „
4. C. (Escharina) Lessoni „
5. C. „ cornuta, „
6. C. „ plicatella, „
7. C. „ elegantula, „
8. C. „ Brongniarti, „
9. C. (Discop.) hippocrepis, Goldf.
10. C. (Discop.) subgranulata, H.
11. C. „ Mohli, „
12. C. „ bidens, „
13. C. „ ringens, „
14. C. (Discop.) irregularis, H.
15. C. „ depressa, „
16. C. „ Oweni, „
17. C. (Margin.) Granti, „
18. C. „ Duchasteli, „
19. C. „ vaginata, H. „
20. C. „ odontophora, „
21. C. „ Deshayesi, „
22. C. „ Koninckiana, „
23. C. „ camerata, „
24. C. (Discop.) subpiriformis, „
25. C. „ signata, „
26. C. (Margin.) Pallasiana, „
27. C. „ velamen, Goldf. = *Discopora* ibid. M.-Edw. = *Marginaria* ib., Röm.
28. C. (Margin.) crustulenta, Goldf. = *Eschara* ibid. Blainv. = *Discopora* ibid. M.-Edw.
29. C. (Dermatop.) monilifera, H.
30. C. „ lyxa, „
31. C. „ ornata, Goldf.
32. C. „ Fanjasi, H.
33. C. „ dentata, „ *C.* ibid. Goldf. = *Membranipora* ibid., Blainv. = *Discopora* ibid., M.-Edw.

Genus Stictiopora, Hag.

Stictiopora clypeata, Hag., Tab. XII. fig. 14.

Genus Lunulites, Lamk.

a. Concentricæ.

1. L. Hagenowi, Bosquet in litt. Tab. XII. fig. 16.

β. Irregulares, Hag.

2. L. Goldfussii, Hag. Tab. XII. fig. 15 = *L.* ibid., Hag. (*op. cit.* p. 287, Tab. V. p. 10) = *L.* ibid., Röm. ('Kr. Geb.' p. 15, 1841) = *L.* ibid., 'Grün.' p. 624, 1846).

Genus Cymbalopora, Hag.

C. radiata, Hag., Tab. XII., fig. 18.

The Cælophyma, Rss., of Hagenow, appear to be ovicells (?) of this species.

C. lævis, Hag., Tab. II. fig. 15, on *Truncilulina repens.*
C. constricta, Hag., Tab. II. fig. 16, on *Idmonea tetrasticha.*
C. granulatum, Hag., Tab. II. fig. 16, on ,, *lichenoides.*

Passage Forms.

C. Salpingina, H.

Escharites, Röm.

1. E. distans, H., Tab. I. figs. 16 and 17.
2. E. gracilis, sp. Goldf. = *Ceriopora* ibid., Goldf. = *Alveolites* ibid., Blainv. = *Meliceritites* ibid., Röm.

Inversaria, H.

1. I. trigonopora, H., Tab. VI. fig. 8.
2. I. tubiporacea, Goldf. = *Ceriopora* ibid., Goldf. = *Alveolites* ibid., Blainv., Lamk.
3. I. milleporacea, Goldf. sp. = *Ceriopora* ibid., Goldf. = *Alveolites*, Blainv., Lamk.

II. Cyclostomata, Busk—Hincks, Waters.

As I have already described the Cyclostomata in a former division of this Report, there will be no necessity for enlarging upon them here. Below are the whole of Hagenow's species:—

A. Tubuliporina, M.-Edw.

Tubulipora, Lamk.	Entalophora, Lamx.
,, parasitica, H.	,, disciformis, H.
Diastopora, M.-Edw.	

Pustulipora, De Blainv.

1. P. tubulosa, H.
2. P. virgula, H. = *Ceriopora* ibid., H.
3. P. nana, H.
4. P. rustica, H.
5. P. Benedeniana, H.
6. P. pustulosa, Goldf. = *Ceriopora* ibid., Goldf. = *Pustulipora* ibid. Blainv. = *Pustulipora* ibid., Lamk. = *Pustulipora Goldfussi*, Röm. = *Pustulipora pustulosa*, Michelin.

7. P. MADREPORACEA, sp. Goldf.=*Ceriopora* ibid., Goldf.=*Pustulipora* ibid., Blainv.=*Pustulipora* ibid., Lamk.=*Pustulipora* ibid., Brown=*Pustulipora* ibid., Reuss.
8. P. VARIABILIS, H.
9. P. DUBIA, H.
10. P. GEMINATA, H.

CRICOPORA, Blainv.(=*Spiropora*, Lamx.).

1. C. VERTICILLATA, G. = *Ceriopora* ibid., Goldf.=*Pustulipora* ibid., Blainv., M.-Edw., Röm.=(??)*Cricopora* ibid., Mich.
2. C. REUSSI, H.=*Ceriopora annulata*, H.=*Cricopora annulata*, Reuss.

CYRTOPORA, Hagenow.
,, ELEGANS, H.

TEREBELLARIA, Lamx.
,, SPIRALIS sp., Gold.

HORNERA, Lamx.
,, TUBULIFERA, H.

IDMONEA, Lamx.

1. I. MACULATA, H.
2. I. CLATHRATA, Goldf. sp.
3. I. VERRICULATA, H.=*Retepora clathrata*, Gold., in part, pl. ix., fig. 12 *c* and *d*.
4. I. LICHENOIDES sp., Goldf.=*Retepora* ibid., Gold.; Lamk. pl. ix., fig. 13 *a* and *b*.
5. I. CANCELLATA sp., Goldf.=*Retepora* ibid., Gold., Lamk. pl. xxxvi., fig. 19 *b*.=?*Idmonea* ibid., Reuss.
6. I. MACILENTA, H.
7. I. DISTICHA sp., Goldf.=*Retepora*, ibid., Goldf., Lamx., Blainv.= ?*Retepora* ibid., Mich., Reuss., pl. ix., fig. 15 *c* and *d*.
8. I. PSEUDO-DISTICHA, H.=*R. disticha*, Goldf. in part, pl. ix., fig. 15 *a* and *b*.
9. I. DORSATA, H.=*R. disticha*, Goldf. in part, pl. ix., fig. 15 *g* and *h*.
10. I. GEOMETRICA, H.
11. I. SULCATA, H.
12. I. LINEATA, H.=*R. disticha*, Goldf. in part, pl. ix., fig. 15 *c* and *f*.
13. I. GIBBOSA, H.
14. I. GENICULATA, H.=*R. clathrata*, Goldf. in part, pl. ix., fig. 12 *e* and *f*.
15. I. TETRASTICHA, H.

TRUNCATULA, Hagenow.

1. T. FELIX, H.
2. T. TRUNCATA sp., Goldf. = *Retepora* ibid., Goldf. = *Retepora* ibid., Lamx.=*Retepora* ibid., M.-Edw.=*Idmonea* ibid., Blainv.
3. T. REPENS, H.

B. CERIOPORINA, Bronn.

FUNGELLA, Hagenow.

1. F. PROLIFERA, H.
2. F. PLICATA, H.
3. F. DUJARDINI, H.

LOPHOLEPIS, Hagenow.

1. L. RADIANS, H.
2. L. ALTERNANS, H.
3. L. IRREGULARIS, H.

DEFRANCIA, Bronn (α), with smooth interspaces.

1. D. DISTICHA, H.
2. D. MICHELINI, H.
3. D. COCHLOIDEA, H.

β, with porous interspaces.

4. D. DIADEMA, sp. Goldf. = *Ceriopora* ibid., Goldf.
5. D. RETICULATA, H.
6. D. CARIOSA, H.
7. D. SELLULA, H.

STELLIPORA, Hagenow.

S. BOSQUETIANA, H.

PLETHOPORA, Hagenow.

1. P. VERRUCOSA, H.
2. P. PSEUDO-TORQUATA, H.
3. P. TRUNCATA, H.

HETEROPORA, De Blainv.

1. H. CRASSA, H. = *Ceriopora anomalopora*, Goldf. = *C. micropora*, Goldf. = (?) *C. cryptopora*, Goldf.
2. H. DICHOTOMA, sp., Goldf. = *Ceriopora* ibid., Goldf. = *H.* ibid., Blainv., Lamk.
3. H. UNDULATA, H.
4. H. TENERA, H. = *Ceriopora cryptopora*, Goldf.
5. H. DUMONTI, H.

NEUROPORA, Bronn.

N. CRETACEA.

DITAXIA, Hagenow.

1. D. ANOMALOPORA, sp. Goldf. = *Ceriopora* ibid., Goldf. = *Heteropora* ibid., Blainv., Lamk.
2. D. COMPRESSA sp., Goldf. = *Ceriopora* ibid., Goldf., Blainv.

CERIOPORA, Goldf.

1. C. SCHWEIGGERI, H.
2. C. POLYTAXIS, H.
3. C. CAVERNOSA, H.
4. C. MICROPORA, Goldf.
5. C. THELOIDEA, H.
6. C. CRYPTOPORA, Goldf. = *Heteropora* ibid., Blainv.
7. C. SESSILIS, H.

CAVARIA, Hagenow.

1. C. RAMOSA, H.
2. C. PUSTULOSA, H.
3. C. MICROPORA, H.

CŒLOCOCHLEA, Hagenow.

C. TORQUATA, H.

'Cretaceous Polyzoa, North America,' Lonsdale; and Messrs. Gabb & Horn.

I have not been able to get access to the various works of Dr. S. G. Morton on the 'Cretaceous Rocks of New Jersey,' published at different dates, from 1834 to 1842, in American scientific journals. The quotations and references in the following lists are from Lonsdale's papers in the 'Quart. Jour. Geol. Soc.' vol. i., and from Messrs. Gabb & Horn's 'Mono. Foss. Pol. of the Sec. and Tert. Formation of North America' ('Journ. Acad. Nat. Sci. Phil.' vol. v. 2nd ser. pp. 111–179, 3 plates, 1862). Dr. Morton's 'Synopsis, Organic Rem. Cret. Group N. A.' was published in 1834.

Cheilostomata.

Polyzoa (Polyparia, Lonsd.) from Timber Creek, New Jersey, N. America.

1. Cellepora tubulata, Lonsd., 'Quart. Jour. Geol. Soc.' vol. i. —Cretaceous.
2. Escharina ? sagena, Lonsd. = *Membraniporella nitida*, Johnst., *Flustra*, ibid., Morton, 'Quart. Jour. Geol. Soc.' vol. i.—Cretaceous.
3. Eschara digitata, Morton ? = *Eschara dichotoma*, Goldf. 'Quart. Jour. Geol. Soc.' vol. i.—Cretaceous.

Cyclostomata.

4. Tubulipora megera, Lonsd. 'Quart. Jour. Geol. Soc.' vol. i. —Cretaceous.
5. Idmonea contortilis, Lonsd. See *ante*, Hornera ibid. = 'Quart. Jour. Geol. Soc.'—Cretaceous.

To this list of five species Messrs. Gabb & Horn add the following additional thirty-five also from American Cretaceous rocks.

Cheilostomata.

Cellepora, Fabr. 1780 (non Lamk. 1801).

6. C. prolifica, G. & H. = *C. bilabiata*, G. & H.—Cretaceous, Timber Creek, N. J.
7. C. pusuela, ,, ,, Timber Creek, N. J.
8. C. exserta, ,, ,, Mallica Hill.
9. C. Janewayi, ,, ,, '7 miles below Yara, Miss.'

Reptocelleporaria, D'Orb. 1851.

10. R. aspera, Gabb & Horn.—Cretaceous, Timber Creek and Mallica Hill.
11. Escharipora typica, Gabb & H. = Cellepora ibid., G. & H. —Cretaceous, Timber Creek, N. J.
12. E. distans, Gabb & H., Cret. Timber Creek, N. J.
13. E. immersa, Gabb & H., ,, Timber Creek, N. J.
14. E. Abbottii, Gabb & H., ,, Mallica Hill.
15. Reptescharipora marginata, Gabb & H., ,, Mallica Hill.
16. Escharinella muralis, Gabb & H., ,, Mallica Hill.
17. Reptescharellina prolifera, Gabb & H., ,, Mallica Hill.

Pliophlæa, Gabb & Horn.

18. ,, sagena, G. & H. = *Membraniporella nitida*, Johnst. (*ante*) = *Flustra sagena*, Mort. ; *Escharina* ibid., Lonsd.

19. BIFLUSTRA TORTA, Gabb & H. = *Membranipora* ?, Cret.
Timber Creek and Mallica Hill.
20. B. DISJUNCTA, Gabb & H. ,, ,,
Timber Creek.
21. MEMBRANIPORA ABORTIVA, Gabb & Horn, ,,
Timber Creek.
22. M. PERAMPLA, ,, ,,
Mallica Hill.
23. M. PLEBEIA, ,, ,,
Mallica Hill.
24. PYRIPORA IRREGULARIS, ,, ,,
Timber Creek.
25. ? REPTOFLUSTRELLA HETEROPORA, Gabb & Horn, ,,
Mallica Hill.

Cyclostomata.

26. RETELEA OVALIS, Gabb & H., Cret.
Mallica Hill.
27. FILIFASCIGERA MEGÆRA, D'Orb. = *Tubulipora* ibid., Lonsdale, ,,
Timber Creek.
28. FASCIPORA AMERICANA, Gabb & H., ,,
Timber Creek.
29. SPIROPORA CALAMUS, ,, = Entalophora, ,,
Timber Creek.
30. ENTALOPHORA QUADRANGULARIS, Gabb & H., ,,
Mallica Hill.
31. ENTALOPHORA CONRADII, ,, ,,
Mallica Hill.
32. IDMONEA CONTORTILIS, Lons. = *Horneria* ibid.—see *ante*, ,,
Timber Creek and Mallica Hill.
33. DIASTOPORA LINEATA, Gabb & H., 'approaches *D. regularis*, D'Orb.'
Cret., Timber Creek, N. J.
34. STOMATOPORA REGULARIS, Gabb & H., Cret.
Timber Creek, N. J.
35. RETICULIPORA SAGENA, ,, ,,
Timber Creek, N. J.
36. RETICULIPORA DICHOTOMA, ,, ,,
Timber Creek, N. J.
37. BICRISINA ABBOTTI, ,, = *Heterocrina* ibid., G. & H. ,,
Timber Creek, N. J.
38. REPTOMULTICAVA CEPULARIS, ,, = *Idmonea* ibid., ,, ,,
Timber Creek, N. J.
39. CRESCIS LABIATA, ,, ,,
Timber Creek, N. J.
40. MULTICRESCIS ? PARVICELLA ,, A doubtful form, ,,
Mallica Hill.

I have thought it best not to suppress a single form that Messrs. Gabb and Horn have catalogued. I have in my cabinet at least sixteen—probably nineteen—of the so-called species from Timber Creek, New Jersey, and I find that that number at least may be allowed to stand; but even the specific names of some of these may very safely be reduced to synonyms. In comparing them with European species I cannot detect any material difference between the American forms and those described by Goldfuss and Hagenow.

'Cretaceous Bryozoa of Bohemia,' Ottomar Noväk (see Bibliography).

This work I have not been able even to look at, and I am indebted to the 'Geological Record' for 1878 for the information given below. In the work, Noväk describes forty-five species, thirty-three of which bear new names; and in a table he gives their range in (5) Cenomanian, (4) Turonian, and (6) Senonian times, which according to Lyall ('Elements,' p. 266), are representatives of our (5) Upper Greensand and (4) Chalk Marl, in part. The list is therefore valuable for the purpose of establishing links between species of Polyzoa from Continental, British and American areas. I should like to possess a copy of the work, if any of my friends have one for sale. I give the list as in the Record, separating only the Cheilostomata from the Cyclostomata.

I. Suborder *Cheilostomata*, Busk.

1. Hippothoa labiata, Noväk.
2. ,, desiderata, ,,
3. Membranipora curta, ,,
4. ,, perisparsa, Noväk.
5. ,, subovata, ,,
6. ,, tuberosa, ,,
7. Lepralia euglypha, Noväk.
8. Biflustra Prazaki, ,,
9. ,, solea, ,,
10. Semieschara teres, ,,
11. Melicertites docens, Noväk, ? Cheilostomata.

II. Suborder *Cyclostomata*, Busk.

1. Berenicea folium, Noväk.
2. ,, lacrimopora, Noväk.
3. ,, pilosa, Noväk.
4. ,, radians, ,,
5. Diastopora acupunctata, Noväk.
6. Stomatopora simplicissima, ,,
7. Proboscina bohemica, ,,
8. ,, difluens, ,,
9. ,, linguata, ,,
10. ,, intermedia, ,,
11. ,, Suessi, ,,
12. Entalophora anomalissima, Noväk.
13. ,, fecunda, ,,
14. ,, Kolinensis, ,,
15. Multelea orphanus, ,,

Osculipora Novak (? New Gen.).

16. ,, plebeia, Noväk.
17. Truncatula tenuis, ,,
18. Heteropora foraminulenta, Noväk.
19. ,, Korycanensis, ,,
20. ,, lepida, ,,
21. ,, magnifica, ,,
22. Petalopora seriata, ,,

This is the whole of the lists of Cretaceous Polyzoa that I have been able to obtain. There are several species described by D'Orbigny and by other authors, but their works were not accessible to me. It is to be hoped that in the monograph of Cretaceous Polyzoa promised to the Palæontographical Society by Mr. Busk, that the whole of the Polyzoa of various horizons will be fully examined. In my fourth British Association Report I gave a fair digest of what is known of British species.

'Part III.—Tertiary Polyzoa, North America,' Lonsdale.

In the first volume of the 'Quart. Jour. of the Geological Soc.,' Mr. William Lonsdale described twenty-six species of 'Polyparia' from the 'Eocene Tertiary' of North America. Nine species are Anthozoa, seventeen Polyzoa (six Cyclostomata, eleven Cheilostomata). In the same Journal he described ten species from the 'Miocene Tertiary' formation of N.A., three of which are Anthozoa, seven Polyzoa (only one of these a Cyclostoma). As the monograph of Messrs. Gabb & Horn is a later publication, many of the species of Lonsdale are rearranged or reduced to synonyms.

1. 'Eocene Polyzoa,' Lonsdale 'Quart. Jour. Geol. Soc.,' vol. i.
2. 'Miocene Polyzoa,' Lonsdale 'Quart. Jour. Geol. Soc.,' vol. i.

1. Escharina tumidula, Lons.—*Loc.* Petersburg.
2. Lunulites denticulata, Conrad, 'Silliman Journ.,' Oct. 1841 (vol. iv.)—*Loc.* Williamsburg.
3. Cellepora informata, Lons.—*Loc.* Petersburg, Virginia.
4. ,, umbilicata, Lons.—*Loc.* Petersburg.
5. ,, quadrangularis, Lons.—*Locs.* Williamsburg, Evergreen.
6. ,, similis, Lons.—*Loc.* Williamsburg.
7. Heteropora ? tortilis, Lons.—*Loc.* Williamsburg, Petersburg.

Cyclostomata.

1. Tubulipora proboscidea ?—*Loc.* Rock's Bridge.
2. ,, —one imperfect specimen.—Eutaw.
3. Idmonea maxillaris, Lons.—*Loc.* Wantoot, S. Carolina. Viewed in front, this coral resembled a Mästricht fossil, considered by Goldf. as a young condition of Idmonea gradata ('Pet. Cor.' p. 244. 'Retepora disticha,' p. 29), but it differs essentially from mature specimens of that species.
4. I. commiscens, Lons.—*Loc.* Rock's Bridge. In the triangular form of the branches, this fossil resembled the Tertiary species of De France or Mil.-Edw. under the names of *Idmonea gradata* and *I. coronopus* ('De F., Atlas des Sc. Nat.' pl. 46, f. 5. M.-Edw. 'Rech. Polyp. Mém. sur les Cris.' pp. 24, 23.)
5. Idmonea sp.—*Loc.* Rock's Bridge.
6. Lichenopora sp.—*Loc.* Eutaw.

Cheilostomata

1. Farcimia sp.—*Loc.* Rock's Bridge, Eutaw, in S. Carolina.
2. Vincularia sp.—*Loc.* Rock's Bridge.
3. Hippothoa tuberculum, Lons.—*Loc.* Rock's Bridge.
4. Eschara tubulata, Lons.—*Loc.* Wilmington.
5. ,, petiolus, Lons.—*Loc.* Eutaw.

6. ESCHARA INCUMBENS, Lons.—*Loc.* Rock's Bridge.
7. „ LINEA, Lons.—*Loc.* Eutaw.
8. „ VIMINEA, Lons.—*Loc.* Eutaw.
9. LUNULITES SEXANGULA, Lons.—*Loc.* Wilmington.
10. „ DISTANS, Lons. — *Loc.* Wilmington — Wantoot? This resembles *L. radiata* and *L. urceolata*, Goldf. (Pet. 12 f. 6, 7).
11. L. CONTIGUA, Lons.—*Loc.* Wilmington.

'North American Tertiary Species, described by Messrs. Gabb & Horn.'

I have already given selections from this monograph when dealing with Cretaceous Polyzoa, and now that I have to give the list of Tertiary fossils, I am confronted by a difficulty as to the horizon of the species. The authors speak of 'Miocene' and 'Pliocene,' but in two foot-notes, one especially below *Cellepora formosa*, I find the following: 'In regard to the use of the terms "Pliocene" and "Miocene" in this country, it will probably be found on more careful examination that there is no real division existing between the two so-called formations;' and at the end of the monograph is the following: 'Since the writing of this monograph, Mr. W. M. Gabb has been called to the post of Palæontologist to the State of California. In regard to the Santa Barbara and the San Pechs deposit he writes, they are amongst the most recent deposits, almost all the species being still extant. Instead of Post-Miocene, they should be called Post-Pliocene.'

In their identifications of species, the authors give many synonyms from D'Orb. and Lonsdale, but when Prof. Smitt wrote his 'Floridan Bryozoa,' he could only identify about three species as belonging to recent Polyzoa; these are given in the text. I wish, however, to direct the attention of students towards the Fossil Polyzoa of North America, Cretaceous and Tertiary, for from what I have been able to judge of species sent to me I feel confident that a rich harvest of forms has yet to be described from many localities; and it is to be hoped that future students will direct more special attention than has yet been given to the purely structural features so ably formulated by both Hincks and Waters, full details of which will be found in the former part of this report. In this monograph also I have adhered to the text and arrangement of the authors. As a piece of palæontological work I cannot speak very highly of this monograph. The creation of new names—both of genera and species—is much to be regretted. However, I have done as full justice to the work as was possible under these circumstances.

Family ESCHARIDÆ, D'Orb. 1851.

Order I. CELLULATA, non OPERCULATA.

Sub-Family ESCHARINÆ.

ESCHARA, Lamk. 1801.

E. TUBULATA, Lonsd. (see *ante*), Eocene, Wilmington, Carolina, North.
2. E. PETIOLUS, Lonsd. (see *ante*), Eocene, Eutaw, Carolina, South.
3. E. INCUMBENS, „ „ „ Rock's Bridge.
4. ? E. ? VIMINEA, „ „ „ Eutaw, „.
5. E. TEXTA, Gabb & H, „ White Limestone, „.

6. E. OVALIS, Gabb & H., Eocene, ? Claiborne, Ala.
related in form of cells to *E. Blandina* and *E. Eurita*, D. Orb.
7. ? E. ? FRAGILISSIMA, G. & H. 'Miocene!' Maryland, St. Mary's river = ? *Cellepora tumida*, D'Orb. = *Escharina* ibid., Lonsd.

LUNULITES, Lamk. 1801.
8. ,, SEXANGULARIS, Lonsd. (see *ante*) 'Eocene,' Wilmington.
9. ,, DISTANS, Lonsd. ,,
10. ,, INTERSTITIA, G. & H. ,, ,, Claiborne, Ala.
11. ,, CONTIGUA, Lonsd. ,,
12. ,, OBLONGA, Emmons 'Geo. Rep. N. Caro.' p. 312, f. 252, 253.

SEMIESCHARA, D'Orb. 1851.
13. ,, TUBULATA. 'Eocene,' Claiborne, Ala ?

CELLIPORA, Fabr. 1780 (not *Cellepora*, Lam.) Cellepora & Discopora, (pars) Lam. 1816.
14. ,, CYCLORIS, G. & H. 'Eocene.'
15. ,, INORNATA, G. & H. *Lepralia ibid.* Smith, 'Florid. Bry.' p. 61, 'Eocene' of Alabama.
16. ,, TUMIDULA, D'Orb = *Escharina ibid.* Do. Miocene, Petersburg, Virginia.
17. ,, FORMOSA, Tuorney & Holmes
18. ,, TESSELATA ,, ,,
19. ,, DEPRESSA ,, ,,
} See head notes beginning of this paper, 'Pliocene.'
Giles Bluff & Goose Creek.
20. ,, URCEOLATA, G. & H.; Miocene Marl, New Jersey.
21. ,, CALIFORNIENSIS ,, Santa Barbara.
22. ,, BELLEROPHON ,, ,,

REPTOCELLEPORARIA, D'Orb. 1881.
23. ,, INFORMATA, D'Orb. = *Cellepora informata*, Lons. (see *ante*).
24. ,, QUADRANGULARIS = *Cellepora* ibid. Lons. (see *ante*).
25. ,, SIMILIS, D'Orb. = *Cellepora* ibid. Lons. (see *ante*).
26. ,, GLOMERATA, G. & H. 'Eocene,' Vicksburg, Missip.

ESCHARELLA, D'Orb. 1851.
27. ,, MICROPORA, G. & H. 'Eocene.'

REPTESCHARELLA, D'Orb. 1851.
28. ,, CAROLINENSIS, G. & H. (rare), 'Eocene,' White Limestone, West of Charleston, S.C.
29. ,, HEERMANNII, G. & H., Miocene Cal. Santa Barb. = *Escharipora annulata*, Smitt.
30. ,, PLANA, G. & H. ? *Cribrilina annulata*, Hincks, same locality.

PHIDOLOPORA, Gabb & H.
31. ,, LABIATA, G. & H. = *Retepora marsupiata*, Miocene, Santa Barbara, Calif.

OLIGOTRESCUM, G. & H.
32. ,, VICKSBURGENSIS, G. & H. = *Lunulites* ibid. = Upper Eocene, Vicksburg, Miss.

ESCHARINELLA, D'Orb.
33. ,, ? LINEA, G. & H., Eocene, S. Carolina.

ENNALLIPORA, G. & H.
34. ,, QUADRANGULARIS, G. & H., Miocene, Petersburg.

DISCOPORELLA, D'Orb., 1851.
35. ,, DENTICULATA, G. H. = *Lunulites* ibid., Con.

REPTOPORINA, D'Orb.
36. ,, CARINATA, G. & H., Santa Barbara.
37. ,, EUSTOMATA, ,,

MULTIPORINA, G. & H.
38. ,, UMBILICATA, G. & H. = *Cellepora* ibid., Lonsd.

REPTESCHARELLINA, D'Orb.
39. ,, DISPARILIS, G. & H., Santa Barbara.
40. ,, ? HEERMANNII, ,, ,,
41. ,, CORNUTA, ,, ,,

FLUSTRELLARIA, D'Orb. ,,
42. ,, MULTIPORA, G. & H. ,,

DISCOFLUSTRELLARIA, D'Orb.
43. ,, BOWEI, G. & H. = *Lunulites* ibid., Lea.

CUPULARIA, Lam.
44. ,, DISCOIDEA, Lam. = *Orbitolites* ibid., Lea.

HETERACTIS, G. & H. = ,, ,,
45. ,, ,, DUCLOSII = *Lunulites* ibid., ,,

MEMBRANIPORA, Blainv.
46. ,, SEXPUNCTATA, G. & H., Horizon, doubtful.
47. ,, SPECIOSA, ,, ,, ,,
48. ,, CALIFORNICA, ,, Santa Barbara.
49. ,, BARBARENSIS, ,, ,, ,,

PYRIFLUSTRELLA, D'Orb.
50. ,, TUBERCULUM, D'Orb. = *Hippothoa* ibid., Lonsd.
,, ,, ,, = *Pyripora* ,, D'Orb.

Order II. CENTRIFUGINATA (*Cyclostomata*, Busk).

Family TUBIGERIDÆ.

IDMONEA.
1. ,, MAXILLARIS, Lonsd. (See *ante*).
,, ,, ,, = *Crisisina* ibid., D'Orb.
2. ,, COMMISCENS, ,, = ,, ,, ,,
3. ,, CALIFORNICA, G. & H. (?), Santa Barbara.

SEMITUBIGERA.
4. ,, TUBA, G. & H., ,, ,,

ENTALOPHORA.
5. ,, PROBOSCIDEOIDES, Lons. (*Tubulipora* ibid., Lons.).
6. ,, PUNCTULATA, G. & H., Santa Barbara.

CRISINA.

7. „ SERRATA, G. & H., Santa Barbara.

CAVEA, D'Orb.

8. „ PRISCA, G. & H.

LICHENOPORA, Def.

9. „ CALIFORNICA, „ „

MULTICRESCIS, D'Orb.

10. „ TORTILIS, G. & H. = ? *Heteropora* ibid., Lonsd.

'Tertiary Polyzoa,' Dr. August Goldfuss ('Petrefacta Germanica').

The Tertiary Polyzoa described and figured by Goldfuss are few in number, but his species have been adopted, re-described, or referred to by every author who has taken up the study as a speciality.

Cheilostomata.

1. GLAUCONOME MARGINARIA, Goldf. (*Vincularia*, or *Cellaria* of authors)
2. „ RHOMBOPORA, Goldf.
3. „ TETRAGONA, „
4. „ HEXAGONA, „
5. CELLEPORA CONGLOMERATA, „
6. „ ANNULATA, „
7. „ TRISTOMA, „
8. „ GRACILIS, „
9. FLUSTRA CONTEXTA, Goldf.
10. SCYPHIA ARTICULATA, „
11. ESCHARA SUBSTRIATA, „
12. „ CELLEPORACEA.
13. RETEPORA VIBICATA.
14. LUNULITES RADIATA, Lamarck.
15. „ URCEOLATA, „
16. „ RHOMBOIDALIS, Münster.
17. „ PERFORATA, „

Cyclostomata.

1. RETEPORA FENESTRATA, Goldf.
2. „ CYATHIFORMIS, „
3. CELLEPORA ECHINATA, Münster.

'Eocene Polyzoa, British.'

The almost barren record of British Eocene Polyzoa has been remarked upon by previous authors, but I am afraid that we owe the barrenness to the want of research rather than to the scarcity of species. Mr. Busk describes three species from the London Clay at Highgate, found in the collection of Mr. Wetherell, 'Geo. Mag.' vol. iii., July 1866:—

1. MEMBRANIPORA LACROIXII ? pl. xii. fig. 1.
2. BIFLUSTRA EOCENA, Busk, pl. xii. fig. 2.
3. DITTOSARIA WETHERELLI, Busk, pl. xii. fig. 3 (GEMELLARIADÆ, Busk).

The *Membranipora* described by Mr. Busk is rather more linear than the more recent form generally met with round our coast; but some time since Professor Judd [1] sent me a specimen of what I consider to be referable to the *M. Lacroixii*, and this was from the oyster beds of Colwell Bay. It differed from Mr. Busk's figured specimen, but as the species varies very much in habit, this I considered of but small consequence. The value of the specimen sent was this. When the cells separated in the line with the side walls I was able to detect the 'Rosettenplatte' or communication pores through which the endosarcal cord passed from cell to cell. These were three in number on the side walls, and they

[1] Discovered by his assistant.

were well preserved; otherwise the beautifully crenulated wall surrounding the orifice was sufficiently indicative of the normal type.

In the 'Catalogue of Tertiary Fossils in the School of Mines' (1878), the only species indicated from different horizons are as follows:—

4. FLUSTRA CRASSA, Desm., Thanet Sands, p. 7.
5. ,, sp., ,, Woolwich and Reading Beds, p. 10.
6. ,, CRASSA, ,, London Clay, Highgate, p. 14.
7. POLYZOON, ,, ,, Sydenham, p. 14.

In Morris' 'Catalogue of British Fossils,' and also in the Palæontological part of Jukes' 'Students' Manual of Geology,' the following species are indicated:—

8. ESCHARA BRONGNIARTI, Lonsd., London Clay, Bracklesham Bay.
9. FLUSTRA CRASSA, Desm., ,, ,, Primrose Hill.
10. CELLEPORA PETIOLUS, Lonsd., Mid-Eocene, Bracklesham.
11. LUNULITES URCEOLATUS, Lam, ,, ,,
= *Coscinoporis pileolus*, Phill. and Wood.
12. IDMONEA CORONOPUS, Defr., Mid-Eocene, Bracklesham Bay.

Besides the above I have no further record, but I have some few fragments by me of undescribed forms from the Middle Eocene, British series. It may be possible that there are still in the cabinets of collectors specimens of Polyzoa that are awaiting description; if so, I shall be glad to hear of such.

'Tertiary, Eocene and Miocene Polyzoa,' Professor A. E. Reuss.

I. In dealing with the following three works of Dr. Reuss I have been careful to present his text with his own indications of synonymy. In the earlier work, published in 1847, the author described and figured no fewer than 120 species of Cheilostomata and 49 species of Cyclostomata. This work of course was published before Mr. George Busk issued his 'British Museum Catalogue,' and also before Professor Smitt gave to the scientific world his principal writings on 'Classification,' &c.; yet in it we are surprised to find how this careful investigator was working towards a natural classification.

II. In the second work, published in 1869, Professor Reuss had the advantage of correcting much of his previous labours, and in the 'Palæontological Studies' many of the species of 'Fossil Polyparia' were reduced to synonyms. In this work, too, Reuss evidently had carefully studied both the classification formulated in the 'British Museum Catalogue' and also the 'Crag Polyzoa' of Mr. Busk. Nearly every species described in this work I have carefully studied from the material supplied by Professor Roemer.

III. In the third work—'Miocene Fossil Bryozoa of Austria and Hungary,' 1884–5, which the author did not live to complete—we have such a piece of work of which no author who has taken up the study of Fossil Polyzoa need to be ashamed. In this we have full revisions of former identifications—more species are reduced to synonyms—but, what I regret most, the Cyclostomata are not touched. Dr. Manzoni completed the second part of this grand work, but, as would be expected, he did not give so many synonyms as Reuss would have done, had the work left his hands in a complete form.

'Fossilen-Polyparien des Wiener Tertiärbeckens,' I., A. E. Reuss, 1847.

Div. B. CELLARIEÆ, Blainv.

BACTRIDIUM, Rss.

1. " GRANULIFERUM, Rss. Marine Limestone.
2. " ELLIPTICUM, " "
3. " SCHIZOSTOMA, " "
4. " HAGENOWII, " "

LUNULITES, Lamk.

5. " HAIDINGERI, Rss., similar to *L. rhomboidalis*, Gold., and *L. Vanderheckii*, Mich.

CELLARIA, Lamk. = *Vincularia*, Defr., *Glauconome*, Gold.

6. " MARGINATA, Goldf. sp. Marine Limestone.
7. " HAIDINGERI, Rss. "
8. " CUCULLATA, Rss. ? = *V. fragilis*, Def. "
9. " EXARATA, " *V. tetragona*, Goldf.
10. " POLYSTICHA, "
11. " MICHELINI, " ? = *V. fragilis*, Mich., similar to *C. cereoides*, Lamx.
12. " DUPLICATA, Rss., similar to No. 11.
13. " CORONATA, "
14. " LABROSA, "
15. " SCHREIBERSI, Rss.
16. " SCROBICULATA, "
17. " HAUERI, "
18. " STENOSTICHA, "
19. " MACROSTOMA, " similar to *Glauc. elliptica*, Hag. No. 2.

Div. C. ESCHARINA, Ehr.

ESCHARA, Lamk.

20. " FISTULOSA, Rss.
21. " EXILIS, "
22. " SULCIMARGO, "
23. " MACROCHEILA, Rss.
24. " BIAURICULATA, "
25. " AMPLA, "
26. " BIPUNCTATA, "
26*. " ACICULARIA = *Acicularia pavantina*, D. Arch.
27. " TUBULIFERA, "
28. " COSCINOPHORA, "
29. " OBESA, "
30. " PAPILLOSA, "
31. ESCHARA SYRINGOPORA, Rss.
32. " UNDULATA, "
33. " PUNCTATA, Phill.
34. " IMBRICATA, Rss.
35. " LARVA, "
36. " POLYSTOMELLA, Rss.
37. " VARIANS, "
38. " CONFERTA, "
39. " DIPLOSTOMA, "
40. " POLYOMMA, "
41. " TESSULATA, "
42. " EXCAVATA, "
43. " COSTATA, "
44. " CRENATIMARGO, "

VAGINOPORA, Defrance = *Escharites* and *Melicerititites*, Röm.

45. " TEXTURATA, Rss.
46. " POLYSTIGMA, "
47. VAGINOPORA GEMINIPORA, Rss.
48. " FISSURELLA, "

Div. D. CELLEPORINA, Ehrh.

CELLEPORA, Lamk. = *Cellepora*, Blainv.; *Discopora*, Lamk. and M.-Ed.; *Escharina* and *Escharoides*, M.-Ed. and Röm.

49. CELLEPORA GLOBULARIS, Bronn. = *Scyphia cellulosa*, Goldf.
50. „ FORAMINOSA, Rss.
51. „ PROLIFERA, „
52. „ POLYTHELE, „
53. „ POLYPHYMA, „
54. „ ROSULA, „
55. „ TETRAGONA, „
56. „ ANNULATA, Goldf.
57. „ VERRUCOSA, Rss.
57* „ CERATOMORPHA, „
58. „ MONOCEROS, „
59. „ CYLINDRICA, „
60. „ ARRECTA, „
61. „ PTEROPORA, „
62. „ MEGALOTA, „ similar to *C. pteropora*.
63. „ ENDLICHERI, Rss.
64. „ SEMICRISTATA, „
65. „ SCRIPTA, „
66. „ RARICOSTATA, „
67. „ MEGACEPHALA, „
68. „ PUPULA, „
69. „ HAUERI, „
70. „ UNGERI, „
71. „ MAGNIFICA, „
72. „ SCHIZOGASTER, „
73. „ HECKELI, „
74. „ CIRCUMORNATA, „
75. „ SERRULATA, „
76. „ PHYSOCHEILA, „
77. „ SCARABÆUS, „
78. „ GRANULIFERA, „
79. „ TEGULATA, „
80. „ CONCINNA, „
81. „ GONIOSTOMA, „
82. CELLEPORA RARIPUNCTATA, Rss.
83. „ TRIGONOSTOMA, „
84. „ PLEUROPORA, „ = *Amphistegina Haueri*, D'Orb.
85. „ CRENILABRIS, Rss.
86. „ DECORATA, „
87. „ PROTUBERANS, „
88. „ DUNKERI, „
89. „ OTOPHORA, „
90. „ OVOIDEA, „
91. „ PACHYDERMA, „
92. „ PLATYSTOMA, „
93. „ CHEILOPORA, „
94. „ TERNATA, „
95. „ MICROSTOMA, „
96. „ ENTOMOSTOMA, „
97. „ PARTSCHII, „
98. „ BARRANDI, „
99. „ ANGULOSA, „
100. „ STENOSTOMA, „
101. „ GRACILIS, Goldf. *l. c.* i. p. 102.
102. „ MINUTA, Reuss.
103. „ HIPPOCREPIS, Gold. *l. c.* i. p. 26.
104. „ PAPYRACEA, Rss.
105. „ TENELLA, „
106. „ QUADRATA, „
107. „ FORMOSA, „
108. „ LEPTOSA, „
109. „ DEPLANATA, „
110. „ TRAPEZOIDEA, „
111. „ APPENDICULATA, Rss., near *C. velamen*, G. Münst.
112. „ FENESTRATA, Rss.
113. „ LOTOPORA, „

114. MEMBRANIPORA RETICULUM, Blainv., 'Man. d'Actin.' p. 44.
115. „ NOBILIS.
116. „ DIADEMA.

117. CŒLOPHYMA GLABRUM, Rss.
118. CŒLOPHYMA STRIATUM, Rss.

RETEPORA, Lamk., removed from the *Cyclostomata* in the division C. *Retepora*.

119. „ CELLULOSA, Lamk.
120. „ RUBESCHII, Rss.
121. RETEPORA ? ELEGANS, Rss.

I. Scleropodia, Ehrh. = Cyclostomata, Busk.

A. Ceriopora, Goldf. = *Ceriopora* and *Alveolites*, Blainv.

1. Ceriopora globulus, Rss.
2. „ spongiosa, Phillip.
3. „ cylindrica, Rss.
4. Ceriopora arbusculum, Rss.
5. „ megalopora, „
6. „ phlyctænodes, „

Heteropora, Blainv.

7. „ anomalopora, sp. Goldf. = *Ceriopora* ibid., G.
8. „ stipitata, Rss.
9. „ dichotoma, Gold. = *Ceriopora* ibid., G.
10. „ stellulata, Rss.

Defrancia, Brom. = *Pelagia*, Lamx.; *Lichenopora*, Dcf.

11. „ deformis, Rss.
12. „ formosa, „
13. „ stellata, Goldf. = *Ceriopora* ibid., G.
14. „ prolifera, Rss.
15. Defrancia, socialis, Rss.
16. „ coronula, „
17. „ dimidiata, „
18. „ pluma, „

Apseudesia, Lam.

19. „ fasciculata, Rss. Similar to *A. dianthus*, Blainv. It unites in itself the characters of *Defrancia* and *Chrysaora*.

Cricopora, Blainv. = *Spiropora*, Lamx.

20. „ verticillata, Mich.
21. Cricopora pulchella, Rss.

Pustulopora, Blainv.

22. „ clavula, Rss.
23. „ sparsa, „
24. Pustulopora anomala, Rss.

? Retepora, Lamk., Goldf.

Hornera, Lamx.

25. „ biloba, Rss.
26. „ verrucosa, Rss.
27. Hornera hippolithus, Dcf.
28. „ seriatopora, Rss.

Idmonea, Lamx.

29. „ carinata, Röm.
30. „ pertusa, Rss. Similar in habit to *I. disticha*, G.
31. „ disticha, Goldf. = *Retepora* ibid., Goldf.
32. „ compressa, Rss.
33. „ cancellata, Goldf. = *Retepora* ibid., Goldf. = Retepora, Lamk. Three species placed under this head removed to *Cheilostomata*, Nos. 119 to 121.

II. Thallopodia, Ehrb.

A. Auloporina, Ehrb.

Tubulipora, Lamk.

34. „ congesta, Rss.
35. „ foliacea, „
36. Tubulipora stelliformis, Mich.
37. „ echinulata, Rss.

Diastopora, M.-Ed. = *Diastopora*, *Mesenteripora*, *Berenicea*.

38. „ minima, Rss.
39. „ rotula, „
40. „ sparsa, „
41. Diastopora flabellum, Rss.
42. „ ? plumula, „
43. „ ? echinata, Mans.

AULOPORA, Goldf.

44. „ RUGULOSA, Rss. | 45. AULOPORA DIVARICATA, Rss.

CRISIA, Lamx.

46. „ EDWARDSII, Rss. | 48. CRISIA HAUERI, Rss.
47. „ HÖRNESII, „

CRISIDIA, Edw. = *Unicellaria*, Blainv.

49. „ VINDOBONENSIS, Rss.

In his 'Bryozoen: Paläontologische Studien über die ältesten Tertiärschichten der Alpen,' Prof. Reuss gives to us the results of studies of the Bryozoa from different localities from which he obtained material, some of which were remarkably rich in species. For myself, I consider that this is one of the most important of his works, and in addition to mere opinion, I am more acquainted with the forms described from the several localities mentioned in this work than the others. From all the localities mentioned, it would be quite possible to add considerably to the number of species, but it will be better to deal with the work as left by the author.

A. BRYOZOA, Taff. von Sangonini.

1. ESCHARA UNDULATA, Rss., pl. xxxii. fig. 6.
2. „ PERFORATA, Rss., pl. xxiii. fig. 5.

B. No Bryozoa. C. No Bryozoa.

D. CROSARA: *a*. CHEILOSTOMATA.

MEMBRANIPORA, Blainv.

1. „ LAXA, Rss., pl. xxxvi. fig. 14.
2. „ HOOKERI, Rss., pl. xxix. fig. 6–8.
3. „ ANGULOSA, Rss., pl. xxix. figs. 9, 11 = *Cellipora* ibid., Rss.
4. MEMBRANIPORA OCEANI, D'Orb., sp. = *Escharina* ibid. 'Pal. Fr. Tert. Crét.;' *Repteschareilina* ibid., D'Orb; *M. oceani*, Busk, 'Crag P.' p. 35.
5. MEMBRANIPORA LEPTOSOMA, Rss. = *Cellipora* ibid., Rss.
6. „ MUNSTERI, Rss.

LEPRALIA (*a*).

7. „ SQUAMOIDEA, Rss.
8. „ SEGUENZAI, Rss., pl. xxxvi. fig. 11.
9. „ GROTIANA, Stol.
10. „ RADIATA-GRANULOSA, Rss. = *L. Hornesi*, Rss.
11. „ MULTIRADIATA, Rss.

LEPRALIA (*b*).

12. „ SUESSI, Rss., pl. xxxvi. f. 17.
13. „ EXCENTRICA, Rss.
14. „ ANNULATA, Rss.
15. „ MONOPORA, Rss., pl. xxxvi. fig. 16.
16. „ OLIGOSTIGMA, Rss., pl. xxxiv. fig. 10 = *L. annulata*, V. M. sp.
17. „ PTEROPORA, Rss. = xxx., f. 4.

HIPPOTHOIDEA = *Alysidota*, Busk.

18. ALYSIDOTE PROMINENS, Rss., pl. xxxvi. fig. 8.

ESCHARA, Ray.

19. „ PAPILLOSA, Rss.

β. CYCLOSTOMATA.

DIASTOPORIDÆ.

DEFRANCIA, Bronn.

1. „ INTERRUPTA, Rss., pl. xxxiv. f. 12: pl. xxxv. f. 9.

STOMATOPORA, Bronn.

2. „ RUGULOSA, Rss. = *Aulopora* ibid., Rss. 'Foss. Pol.'

RADIOPORA, D'Orb.

3. „ PILEOLUS, Rss., pl. xxxvi., fig. 12 = *Domopora* ibid.

MULTITUBIGERA, D'Orb.

4. „ MICROPORA, Rss., pl. xxxvi. f. 15.

E. BRYOZOA, Schists, Val di Lonti.

CHEILOSTOMATA: *a*. ARTICULATA.

CELLULARIDÆ.

SCRUPOCELLARIA, Van Ben.

1. „ ELLIPTICA, Rss., pl. xxix., fig. 3 = *Bactridium* ibid., Rss.
2. „ GRACILIS, Rss., pl. xxix. fig. 4.

SALICORNARIDÆ.

SALICORNARIA, Cuv.

3. „ REUSSI, D'Orb. sp., pl. xxix., fig. 5 = *Cellaria marginata*, Rss. = *Vincularia Reussi*, D'Orb.

CELLARIA, Lamx.

4. „ MICHELINI, Rss.
5. „ SCHREIBERSI, Rss., pl. xxiv., figs. 5, 6.

β. INARTICULATA.

MEMBRANIPORA, Blainv.

6. „ HOOKERI, Rss.
7. „ MONOPORA, Rss., pl. xxix. fig. 7 = *M. appendiculata*, Rss.
8. „ ANGULOSA, Rss., pl. xxix figs. 9–11 = *Cellepora* ibid., Rss. = *Eschara excavata*, Rss.
9. „ DEPLANATA, Rss., pl. xxix. fig. 12 = *Cellepora* ibid., Rss.

LEPRALIA

10. „ SPARSIPORA, Rss., pl. xxx. fig. 1.
11. „ PTEROPORA, Rss. pl. xxx. fig. 4 = *Cellepora* ibid., Rss.

CELLEPORARIA, Lamx.

12. „ GLOBULARIS, Bronn. = *Cellepora* ibid., Bronn.; *Reptocelleporaria* ibid., D'Orb.
13. CELLEPORARIA PROTEIFORMIS, Rss., pl. xxx. figs. 2–6 = *Eschara diplostoma*, Rss.

Batopora, Rss.

14. „ multiradiata, Rss., pl. xxxi. figs. 1–4.

Bactridium, Rss.

15. „ Hagenowi, Rss., pl. xxxi. figs. 5–6.

Retepora, Imper.

16. „ simplex, Busk, pl. xxxi. fig. 7.
17. „ cellulosa, L., pl. xxxi. fig. 8.
18. „ tuberculata, Rss., pl. iii. fig. 9–10.

Flustrellaria, D'Orb.

19. „ trapezoidea, Rss., pl. xxix. fig. 14 = *Cellepora* ibid., Rss.

Eschara, Ray.

20. „ syringopora, Rss., pl. xxxii. fig. 1.
21. „ papillosa, „ pl. xxxi. figs. 11–17.
22. „ stenosticha, „ pl. xxxii. fig. 2 = *Cellaria* ib. Rss.
23. „ polysticha, „ pl. xxxii. fig. 3 = *Cellaria* ib. Rss.
24. „ subchartacea, D'Arch.
25. „ semilævis, Rss., pl. xxxii. fig. 7–8 = *E. larva*, Rss.
26. „ Suessi, „ „ „ 9.
27. „ bisulca, „ „ „ 10.
28. „ nodulifera, „ „ „ 11–12.
29. „ microdonta, „ „ „ 13.
30. „ haueri, „ „ „ 14–16 = *Cellaria* ib., Rss. = *Eschara crenatomargo*, Rss.
31. „ phymatopora, Rss., pl. xxxiii. fig. 1.
32. „ parallela, „ „ „ 2.
33. „ semitubulosa, „ „ „ 3.
34. „ minor, „ „ „ 4.
35. „ Hornesi, „ „ „ 6–7.
36. „ duplicata, „ „ „ 8–10 = *Cellaria* ib., Rss.
37. „ heterostoma, „ xxvi. „ 5.
38. „ alifera „ xxxiii. „ 11.

Biflustra, D'Orb.

39. „ macrostoma, Rss. pl. xxxiii. figs. 12–13 = *Cellaria* ib., Rss.

Vincularia, Def.

40. „ Haidingeri, Rss. pl. xxxiii. fig. 14–15 = *Cellaria* ib., Rss.
41. „ geometrica „ „ „ 16.
42. „ exarata „ pl. xxxiv. „ 1 = *Cellaria* ib., Rss.
43. „ impressa. „ „ „ 2.

Acropora, Rss.

44. „ coronata „ pl. xxxiv. „ 3–5 = *Cellaria* ib., *Eschara conferta*, Rss.

Selenaridæ.

Cupularia, Lamx.

45. „ bidentata, Rss., pl. xxix. fig. 1–2.

Lunulites, Lamx.

46. „ quadrata, Rss., pl. xxviii. fig. 18.

CYCLOSTOMATA, Busk.

CRISIDÆ.

UNICRISIA, D'Orb.

1. „ TENERRIMA, Reuss, pl. xxxiv. fig. 7 = *Unicrisia vindobonensis*, D'Orb., 'Pal. Franç. Ter. Cr.;' *Crisia vindobonensis*, Rss.

CRISIA, Lamx.

2. „ EDWARDSI, Rss.
3. „ SUBÆQUALIS, Rss., pl. xxxiv. fig. 8.

DISCOSPARSA, D'Orb. = PATINELLA, Gray.

4. „ TENUIS, Rss., pl. xxxiv. figs. 9–10.
5. „ REGULARIS „ „ „ 11.

DEFRANCIA, Bronn.

6. „ INTERRUPTA, Rss., pl. xxxiv. fig. 12; pl. xxxvi. fig. 9.

BUSKIA, Rss.

7. „ TUBULIFERA, Rss.

IDMONEA, Lamx.

8. „ RETICULATA, Rss., pl. xxxiv. fig. 13 (=*Crisina*).
9. „ GRACILLIMA, „ xxxv. „ 1–2.
10. „ CONCAVA „ „ „ 3–4.

HORNERA, Lamx.

11. „ CONCATENATA, Rss., pl. xxxv. figs. 5–6.
12. „ TRABECULARIS, „ „ „ 7=*H. hippolithus*, Def., D'Arch.
13. „ ASPERULA „ „ „ 8–9.
14. „ SERRATA „ „ „ 10–11.
15. „ D'ARCHIARDII „ „ „ 12.

FILISPARSA, D'Orb.

16. „ VARIANS, Rss. = *Pustulopora anomala*, Rss. = *Hornera biloba*, Rss.

ENTALOPHORA, Lamx.

17. „ ATTENUATA, Stol., pl. xxxvi. figs. 1–2 = *Pustulopora* ib., Stol.; *Pustulopora anomala*, Rss.

SPIROPORA, Lamx.

18. „ CONFERTA, Rss., pl. xxxvi. fig. 3 = *Cricopora verticillata*, Rss.
19. „ PULCHELLA, Rss., pl. xxxvi. figs. 4–5=*Cricopora* ib., Rss.
20. „ TENUISSIMA, „ „ „ 6.

HETEROPORA, Blainv.

21. „ SUBRETICULATA, Rss., pl. xxxvi. fig. 7.

Bryozoenschichte von Montecchio Maggiore.

SALICORNARIA, Cuvier.

1. „ REUSSII, D'Orb.

CELLARIA.

2. „ SCHREIBERSI, Rss.

MEMBRANIPORA.
3. „ HOOKERI, J. Haine.
4. „ ANGULOSA, Rss.
5. „ DEPLANATA, „

LEPRALIA.
6. „ MULTIRADIATA, Rss.
7. „ LABIOSA „ pl. xxx. fig. 5.

CELLEPORARIA.
8. „ PROTEIFORMIS, Rss.

ESCHARA, Ray.
9. „ PAPILLOSA, Rss. pl. xxxi. f. 11–17.
10. „ SYRINGOPORA, Rss.
11. „ POLYSTICHA „
12 „ BISULCA „
13. „ NODULIFERA „
14. „ DUPLICATA „ pl. xxiii. fig. 8–9.
15. „ FENESTRATA „ pl. xxxiii. fig. 5.

BIFLUSTRA, D'Orb.
16. „ MACROSTOMA, Rss.

VINCULARIA.
17. „ HAIDINGERI, Rss.

ACROPORA.
18. „ CORONATA, Rss.
19. „ DUPLICATA „ pl. xxxiv. fig. 6.

CYCLOSTOMATA.

ENTALOPHORA.
1. „ ATTENUATA, Stol. sp.

FILISPARSA, D'Orb.
2. „ VARIANS, Rss.
3. HORNERA CONCATENATA, Rss.

IDMONEA.
4. „ GRACILLIMA, Rss.
5. „ CONCAVA.

This is the complete list of species from this locality as given by Reuss, but from the material sent to me some years since by Prof. Roemer of Breslau, I have been able to find nearly the whole of the species described from Val di Lonti.

Terebratularienschichte von Prabona.

1. MEMBRANIPORA ANGULOSA, Rss = *Polyeschara*, Rss.
2 „ GRACILIS, Rss., pl. xxix. fig. 13 = *Cellepora* ibid., Goldfuss; *Eschara andegavensis*, Mich.; *Lepralia gracilis*, Rss.; *Membranipora andegavensis*, Busk.
3. LEPRALIA SPARSIPORA, Rss.
4. „ ANGISTOMA, pl. xxx , fig. 3.
5. CELLEPORARIA CONGLOMERATA, Goldf. sp.
6. „ CIRCUMCINCTA, Rss., pl. xxx. figs. 10, 11.
7. BATOPORA MULTIRADIATA, Rss.
8. ESCHARA PAPILLOSA, Rss.

San Martino.

1. MEMBRANIPORA ANGULOSA, Rss.
2. CELLEPORARIA CONGLOMERATA, Goldf.
3. LUNULITES QUADRATA, Rss.

(*Cyclostomata*)

1. RADIOPORA BOLETIFORMIS, Rss., pl. xxviii. fig. 27.

San Vito di Brendola.

CELLEPORARIA CONGLOMERATA, Goldf.

Bryozoenschichten von Granella.

1. CUPULARIA BIDENTATA, Rss.
2. LUNULITES QUADRATA ,,

This completes the whole of the lists given by Reuss from the several localities named.

Prof. Ritter von Reuss: 'Die fossilen Bryozoen des Oesterreichisch-ungarischen Miocäns' (Fossil Bryozoa of the Austro-Hungarian Miocene).

In the brief notice of this memoir, the author said that some of the species described in a former memoir (the first of the three papers now given as published in 1849) are now suppressed, and the notice introductory to the present paper mentions 17 species of *Membranipora*, 75 of *Lepralia*, 2 of *Scrupocellaria*, and one of *Salicornaria* ('Geol. Record,' vol. i. 1854, p. 320).

BRYOZOA (Ehr.)

CHEILOSTOMATA, Busk.

,, ARTICULATA Rss.

SALICORNARIA (*Cellaria* of Hincks).

1. ,, FARCIMINOIDES, Johnst. For synonyms see *ante*, *Cellaria fistulosa*, Linn.

CELLARIA, Lamk.

2. ,, CEREOIDES, Ell. & Sol. 'Oligocän' = *Cellaria Michelini*, Rss. *l. c.* p. 61, 'Foss. P. Wien.' = *Tubucellaria opuntoides*, D'Orb., Pal. Fr.' v. p. 336 = *Cellaria Michelini*, Stol. 'Foss. Bry. Orakei Bay' = *Cellaria Michelini*, Rss., 'Pal. Stud. alt. Tert.' = *Vincularia Michelini*, D'Orb. 'Pal. Fr.' v. p. 59 = *Vincularia fragilis*, Mich. (non Def.).

SCRUPOCELLARIA, v. Ben.

3. ,, ELLIPTICA, Rss. 'Ober Oligocän' = *Bactridium* ibid. Rss. *l. c.* 'Foss. P. W.' p. 56 = *Bactridium* ibid. 'Pal. Stud. alt. Tert.' = *Canda* ibid., D'Orb. 'Pal. Fr.' v. p. 48 = *Bactridium granuliferum*, Rss. *l. c.* p. 56 = *Canda granulifera*, D'Orb. & Rss. = *Bicellaria granulifera*, Rss.
4. S. SCHIZOSTOMA, Rss. = *Bactridium* ibid. Rss. *l. c.* p. 56 = *Canda* ibid., D'Orb. 'Pal. Fr.' v. p. 333.

INARTICULATA, Rss.

MEMBRANIPORIDÆ.

LEPRALIA,

5. ,, UNGERI, Rss. = *Celleporia* ibid., Rss. *l. c.* p. 14 = *Celleporia* ibid., D'Orb. 'Pal. Fr.' v. p. 398, Leithakalke.

6. Lepralia semicristata = *Cellepora* ibid., Reuss. *l. c.* p. 92 = *Reptescharella* ibid., D'Orb. 'Pal. Fr.' v. p. 453. 'Similar to *L. variolosa*,' Johnst.
7. Lepralia binata, Rss. 'Foss. Bry. Öst.-ung.'
8. „ Barrandii, Rss. = *Cellepora* ibid., Rss. *l. c.* p. 92 = *Repteschareellina* ibid., D'Orb. 'Pal. Fr.' v. p. 452.
9. Lepralia pleuropora, Rss. = *Cellepora* ibid., Rss. *l. c.* p. 88 = *Cellepora crinilabris*, Rss. *l. c.* p. 88 = *Repteschareellina pleuropora*, D'Orb.
10. Lepralia gastropora, Rss. 'Mittel Oligocän. Öst.-ung.' Similar to *L. pungens*, Rss., 'Septarien.' and *L. umbilicata*, Röm.
11. Lepralia inamœna, Rss., 'Öst.-ung. Bryozoa.'
12. „ decorata, Rss. (= *Microporella*, Hks.) = Manzoni, 'Bry. Foss. It.' ii. p. 4 = *Cellepora decorata*, Rss. *l. c.* p. 89.
13. Lepralia megalata, Rss. = *Cellepora* ibid., Rss. *l. c.* p. 81 = *Reptescharipora* ibid., D'Orb., 'Pal. Fr.' v. p. 490.
14. Lepralia personata, Rss. 'Öst.-ung. Bry.': 'approaches' *L. violacea*, Johnst.; *L. pteropora*, Rss.; *L. stenua*, Manz.
15. Lepralia coccinea, Johnst. (= *Mucronella*, Hks.) = *Cellepora pteropora*, Rss. *l. c.* p. 81 = *Distans escharellina* ibid., D'Orb. 'Pal. Fr.' v. p. 451 = *Lepralia* ibid., Manz. 'Foss. It.' iii. p. 8 = *Lepralia mammillata*, Manz., 'Foss. It.' ii. p. 4 = Oligocene of Crosara.
16. Lepralia odontostoma, Rss. 'Foss. Bry. Öst.-ung.'
17. „ arceolata, Rss. „ „
18. „ glabra, Rss. „ „
19. „ microstoma, Rss. = *Cellepora* ibid., Rss. *l. c.* 92 = *Reptescharellina* ibid., D'Orb. 'Pal. Fr.' v. 453, Leithakalke.
20. Lepralia cornigera, Rss. 'Foss. Bry. Öst.-ung.'
21. „ entomostoma, Rss. Ober Oligocän = *Cellepora* ibid., Rss. *l. c.* p. 92. *Reptescharellina* ibid., D'Orb. 'Pal. Fr.' v. p. 452.
22. Lepralia ansata, Johnst. (*Schizoporella unicornis*, Hks.).
22*a*. „ var. porosa, Ober Oligocän = *Cellepora Dunkeri*, Rss. *l. c.* p. 90 = *Reptescharellina* ibid., D'Orb. 'Pal. Fr.' v. p. 452 = *Lepralia spinifera*, Manz. 'Bry. Pli. It.' p. 7 = *Lepralia unicornis*, Busk, 'Crag P.' p. 45.
22*b*. Lepralia, var. *tetragona*, Rss. = *Cellepora* ibid., Rss. *l. c.* p. 78; *Lepralia* ibid., Manz. 'Foss. Ital.' p. 6, and iii. p. 8 = *Reptoporina* ibid., D'Orb. 'Pal. Fr.' v. p. 442. Mittel and Ober Oligocän; Eng. Crag
23. Lepralia Gonversi, Rss. 'Foss. Bry. Öst.-ung.'
24. „ lima „ „ „ „
25. „ intermedia, Rss. „ „ „
26. „ vicina „ „ „ „
27. „ capitata, Rss. (= *Chorizopora Brongniartii*), 'Foss. Bry. Öst.-ung.'
28. Lepralia clavula, Manz., 'Bry. Foss. It.' iii. p. 8.
29. „ schizogaster, Rss. = *Cellepora* ibid. Rss., *l. c.* p. 84 = *Mollia* ibid., D'Orb. 'Pal. Fr.' v. p. 388.
30. Lepralia trigonostoma, Rss. = *Cellepora* ibid., Rss. *l. c.* i. p. 87 = *Reptoporina* ibid., D'Orb., 'Pal. Fr.' v. p. 442.
31. Lepralia hypsostoma, Rss., 'Foss. Bry. Öst.-ung.'; nearly allied to *L. megalota*, Rss.

32. Lepralia Sturi, Rss., 'Foss. Bry. Öst.-ung.'; nearly allied to *L. megolata*, Rss.
33. Lepralia violacea, Johnst. (*Microporella*, Hks.) = *Cellepora Heckeli*, Rss., *l. c.* p. 85 = *C. Heckeli*, Manz., 'Bry. Pli. It.' 1869, p. 5.

Reuss says, 'Perhaps this is the place for *L. diversipora*, Rss., from the Septarienthon.'

34. Lepralia tenella, Rss. (*Schizoporella*, *vide* Waters) = *Cellepora* ibid., Rss. *l. c.* p. 94; *Reptoporina* ibid. D'Orb, 'Pal. Fr.' v. p. 442. '*L. rudis*, Manz., from Castellarquato is very similar, if not identical with this sp.'—Rss. 'Much resembles *L. subimmersa* and *anceps*, MacGill., *vide* Waters.'
35. Lepralia otophora, Rss. (*Schizoporella vulgaris*, Hks.) = *Cellepora* ibid., Rss. *l. c.* p. 90.
36. Lepralia pauper, Rss., 'Foss. Bry. Öst.-ung.'
37. „ arrecta, „ = *Cellepora* ibid., Rss., *l. c.* p. 81 = *Cellepora* ibid., D'Orb. 'Pal. Fr.' v. p. 398. Similar to the Oligocän *L. Grotriani*, Rss.
38. Lepralia scripta, Rss. (*Cribrilina radiata*, Hks.) = *Cellepora* ibid., Rss. *l.c.* p. 82 = *Cellepora* ibid., D'Orb. 'Pal. Fr.' v. p. 398 = *Cellepora megacephala*, Rss., *l. c.* p. 88. Similar forms to this: *L. innominata*, Couch; *L. annulata*, Fabr. sp.; *L. multiradiata*, Rss. Manzoni describes two forms: one from the Miocene of Turin, the other from the Pliocene.
39. Lepralia rarecosta, Rss. = *Cellepora* ibid., Rss. *l. c.* p. 83; *Mollia* ibid., D'Orb. 'Pal. Fr.' v. p. 388.
40. Lepralia Auingeri, Rss., 'Fol. Bry. Öst.-ung.'
41. „ Fuchsi „ „ „ similar to *L. Grotriani*, Rss.; *L. Peachii*, Busk, 'C. P.'
42. Lepralia serrulata, Rss. = *Cellepora* ibid., Rss., *l. c.* p. 85 = *Cellepora* ibid., D'Orb., 'Pal. Fr.' v. p. 389 = *Cellepora crassilabris*, Rss., *l. c.* p. 40; *Reptoporina crassilabris*, D'Orb.
43. Lepralia tenera, Rss., 'Foss. Bry. Öst.-ung.'
44. „ ternata, „ = *Cellepora* ibid., Rss., *l. c.* p. 91; *Reptescharellina* ibid., D'Orb. 'Pal. Fr.' v. p. 452.
45. Lepralia regularis, Rss., 'Foss. Bry. Öst.-ung.'
46. „ incisa, „ „ „
47. „ chilopora, „ = *Cellepora* ibid., Rss. *l. c.* p. 91.
48. „ Partschii, „ *Cellepora* ibid., Rss. *l. c.* p. 91; *Reptoporina* ibid., D'Orb. 'Pal. Fr.' v. p. 242.
49. Lepralia complicata, Rss., 'Foss. Bry. Öst.-ung.'
50. „ rugulosa, „ „ „ (near to *L. Brongniartii*, Aud.).
51. Lepralia venusta, Eichw., sp., *Cellepora* ibid., Eichw., 'Letha rossiac' iii. p. 89; *Cellepora* ibid., Manz., 'Bry. Pl. Ital.' ii. p. 8.
52. Lepralia monoceros, Rss.; *Cellepora* ibid., Rss., *l. c.* p. 80; *Cellepora* ibid., D'Orb. 'Pal. Fr.' v. p. 465.

52*. Lepralia Haueri, Rss. = *Cellepora* ibid., Rss. = *Reptescharella* id., D'Orb.

53. Lepralia peltata, Rss., 'Foss. Bry. Öst.-ung.'
54. „ Manzonii, „ „ „
55. „ Endlicheri, Rss. (*Umbonula verrucosa*, Esper); *Cellepora*, Rss. *l. c.* p. 82; *Reptoporina* ibid., D'Orb. 'Pal. Fr.' v. p. 442; ? *Cellepora orbicula*, Eichw.

56. LEPRALIA SCARABÆUS, Rss. (*Umbonula verrucosa*, Esper); *Cellepora*, Rss. *l. c.* p. 86, and D'Orb.
57. „ SERIATA, Rss., 'Foss. Bry. Öst.-ung.'
58. „ GRANULIFERA, Rss.; *Cellepora* ibid., *l. c.* p. 86, and D'Orb. 'Pal. Fr.'
59. „ LATA, Busk; Manz. 'Bry. Foss. It.' p. 4.
60. „ ASPERRIMA, Rss., 'Foss. Bry. Öst.-ung.'
61. „ OGIVALIS, „ „ „
62. „ NUDA, „ „ „
63. „ CINGULATA, „ „ „
64. „ CIRCUMORNATA, Rss.; *Cellepora* ibid., Rss. *l. c.* p. 85; *Reptescharella* ibid., D'Orb. 'Pal. Fr.' v. p. 455.
65. „ APERTA, Rss., 'Foss. Bry. Öst.-ung.'
66. „ CERATOMORPHA, Rss.; *Cellepora*, Rss. *l. c.* p. 80; *Reptescharellina* ibid., D'Orb. 'Pal. Fr.' v. p. 429.
67. „ CRASSA, Rss. 'Foss. Bry. Öst.-ung.'
68. „ RAREPUNCTATA, Rss. = *Cellepora* ibid. Rss., *l. c.* p. 87, and D'Orb.
69. „ GONIOSTOMA, Rss. = *Cellepora* ibid. Rss., *l. c.* p. 87, and D'Orb.
70. „ CYCLOCEPHALA, Rss. 'Foss. Bry. Öst.-ung.'
71. „ TURGESCENS, „ „ „
72. „ SULCIFERA, „ „ „
72*. „ INSIGNIS, „ „ „
73. „ PLANICEPS, „ „ „
74. „ GROSSIPORA, „ „ „
75. „ GRANOSO-POROSA, Rss. „ „ similar to *L. tenella*, Rss.; similar to *L. rudis*, Manzoni.
76. „ ANISOSTOMA, Rss. 'Foss. Bry. Öst.-ung.'
77. „ FILOCINCTA, „ „ „

MEMBRANIPORA, Blainv.

78. „ SUBTILIMARGO, Rss. 'Foss. Fauna deut. Oberoligocän,' ii. p. 17; *M. laxa*, Rss. 'Ält. Tert. Alp.' ii. p. 40.
79. MEMBRANIPORA ELLIPTICA, Hag. sp. = *Cellepora* ibid., Hag. = *Marginaria* ibid., Röm.
80. MEMBRANIPORA LOXOPORA, Rss. = *Cellepora* ibid., Rss., *l. c.* p. 97 = *Reptoflustrella* ibid., D'Orb. 'Pal. Fr.' v. p. 571.
81. MEMBRANIPORA FENESTRATA, Rss. = *Cellepora* ibid., Rss., *l. c.* p. 97, and D'Orb.
82. MEMBRANIPORA LACROIXII, Sav., sp. = *M. Savartii*, Busk, 'Crag P.' p. 31; Manzoni, 'Bry. Foss. It.' ii. p. 3; *M. reticulum*, Rss., *l. c.* p. 98; Mich. 'Icon. Zoo.' p. 74. In the Pliocene of Voltura and in the Red Crag.
82A. M. LACROIXII, var. *Diadema*, Rss., *l. c.* p. 98.
83. MEMBRANIPORA APPENDICULATA, Rss. = *Cellepora* ibid., Rss. *l. c.* 96; *Reptoflustrella* ibid., D'Orb. 'Pal. Fr.' v. p. 571.

'The nearly allied *M. velamen*, Goldf., differs in form of cell and absence of vibracula. Our species is very similar to many forms of the *M. trifolium*, Wood.'—Reuss.

84. MEMBRANIPORA SEMIAPERTA, Rss. 'Foss. Bry. Öst.-ung.'
85. „ PLATYSTOMA, „ = *Cellepora* ibid., Rss. *l. c.* p. 91.
86. „ INCORRUPTA, „ 'Foss. Bry. Öst.-ung.'

87. MEMBRANIPORA HOLOSTOMA, S. Wood, sp.; Busk, 'Crag Pol.' p. 36 = *Flustra holostoma*, S. Wood.

88. MEMBRANIPORA BIDENS, Hag., sp.; *Cellepora hippocrepis*, Rss. *l. c.* p. 94; *C. subhippocrepis*, D'Orb. 'Pal. Fr.' v. p. 398; *C. bidens*, Hag. 'Maest. Kreid.' p. 92; *M. bidens*, Busk, 'Crag Polyzoa,' p. 34.

Range.—Tufaceous Chalk, Maestricht; Pencil Chalk, Rügen; English Crag.

89. MEMBRANIPORA MINUTA, Rss.; *Cellepora* ibid., Rss. *l. c.* p. 93; *Reptescharella* ibid., D'Orb. 'This species occupies, as it were, a middle place between *M. gracilis* and *M. bidens.*'—Reuss.

90. MEMBRANIPORA GRACILIS, V. Mün. sp. = *Cellepora* ibid. Goldf. 'Pet. Germ.' 1826, p. 162; *Cellepora* ibid., Rss. *l. c.* p. 93; *Eschara andegavensis*, Mich. 'Icon. Zoo.' p. 329; *Lepralia gracilis*, Rss., 'Fauna Deutsch. Oberoligocen'; *M. andegavensis*, Busk, 'Crag Pol.' p. 35; *M. andegavensis*, Manzoni, 'Bry. Foss. It.' ii. p. 2.

91. MEMBRANIPORA FORMOSA, Rss.; *Cellepora* ibid., Rss. *l. c.* p. 95; *Cellepora* ibid., D'Orb. 'Pal. Fr.' v. p. 398. See *M. trifolium*, Busk, 'Crag Poly.'

92. MEMBRANIPORA PAPYRACEA, Rss.; *Cellepora* ibid., Rss. *l. c.* p. 94; and D'Orb. 'Pal. Fr.' p. 398.

93. MEMBRANIPORA ANGULOSA, *Cellepora* ibid., Rss. *l. c.* p. 93; and D'Orb. 'Pal. Fr.'; *Eschara excavata*, Rss. *l. c.* p. 72; *E. subexcavata*, D'Orb. p. 72. Rss., 'Pal. Stud. Ält.' and 'Foss. Foram. and Bry.' 'This is doubtless the place for *M. deplanata.*'—Reuss.

94. MEMBRANIPORA STENOSTOMA, Rss., *Cellepora* ibid., Rss. *l. c.* p. 93, and D'Orb.

Part II. 'Foss. Bry. Öst.-ungar Miocen,' Manzoni.

In the second part of this work Manzoni made fifty-two additions of species, so as to complete the list left unfinished by the lamented author. Manzoni's arrangement differs considerably from that of Reuss, but in accordance with the general principle that I have heretofore been guided by, I give the arrangement of that author rather than interfere with the text. It is only necessary to give the catalogue of species, but it is greatly to be regretted that Reuss did not live to revise the whole of his species, as he has done in the first part of the work.

BRYOZOA, CHEILOSTOMATA, CELLEPORIDÆ.

CELLEPORARIA, Lamx.

1. „ VERRUCOSA, Rss., *loc. cit.*[1] p. 79.
2. „ GLOBULARIS, Bronn; Rss. *loc. cit.* p. 76.
3. „ POLYTHALE, Rss. „ „ p. 77.
4. „ CRASSA, Manzoni, 'Öst.-ungar.'
5. „ AVICULIFERA, „ „

CUMULIPORA, Münster.

6. „ TRANSILVANICA, Rss.; Rss. in Mss., Upper Marl of Lapugy.

BATOPORA, Rss.

7. „ ROSULA, Rss., *loc. cit.* p. 78; 'Bry. deutsch. Oberoligocän,' tab. i. fig. 7; tab. ii. fig. i. Marl of Baden.

[1] *Foss. Pol. Wien. Tertiärbeck.*

HEMIESCHARA, Busk.

8. „ GEMINIPORA, Rss., *l. c.* p. 74; 'Foss. Fauna Steinsalz,' [p. 102.
9. „ POROSA, Rss. In Mss.
10. „ MARGINATA, Rss., 'Öst-ung.' Marl of Lapugy.
11. „ ? TUBIGERA, Manz. „

ESCHARA, Ray.

12. „ MACROCHILA, Rss. *l. c.* p. 65.
13. „ CHIRAGRA, „ in Mss.
14. „ GOTRIANA, „ 'Fauna deutsch. Oberoligocän;' 'Bry. deutsch. Sept.' p. 66.
15. „ EXPANSA, Reuss, in Mss.
16. „ SULCIMARGO, „ *l. c.* p. 65.
17. „ FILISPARSA, Manz., 'Öst.-ungar.'
18. „ AMPLA, Rss., *l. c.* p. 66.
19. „ BIAURICULATA, Rss. *l. c.* p. 66.
20. „ MONILIFERA, M.-Ed., *l. c.* p. 69, 'Crag Polyzoa.'
21. „ STIPITATA, Rss., in Mss. Marl of Lapugy.
22. „ IMBRICATA, Rss., *l. c.* p. 69.
23. „ REGULARIS, Rss., 'Deutsch. Septar.' p. 69; Manzoni, 'Bry. Foss.' iv.
24. „ UNDULATA, Rss., *l. c.* p. 68, 'Foss. Faun. Steinsalz.'
25. „ COSCINOPHORA, Rss., *l. c.* p. 67, 'Bry. deutsch. Septar.;' 'Fauna deut. Oberoligocän,' p. 36 = *Microporella* ibid., forma *armata*, Waters.
25. „ POLYSTOMELLA, Rss., *l. c.* p. 70.
26. „ POLYOMMA, „ „ 71.
27. „ TESSULATA, „ „ 71.
28. „ CONFERTA, „ „ 71.
29. „ DELICATA, Manzoni, 'Öst.-ungar.'
30. „ POROSA, M.-Edw., 'Crag Poly.' p. 66.
31. „ FORMOSA, Manzoni, 'Öst.-ungar.'
32. „ MINAX, „ „
33. „ NEGLECTA, „ „
34. „ OCULATA, „ „
35. „ FLABELLARIS, „ „
36. „ PATULA, „ „

BIFLUSTRA, D'Orb.

37. „ CONTABULATA, Rss., in Mss.
38. „ EXCAVATA, „ *l. c.* p. 72.

FLUSTRELLARIA, D'Orb.

39. „ TEXTURATA, Rss., *l. c.* p. 73, 'Foss. Fauna Steinsalz,' p. 103.
40. „ MACROSTOMA, Rss., *l. c.* p. 64.
41. „ AUTOCTONA, Manz., 'Öst.-ungar.'

RETEPORA, Imp.

42. „ CELLULOSA, Linn., Rss., *l. c.* p. 48; 'Crag Poly.' p. 74.
43. „ RUBESCHII, Rss., „ „ „

VINCULARIA, Defr.

44. „ CUCULLATA, Rss., *l. c.* p. 60; *l. c.* p. 72, as *Eschara costata*; 'Fau. deutsch. Oberoligocän' as *E. Reussi*, Stol.; 'Pal. Stud. Alt. Tert.,' *Vincularia Haidingeri*.

45. VINCULARIA BINOTATA, Rss. Mss., 'Öst.-ungar.'

MYRIOZOUM, Donati.

46. „ PUNCTATUM, Phill., Rss. *l. c.* p. 73; 'Faun. deutsch. Oberoligocän,' p. 50; 'Bry. deutsch. Sept.' p. 74.

CUPULARIA, Lamx.

47. „ HAIDINGERI, Rss., *l. c.* p. 58.
48. „ CANADENSIS, Busk, 'Crag Polyzoa,' p. 87; Manzoni, 'Bry. Foss.' i. p. 10.

LUNULITES, Lamx.

49. „ ANDROSACES, Alt., Manz. 'Bry. Foss.' i. p. 13.

In an appendix Manzoni gives the following:

50. ? GEMELLARIA, Sav.

Part III. 'Foss. Bry. Öst.-ungar.,' Manzoni.

In the 'Geological Record' for 1877, p. 315, Professor Nicholson gives a brief note on Part III. of the 'Fossil Bryozoa of the Miocene of Austria and Hungary.' This work I have not seen. It deals with species belonging to the Cyclostomata. The new forms described are:—

1. IDMONEA VIBICATA,	Manz.	6. PUSTULOPORA PROBOSCINA,	Manz.
2. FILISPARSA ELEGANTISSIMA,	„	7. PATINELLA CYATHIFORMIS,	„
3. „ ASTALIS,	„	8. DISCOTUBIGERA INSIGNIS,	„
4. „ TYPICA,	„	9. „ ACTINOIDES,	„
5. PUSTULOPORA RUGULOSA,	„		

'Polyzoa (Bryozoa) from the Upper and Lower Oligocene,'
Professor Roemer.

Professor Roemer, in his 'Norddeutschen Tertiär-Gebirges,' Cassel, ed. 1863, adopts a classification similar to that of Mons. Pictet in some respects, but with three divisions instead of two. Pictet[1] divides the Polyzoa or Bryozoa thus:—

A. CELLULATA, D'Orbigny, have three families (CHEILOSTOMATA, Busk).

I. CELLARIOIDES.
II. ESCHAROIDES.
III. FLUSTRELLOIDÆ.

B. CENTRIFUGINÆ, with three families (CYCLOSTOMATA, Busk).

I. RADICELLÆ.
II. OPERCULINÆ.
III. TUBULIPORIDÆ, Milne-Ed.

Roemer adds another family—literally another division.

C. CERIOPORIDÆ, D'Orbigny.

The 114 species given by Roemer as described in his monograph are distributed under 52 genera which, in the introduction that prefaces the descriptive part, has a rather elaborate synopsis. I have not broken the text of the author.

[1] Jukes' *Manual of Geology.*

A. CELLULATA = Cheilostomata, Busk.

CELLARIA, Lamk.

1.	,,	AFFINIS, Reuss, Upper Oligocene.			

VINCULARIA, Defranc (Cellaria pt.).

2.	,,	MARGINATA,	V. Münst.	Upper	Oligocene.
3.	,,	HEXAGONA,	,,	,,	,,
4.	,,	TETRAGONA,	,,	,,	,,
5.	,,	RHOMBIFERA,	,,	,,	,,
6.	,,	ESCHARELLA,	Röm.,	Lower	,,
7.	,,	PORINA,	,,	,,	,,

CELLEPORARIA, D'Orb.

8. ,, RAMULOSA, L. (= Cellepora ibid., Hincks), Upper Oligocene.

CYCLESCHARA, Röm.

9. ,, MARGINATA, Röm., Lower Oligocene.

ESCHARA, Lamk.

10.	,,	HETEROPORA,	,,	,,	,,
11.	,,	SUBTERES,	,,	,,	,,
12.	,,	DEFORMIS,	,,	,,	,,
13.	,,	SPONGIOSA,	,,	Upper	,,
14.	,,	PUNCTULATA,	,,	,,	,,
15.	,,	ORNATA,	,,	,,	,,
16.	,,	GLABRA,	,,	,,	,,

PORINA, D'Orb. (adopted by Hincks).

17.	,,	CONFLUENS,	Röm.,	Lower	Oligocene.
18.	,,	QUADRATA,	,,	,,	,,
19.	,,	DUBIA	,,	,,	,,
20.	,,	GRANULOSA	,,	,,	,,
21.	,,	OCCULATA	,,	Upper	,,

ESCHARIPORA, D'Orb.

22. ,, SUBSTRATA ,, ,,

23. ESCHARELLA CAUDATA, R. ('Might be united with *E. affinis* and in that case would be the only species occurring as well in the Upper as in the Lower Oligocene,'—Röm. p. 10).

24. ESCHARELLA AFFINIS, Röm., Upper Oligocene.

25. ,, CELLEPORACEA, Von. Münst. ,, ,,

PORELLA, Röm.

26. ,, MONOPS, Röm., ,, ,,

PORELLINA, D'Orb.

27.	,,	DECAMERON,	Röm.,	Lower	,,
28.	,,	LABIATA	,,	,,	,,
29.	,,	ELEGANS	,,	,,	,,

ESCHARIPORA, D'Orb.

30. ,, POROSA, Phill. (?), Upper ,,

BIFLUSTRA, D'Orb.

31. ,, PUNCTATA, Röm., Lower ,,

	Cellepora, D'Orb.		
32.	,,	mamillata, Phill., = *Discopora* ibid., Phill.	Upper Oligocene
33.	,,	geometrica, Röm.	(Bünde)
34.	,,	tenella, Röm.	Upper Oligocene.
35.	,,	millepunctata, Röm.	Lower ,,
36.	,,	papyracea,	Upper ,,
	Reteporina, D'Orb. (*Microporella*? Hincks).		
37.	,,	pertusa Röm.	Lower Oligocene.
38.	,,	umbilicata, Röm.	Upper ,,
39.	,,	capitata, ,,	,, ,,
40.	,,	asperella, Rss.	,, ,,
	Repteschарellina, D'Orb. (*Micropora*, pt. Hincks).		
41.	,,	triceps, Röm.,	Upper Oligocene.
42.	,,	rectangula, Rss. ,,	,,
	Reptescharella, D'Orb. (*Cribrilina*, pt. Hincks).		
43.	,,	ampullacea, Röm.,	Upper Oligocene.
44.	,,	cornuta, ,,	,, ,,
45.	,,	globulosa,	(Hildesheim).
46.	,,	coccinea, Röm.,	Bünde.
47.	,,	ornata,	,,
	Repteporellina, D'Orb.		
48.	,,	plana, Röm.,	Upper Oligocene.
48.*	,,	bella, ,,	,, ,,
	Reptescharipora, D'Orb.		
49.	,,	tristoma, Goldf.,	Bünde.
50.	,,	tetrastoma, Röm ,	Upper Oligocene.
51.	,,	subpunctata, ,,	,, ,,
52.	,,	tripora, ,,	,, ,,
	Membranipora, Blainv.		
53.	,,	simplex, Röm.,	Upper Oligocene.
54.	,,	ovata, ,,	,, ,,
55.	,,	Syltana,	(Miocene, Isle of Sylt).
	Reptoflustrina, D'Orb.		
56.	,,	biauriculata, Röm.,	Upper Oligocene.
	Cellulipora, D'Orb.		
57.	,,	annulata, V. Mün.,	Bünde.
58.	,,	globus, Röm.,	Lower Oligocene.
	Cumulipora, Von Münster.		
59.	,,	pumicosa, Röm.,	,, ,,
60.	,,	fabacea, ,,	,, ,,
61.	,,	favosa, ,,	Upper ,,
	Stichopora, Hagenow.		
62.	,,	fragilis.	,, ,,
	Lunulites, Lamk.		
63.	,,	hemisphæricus, Röm.,	Lower Oligocene.
64.	,,	polyporus, ,,	,, ,,
65.	,,	semiplexus, Rss.,	,, ,,

66. LUNULITES MICROPORUS, Röm., Upper Oligocene.
67. „ HIPPOCREPIS, L. „ „
68. „ PERFORATUS, Goldf. „ „

DISCOFLUSTRELLA, D'Orb.
69. „ HAIDINGERI, Rss. (= *Cupularia* ibid. Rss.) Miocene ?
70. „ CAMPANULA, Röm., Miocene.

DISCOESCHARITES, F. A. R.
71. „ MAMILLATA, Röm., Lower Oligocene.
72. „ IRREGULARIS, „ Upper „

B. TUBULIPORIDEA = Cyclostomata, Busk.

STOMATOPORA, D'Orb. (? Bronn).
1. „ MINIMA, Röm., Upper Oligocene.

TUBULIPORA, M.-Edw.
2. „ TRIFARIA, Röm., Upper Oligocene.
3? „ ?ECHINATA, Goldf., Upper Oligocene.

DIASTOPORA, Lamk.
4. „ DISCIFORMIS, Goldf., Upper Oligocene.

CRISIA, M.-Edw.
5. „ GRACILIS, Röm. „ „

HORNERA (no author's name)
6. „ BIPUNCTATA, Röm. „ „
7. „ TORTUOSA, „ „ „
8. „ NITENS, „ „ „
9. „ LAMELLOSA, „ Lower „
10. „ GRACILIS, Phill. Upper „

IDMONEA, Lmck. (? Lamx.).
11. „ BISERIATA, Phill. „ „
12. „ MINIMA, Röm. Lower „

BIDIASTOPORA, D'Orb.
13? „ ? DENTATA, Röm. Upper „

MESENTERIPORA, Blainv.
14. „ CUSPIDATA, „ „

PERIPORA, D'Orb.
15. „ VARIABILIS, Gold. (= *Ceripora* ibid.) Upper Oligocene.

PUSTULIPORA, Edw. (? Blainv.) = *Entalopora*.
16. „ RAMOSA, Röm. Upper Oligocene.
17. „ INCRASSATA, Röm. „ „

ESCHARITES, A. Röm.
18. „ INÆQUALIS, Röm., Lower Oligocene.
19. „ PUNCTATA, „ „

CHISMA, Lonsd.
20. „ HETEROPOROSUM, Röm. „ „

ECHINOPORA, D'Orb.
21. „ SULCATA „ „

MYRIOZOUM, Donati.
22. „ LONGÆVUM, Röm., Upper Oligocene.
RETEPORA, Lamk.
23. „ VIBICATA, Goldf. „ „
RETEPORIDEA, D'Orb.
24. „ GRACILIS, Phill.
25. „ BILATERALIS, Röm.; Upper Oligocene.

The genera and species 18 to 25 have no right to be placed in this group.

C. CERIOPORIDEA.

TURBINIA, Michelin.
26. „ INFUNDIBULUM, Röm., Lower Oligocene.
PELAGIA, D'Orb.
27. „ DEFRANCIANA, Mich.
ACTINOPORA, D'Orb.
28. „ SIMPLEX, Röm. „ „
29. „ PLANA, „ „ „
30. „ MULTIPORA „ Upper „
STELLIPORA, D'Orb.
31. „ TRUNCATA „ „ „
RADIOPORA, D'Orb.
32. „ TUBULIFERA „
PLETHOPORA, Hagenow.
33. „ ÆQUIPOROSA, Röm. Upper Oligocene.
34. „ BREVIS, „ Lower „
HETEROPORA, Blainv.
35. „ PUNCTATA, Phill. sp. (Millepora).
36. „ GRACILIS, „ „ (Cellaria), Upper Oligocene.
37. „ ? SULCATO-PUNCTATA, Röm., Lower Oligocene.
CERIOPORA, Lamck. (?)
38. „ SEMINULA, Röm., „ „
39. „ LUNULA, „ „ „
40. „ INCRASSATA, „ Upper „
41. „ INEQUALIS, „ „ „
42. „ ARBUSCULUS, „ „ „

'Oligocene Bryozoa from Latdorf.'—Stoliczka.

CHEILOSTOMATA.[1]

CELLARIA, Lamx.
1. „ MICHELINI, Rss., 'Pol. Wiss. Beck.' p. 61 = *Vincularia fragilis*, Mich. 'Icon.' p. 175.
2. „ BEYRICHI, Stol., Latdorf.
LEPRALIA, Johnst.
3. „ GROTRIANA, Stol. „
4. „ PEDICULARIS, „ „
5. „ MACROPORA, „ „

[1] With this list Stoliczka places as *Bidiastopora* the *Eschara tubulifera*, Rss. Does the author regard this as a Cyclostomatous Polyzoon?—G. R. V.

MEMBRANIPORA = *Flustrellaria*, D'Orb.
6. ,, ROBUSTA, Rss.
MEMBRANIPORA = *Semiflustrella*, D'Orb.
7. ,, ANHALTINA, Stol., Latdorf.
7.* ALVEOLARIA BUSKI, Stol.
8. BIFLUSTRA CLATHRATA, Phill. (as *Eschara*)
9. ,, GLABRA ,, ,,
ESCHARA (= *Escharifora*, D'Orb.)
10. ,, MORTESIGA, Stol., Latdorf.
11. ,, ORNATISSIMA ,, ,,
12. ,, CRENULATA ,,
13. ,, SUBOVATA ,, (= *Flustrina*, D'Orb.)
14. ,, PULCHRA ,, (= *Porellia*, ,,)
15. ,, MONILIFERA, M.-Ed. (= *Escharipora*, D'Orb.) = *E. punctata*, Phill.
16. ,, PROTEUS, Rss.
17. ,, REUSSI, Stol ? = *E. costata*, Rss. 'Pol. W. Beck.' p. 72.
18. ,, COSCINOPHORA, Rss. p. 72.
19. ,, PORULOSA, Stol. (= *Porina*, D'Orb.)
20. CELLEPORA GLOBULARIS, Bronn, Rss. 'Pol. W. Beck.' p. 76.
21. ORBITULIPORA HAIDINGERI, Stol.
22. RETEPORA RUBETSCHI, Rss. 'Polyp.' p. 48.
,, FASCIATA, Stol.
23. STICHOPORINA REUSSI, Stol.
24. LUNULITES SUBPLANA, Rss.
25. ,, LATDORFENSIS, Stol.

CYCLOSTOMATA.

1. PUSTULOPORA ATTENUATA, Stol.
2. ,, PULCHELLA, Rss. = *Cricopora* id., 'Pol. W. Beck,' p. 40.
3. ,, RETIFERA, Stol. (= *Clausa*).
4. HORNERA HIPPOLYTA, Def., Busk, Rss.
5. ,, RETEPORACEA, M.-Ed.
6. ,, VERRUCOSA, Rss., 'Zeit. deut. Gesell.' 1851.
7. ,, POROSA, Stol.
8. ,, GRACILIS, Phill.
9. ,, SUBANNULATA, Phill. (and = *biseriata*, Phill.)
10. ,, SERIATOPORA, Rss. = *Idmonea*, D'Orb.
11. FILISPARSA TENELLA, Stol.
12. IDMONEA FORAMINOSA, Rss. = *Crisina*.
13. ,, GIEBELI, Stol. = *Tubigera*.
14. ,, DELICATULA, Busk ,, Crag Polyzoa.
15. ,, TENUISULCA, Rss. ,,
16. ,, HÖRNESI, Stol. ,,
17. DOMOPORA PROLIFERA, Rss. sp. 'Pol.' p. 37.
18. PAVOTUBIGERA ANHALTINA, Stol.
19. HETEROPORA SIMILIS, Stol.

'Tertiary Bryozoa of N. W. Germany.'—Phillipi.

1. CELLARIA HEXAGONA, V. M. = *Glauconome* ibid.
2. ,, TETRAGONA, ,, = ,, ,,

3. Cellaria marginata, V. M. = *Glauconome.*
4. " rhombifera, " = "
5. " gracilis, Phillipi.
6. Eschara glabra, Phill., allied to
6a. " teretiuscula, Phill.
7. " punctata, "
8. " porosa, "
9. " clathrata, "
10. " diplostoma, "
11. " celleporacea, Goldf.
12. Discopora circumcincta, Phill. (*Lepralia*, Johnst.).
13. Retepora cellulosa, Lamk.
14. Millepora truncata, = *Myriopora*, Blainv.
15. Lunulites radiata, Lamk.

Cyclostomata.

1. Hornera gracilis, Phill.
2. " biseriata, " (see Stoliczka).
3. " subannulata, Phill.
4. Ceriopora variabilis, Goldf.
5. " stellata, "
6. " spiralis, "
7. " minuta, "

'Bryozoa of the Neozoic Period, New Zealand.'—Rev. J. E. T. Woods, F.G.S.

As I have given a very full list of the Bryozoa from Australia when dealing with the Papers of Mr. A. W. Waters, I need only give the following list, without the elaborate but valuable details of Mr. Woods. I think, however, that it would be unfair to the author not to give his views as to the horizon of the species.

Cheilostomata.

Eschara, Ray.
1. " monilifera, M.-Ed. Miocene or Upper Eocene.
2. " ampla, T. Woods. Oamansu " "
3. " Buskii, " " " "

Porina, D'Orb., 1852.
4. " Dieffenbachiana, Stol.

Celleporaria, Lamx., 1821 = *Cellepora*, Busk.
5. " gambierensis, T. Woods. Upper Eocene.
6. " papillosa, T. Woods. Napier. Upper Eocene.
7. " nummularia, Busk.

Salicornaria, Cuvier.
8. " immersa, T. Woods.

Vincularia, Defr., 1829.
9. " maorica, Stol.

Cellaria, Ell. and Stol., 1787.
10. " punctata, T. Woods.

Selenaria, Busk, 1852.
11. " squamosa, T. Wood. Upper Miocene.

CYCLOSTOMATA.

ENTALOPHORA, Lamx., 1821.
1. „ ZEALANDICA, Mantell.
2. „ NODOSA, T. Woods.
SPIROPORINA, Stol.
3. „ VERTEBRALIS, T. Woods.
4. „ IMMERSA, „
FUNGELLA, Hag.
5. „ LOBATA, T. Woods.
IDMONEA, Lamx., 1821.
6. „ ALTERNATA.
7. FASCICULIPORA INTERMEDIA, T. Woods.
8. „ RAMOSA, ? „

'A Synopsis of the known Species of Australian Tertiary Polyzoa.'—Robert Etheridge, jun.

Previous to the publication of Mr. Waters's papers on Australian Polyzoa, Mr. Etheridge wrote the Synopsis now under review. It was read before the Royal Society of New South Wales in 1877, and I think that it would be unwise to pass it over. Much of the information is embodied in the fuller papers of Mr. Waters. The paper is especially valuable on account of the bibliography; but as the new species, &c., are embodied from the MS. notes of Mr. Busk, many of these have been disregarded by Mr. Waters. Mr. Busk's notes were published in the 'Quart. Jour. Geol. Soc.' 1863. I give the list from Mr. Etheridge.

CHEILOSTOMATA.

1. CANDA ANGULATA, Busk.
2. ONCHOPORA PUSTULOSA, Busk (MS.)
3. „ VERTEBRALIS, Stoliczka.[1]
4. SALICORNARIA GRACILIS, Busk.
5. „ PARKERI, „ (MS.)
6. „ SINUOSA, Hassell.
7. „ TENUIROSTRIS, Busk.
8. CABEREA LATA, Busk.
9. CELLEPORA COSTATA, Busk (MS.)
10. „ ECHINATA, Sturt.
11. „ GAMBIERENSIS, Busk (MS.) = *Eschara celleporiacea*, Sturt.
12. „ HEMISPHÆRICA, „ „ = *Cellepora escharoides*, „
13. „ SPONGIOSA, „
14. „ TUBULOSA, „
15. CŒLESCHARA AUSTRALIS, Busk (MS. genus and sp.)
16. ESCHARA ARCUTA, Busk (MS.)
17. „ BIMARGINATA, Busk (MS.)
18. „ HASTIGERA, „ „
19. „ INORNATA, „ „
20. „ OCULATA, „ „
21. „ PAPILLATA, „ „

[1] *Spiroporina*, Stol., Mr. Busk considers to be, according to this list, a Cheilostomatous and not a Cyclostomatous form. See Wood's list No 3, Cyclos.

22. ESCHARA PIRIFORMIS, Sturt.
23. „ SIMPLEX, Busk (MS.)
24. „ sp. ind., Woods' 'Geol. Observations.'
25. „ sp. ind., Sturt.
26. „ CAVERNOSA, T. Wood, from 'Roy. Soc. N.S.W.' vol. x. 1877.
27. „ PORRECTA, T. Wood. Mount Gambier.
28. „ CLARKEI, „
29. „ VERRUCOSA, „
30. „ RUSTICA, „
31. „ ELEVATA, „ (? = *monolifera*, Busk).
32. „ LIVERSIDGEI, T. Wood.
33. „ OCULATA, T. Wood.
34. „ TATEI, „
35. „ BUSKII, „
36. LEPRALIA DOLIFORMIS, Busk (MS.)
37. „ STAWELLENSIS, M'Coy.
38. „ SUBCARINATA, Busk (MS.)
39. „ SUBMARGINATA, Busk (MS.)
40. LUNULITES, sp. ind., T. Woods.
41. MELECERITA ANGUSTILABRA, Busk (MS.)
42. MEMBRANIPORA APPRESSA, Busk (MS.)
43. „ BIDENS, Hagenow.
44. „ CYCLOPS, Busk.
45. „ STENOSTOMA, Busk.
46. PSILESCHARA PUSTULOSA, Busk (genus and sp. MS.)
47. „ SUBSULCATA, „ (MS.)
48. RETEPORA DISTICHA, Sturt.
49. „ M'COYI, R. Ether. jun.
50. „ MONILIFERA, McGil.
51. „ VIBICATA, Sturt (non Goldfuss) ? = *R. Beaniana*, King.
52. SCUTULARIA PRIMA, Busk (genus and sp. MS.).

CYCLOSTOMATA.

1. CRISIA EBURNEA, Linn. 'Only one species has as yet been noted from the Australian Tertiaries' (R. Etheridge). 'I have several species from the Yarra Yarra material' (G. R.V.)
2. HORNERA GAMBIERENSIS, Busk.
3. „ RUGULOSA, „
4. IDMONEA LIGULATA, Busk. MS.
5. „ MILNEANEA, D'Orb.
6. ENTALOPHORA DISTANS, Busk (*Pastulopora*, Eth.)
7. „ UNGULATA, Woods.
8. „ CORRUGATA, „
9. TUBULIPORA GAMBIERENSIS. (Mount Gambier. No author's name).

Mr. George Busk.

It seems to me to be almost out of place to make any elaborate remarks of the place which the masterly work of Mr. Busk, 'Fossil Polyzoa of the Crag,' occupies in the literary history of the Polyzoa as a distinct group. In this work the author not only described and figured all the then known Polyzoa from the Crag, but we owe to him the elaborate synopsis of the

Cheilostomata and Cyclostomata which prefaces the two groups of fossil forms. In addition to this we have another, a preface which deals with morphological details, which have been, and always will be, of supreme advantage to the Palæontological student. I think that it may be said that the publication of this work inaugurated an epoch out of which later writers have emerged with difficulty. The work, however, of Mr. Busk dealt only with superficial details, and but very rarely with structure. It may be said, however, that the authors who gave to us the elaborate monographs which this report fully indicates by the lists given, dealt only with superficial characters; and it was reserved for later writers to deal with and interpret the meaning of tissue and structure of the fossil by the study of living species. Hence the publication of the works of Mons. Joliet, Claparède, Nitsche, Barrois, and others, has given a new direction of thought in the study of fossil forms; and, so far as superficial character can possibly indicate the relative positions species should occupy in a natural grouping, the cell and the cell-orifice furnish us with details only dimly visible to authors who wrote previous to Professor Smitt, Mr. A. W. Waters and also Rev. T. Hincks. I have given to the student in the first part of this Report ample material by which Busk and others can be brought into harmony with the more modern classification. It is because of this that I had no desire to alter the text.

'A Monograph of the Fossil Polyzoa of the Crag.' By George Busk, F.R.S., &c., 1859.

Sub-Order I. CHEILOSTOMATA.

SCRUPOCELLARIA, Van Ben., p. 19.

1. ,, SCRUPOSA ? Linn., pl. i. fig. 6, p. 19.

SALICORNARIA, Cuvier.

2. ,, CRASSA, S. Wood (as *Cellaria*), pl. xxi. fig. 4–6.
3. ,, SINUOSA, Hassall (as *Farcimia*), ,, fig. 5.

HIPPOTHOA, Lamx.

4. ,, PATAGONICA, Busk, pl. i. fig. 5 = *Alecto vesiculosa* (?), Mich.
5. HIPPOTHOA ABSTERSA, S.W., pl. xxii. fig. 6 = *Lepralia* ibid. S.W. = *Criserpia pyriformis* (?), Mich.
6. HIPPOTHOA DENTATA, S.W., pl. i. fig. 7 = *Catenaria* ibid. S.W.

ALYSIDOTA, Busk = *Phylactella*, Hincks.

7. ,, LABROSA, Busk, pl. xxii. fig. 7 = *Lepralia* ibid. Busk.
8. ,, CATENA, S.W., pl. vii. fig. 7 = *Lepralia* ibid. S.W.

MEMBRANIPORA, Blainv.

9. ,, TUBERCULATA (?), Bosc, pl. ii. fig. 1 = *Flustra*, ibid. Bosc = *F. membranacea*, Esper = *F. crassidentata*, Lamk.
10. MEMBRANIPORA MONOSTACHYS, Busk, pl. ii. fig. 2 = *Flustra pustulosa* (?), D'Orb. = *Memb. nobilis* (?), Reuss.
11. MEMBRANIPORA SAVARTII, Aud., pl. ii. fig. 6 = *Flustra* ibid., Sav. = *M. Ligeriensis* (?), D'Orb.
12. MEMBRANIPORA DUBIA, Busk, pl. iii. fig. 12.
13. ,, TRIFOLIUM, S. Wood, pl. iii. figs. 1, 2, 3, 9.
14. ,, POUILLETII, Aud., pl. iii. figs. 4, 5, 6 (as *Flustra* ibid. Aud.).

15. Membranipora rynchota (Busk), pl. iii. fig. 7 = *M. trifolium* (? var.), S. W.
16. Membranipora aperta, Busk, pl. iii. fig. 13.
17. „ oblonga, Busk, pl. ii. fig. 3.
18. „ bidens, Hagenow, pl. ii. fig. 4 = *Cellepora* ibid. Hag. = *C. hippocrepis* (?), Rss.
19. Membranipora andegavensis, Mich., pl. ii. fig. 5 = *Eschara* ibid. Mich.
20. Membranipora fissurata, Busk (no figure), p. 35.
21. „ oceani, D'Orb., pl. iii. fig. 8 = *Escharina* (*Cellepora* ibid.), D'Orb.
22. Membranipora holostoma, S. W., pl. iii. fig. 11 (as *Flustra* ibid.), S. W.

Lepralia, Johnst. (Busk gives, p. 37, 16 synonymous genera for the old *Lepralia*.)

I. Armatæ.

(*a*) *With oral spines.*

23. Lepralia punctata, Hassall, pl. iv. fig. 1.
24. „ innominata, Couch, pl. iv. fig. 2.
25. „ puncturata, S. W., pl. vi. fig. 2.
26. „ Woodiana, Busk, pl. vii. figs. 1–3.
27. „ ? ciliata, Linn., pl. vii. fig. 6 (? *Microporella*, Hincks) = *Cellepora crenilabris*, Rss.
28. „ Morrisiana, Busk, pl. vii. fig. 8 = *Cellepora tristoma* (?), Goldf.

(*b*) *Without oral spines.*

29. Lepralia violacea, Johnst., pl. iv. fig. 3 (*Microporella*, Hincks).
30. „ plagiopora, Busk, pl. iv. fig. 5 = *Cellepora Heckelii* (? Rss.). Name suppressed by Busk.
31. „ Edwardsiana, Busk, pl. v. fig. 2 = *L. Milneana*, Busk = *Edwardsiana*, 'Crag Polyzoa,' p. 132.
32. „ unicornis, Johnst., pl. iv. fig. 4 = *Cellepora tetragona*, Rss.
33. „ ansata, Johnst., pl. vii. fig. 2 = *Cellepora Dunkeri*, Rss. = *C. protuberans* (?), Rss.
34. „ Brongniarti, Aud., pl. vi. fig. 1.
35. „ mamillata, S. W., pl. vi. fig. 5 (as *Cellepora*).
36. „ bicornis, Busk, pl. viii. figs. 6, 7.
37. „ ? biaperta, Mich., pl. vii. fig. 5 = *Eschara* ibid., Mich. Icon.

II. Inarmatæ.

(*a*) *With oral spines.*

38. Lepralia variolosa, Johnst., pl. iv. fig. 4, 8; pl. viii. fig. 8.
39. „ Peachii, Johnst., pl. v. figs. 6, 7, 8; pl. vi. fig. 4.
40. „ ventricosa, Hassall, pl. vi. figs. 3, 6, 8.
41. „ Bowerbankiana, Busk, pl. vii. fig. 4.
42. „ lobata, Busk, pl. vi. fig. 7; pl. xxii. fig. 4.

(*b*) *Without oral spines.*

43. Lepralia pyriformis, S. W., pl. v. fig. 3.
44. „ hyalina, Linn., pl. v. fig. 1 (*Cellepora* ibid., Linn.).

45. LEPRALIA PAPILLATA, Busk, pl. v. f. 5.
46. „ HAIMESEANA, Busk, pl. viii. fig. 1.
47. „ MALLUSII, Aud. (*Eschara*), pl. viii. fig. 3.
48. „ REUSSIANA, Busk, pl. viii. fig. 2.
49. „ INFUNDIBULATA, Busk, pl. viii. fig. 4.
50. „ PALLASIANA, Moll., pl. ix. fig. 7.
51. „ MEGASTOMA, Busk, pl. viii. fig. 5.
52. „ MILNEANA, Busk (See 'Crag Pol.,' p. 132) = *L. Edwardsiana*, Busk, No. 31 above.

CELLEPORA (pars), O. Fab. 1780.

(*a*) *Ramose, not encrusting.*

53. CELLEPORA CORONOPUS, S. Wood, pl. ix. figs. 1–3 = *Scyphia cellulosa*? Goldf.
54. „ RAMULOSA, Linn., pl. ix. fig. 2.
55. „ COMPRESSA, Busk, pl. ix. fig. 4.
56. „ CÆSPITOSA, Busk, pl. ix. fig. 5.

(*b*) *Encrusting, adnate, massive.*

57. „ EDAX, Busk, pl. ix. fig. 6; pl. xxii. fig. 3.
58. „ TUBIGERA, Busk, pl. ix. fig. 8–10.
59. „ SCRUPOSA, Busk, „ „ 9.
60. „ PARASITICA, Mich., „ „ 11–13.
61. „ DENTATA, Busk, pl. ix. fig. 12.

ESCHARA, Ray. (*a*) *Foliaceous.*

62. „ PERTUSA, M.-Edw., pl. x. fig. 2.
63. „ INCISA, „ „ „ 3.
64. „ POROSA, „ pl. xi. fig. 4.
65. „ SINUOSA, Busk, pl. x. fig. 6.
66. „ CORNUTA, „ pl. iv. fig. 7; pl. x. fig. 5.

(*b*) *Lobate or ramose.*

67. „ SEDGWICKII, M.-Edw., pl. x. fig. 1.
68. „ MONILIFERA, „ pl. xi. figs. 1–23.
69. „ SOCIALIS, Busk, p. 131, pl. xxii. fig. 1.

MELICERITA, M.-Edw.

70. „ CHARLESWORTHII, M.-Edw., pl. x. fig. 4 = *Melicertina*, ibid., Ehrenb. = *Ulidium* ibid., S. Wood.

BIFLUSTRA, D'Orb.

71. „ DELICATULA, Busk, pl. i. figs. 2 and 4; pl. ii. fig. 7.
72. FLUSTRA? DUBIA, Busk, p. 132, pl. i. fig. 3.

RETEPORA, Imp.

73. „ CELLULOSA, Linn., pl. xii. figs. 1–7.
74. „ BEANIANA, King, „ figs. 2, 5, 6, 7.
75. „ NOTOPACHYS, Busk, „ fig. 4.
76. „ SIMPLEX, „ „ fig. 3.

HEMESCHARA, Busk = *Semieschara*, *Semiescharipora*, *Multiescharipora*, all D'Orb.

77. HEMESCHARA IMBELLIS, Busk, pl. iv. fig. 6; pl. x. fig. 7 = *Eschara pertusa* (?), Mich.

Family VII. Busk. Group *Liberæ.*

SELENARIDÆ, Busk, 1853 = *Escharidæ*, (pars) D'Orb; *Polypiers foraminés*, Lamk.; *Cellariæa*, (pars) Blainv.; *Milleporées*, (pars) Lamx.; *Asterodiscina*, Lonsd.—Dixon, 'Geo. of Sussex.'

'*Zoarium* free (?), orbicular or irregular, conical, or depressed, convex on one side, and plane or concave on the other; composed of a single layer of cells, usually of two kinds, which open on the convex surface only.'—'Crag Polyzoa,' p. 78.

This family Mr. Busk comments upon very fully in the above work, and as he has had many more facilities of studying the group than I can ever hope to have, I gladly refer the student to the pages of the 'Crag Polyzoa' for the general remarks. The following is the synopsis of genera and also a full list of known fossil species below the Crag, which will be, I feel confident, acceptable to students who have not access to the author's works.

Synopsis of genera (four admitted).

1. CUPULARIA, Lamx.
   (*a*) Each cell with a vibracular chamber at its apex or distal extremity.
2. LUNULITES, Lamx.
   (*b*) The cells and vibracular chambers disposed or separate, usually alternate rows radiating from the centre.
3. SELENARIA, Busk.
   (*c*) Certain of the cells of a different conformation to the rest, furnished with a vibraculum.

   STICHOPORA, Hagenow.
   (*d*) No apparent vibracular chambers distinct from the true cell.
4. CONESCHARELLINA, D'Orb.
   (*e*) Vibracula replaced by small avicularia; mouth of cell circular.

CRETACEOUS genera and species.

SELENARIA CONICA, D'Orb. = *Lunulites* ibid. Defr.
STICHOPORA CLYPEATA, Hagenow.
CUPULARIA MUNSTERI, „

LUNULITES PLANA, D'Orb.
„ ROSACEA, „
„ PETALOIDES, D'Orb.
„ REGULARIS, „
„ PAPYRACEA, „
„ TUBERCULATA, „
„ CRETACEA (? Defrance) (? D'Orb).

LUNULITES BOURGEOISII, D'Orb.
„ DOMA, „
„ CLYPEIFORMIS, „
„ HAGENOWI, Bosquet.
„ GOLDFUSSI, Hagenow.
„ MITRA, „
„ SEMILUNARIS, „
„ SPIRALIS, „

EOCENE.

CUPULARIA RHOMBOIDALIS, Münster.
„ HAIDINGERI, Reuss.

LUNULITES URCEOLATA, Lamk. (non Goldf., Lamx.).
„ RADIATA, „

LUNULITES CONTIGUA, Lonsdale.
„ DISTANS, „
„ SEXANGULA, „

MIOCENE, or more recent than Eocene.

CUPULARIA DENTICULATA, Conrad.
„ INTERMEDIA, Michellotti.
„ UMBELLATA, Defrance.
„ VANDERBECKEI, Mich.
LUNULITES ANDROSACES, Michellotti.
„ CUVIERI, Defrance.
„ CONICA, „ 'Crag.'
„ PUNCTATA, Leymerie.

Doubtful forms; uncertain as to position or genus:—

LUNULITES SPONGIA, Morren.
„ DUCLOISIA, Lea; Claiborne, Alabama.
„ BOUEI, „ „ „
„ DEPRESSA (?), Conrad.
„ PINEA (?), Risso; Defrance.
„ QUINCUNCIALIS, Dujardin.

Only two of the four genera admitted by Mr. Busk are represented in the Crag.

(Crag Polyzoa—continued.)

CUPULARIA, Lamx. = *Lunulites* (pars), Defr., Goldf., Blainville, Lonsdale, Deslongchamps = *Lunulites spiralis*, Hag., Geinitz., Grund., p. 623.

78. CUPULARIA DENTICULATA, Conrad, 'Crag P.' pl. xiii. fig. 1.
79. „ CANARIENSIS, Busk, pl. xiii. fig. 2.
80. „ POROSA, „ „ „ 5.

LUNULITES, Lamx.

81. „ CONICA, Defrance, pl. xiii. fig. 4 = var. *a*, *depressa* = *L. urceolata*, Goldf.

Sub-Order II. CYCLOSTOMATA.

CRISIA, Lamx.

1. „ DENTICULATA (?), Lamk. sp., pl. i. fig. 8 = *Cellaria* ibid. Lamk.

HORNERA, Lamx.

2. „ INFUNDIBULATA, Busk, pl. xiv. fig. 1.
3. „ RETEPORACEA, Milne-Ed., „ „ 2.
4. „ CANALICULATA, Busk, „ „ 3.
5. „ RHIPIS, „ „ „ 4.
6. „ HUMILIS, „ „ figs. 5–6.
7. „ PERTUSA, „ „ fig. 7.
8. „ HIPPOLYTA (?), Defr., „ figs. 8–9.
9. „ LUNATA, Busk, pl. xvi. fig. 4.
10. „ FRONDICULATA, Lamx., pl. xv. figs. 1–2; pl. xvi. fig. 6.
11. „ STRIATA, M.-Ed., pl. xv. fig. 3; pl. xvi. fig. 5.
12. „ RHOMBOIDALIS, Busk, pl. xv. fig. 4.

IDMONEA, Lamx.

13. „ PUNCTATA, D'Orb. pl. xv. fig. 5; pl. xvi. fig. 3 = *Laterocava* ibid. D'Orb.

14. IDMONEA FENESTRATA, Busk, pl. xv. fig. 6.
15. „ DELICATULA, „ „ „ 8.
16. „ INTRICARIA, „ „ „ 7.

PUSTULOPORA, Blainv.

17. „ CLAVATA, Busk, pl. xvii. fig. 1 = *P. gracilis*, Milne-Ed. = *P. echinata*, Römer = *Entalophora linearis*, D'Orb.
18. PUSTULOPORA PALMATA, Busk, pl. xviii. fig. 2.
19. „ SUBVERTICILLATA, Busk, pl. xviii. fig. 1.

MESENTERIPORA, Blainv.

20. „ MEANDRINA, S. W., pl. xvii. fig. 2; pl. xviii. fig. 4; pl. xx. fig. 2 = *Diastopora* ibid., Wood = *D. Eudesiana*, M.-Edw. = *Ditaxia compressa*, Goldf., Hag. = *Mesenteripora neocomiensis* (?), D'Orb.

TUBULIPORA, Lamk.

21. „ PHALANGEA, Couch, pl. xviii. fig. 6.
22. „ FLABELLARIS (?), Fab. sp., pl. xviii. fig. 3; pl. xx. fig. 9 = *Diastopora vassiacensis*, D'Orb. = *D. plumula*, Rss.

ALECTO, Lamx.

23. „ REPENS, S. Wood, pl. xx. figs. 5–8 = *Idmonea ramosa*, D'Orb.
24. ALECTO DILATANS, W. Thomson, pl. xx. figs. 6–7 = *Diastopora echinata*, Rss. = *Idmonea divaricata, depressa, Cenomana, elegans*, D'Orb.

DIASTOPORA (*Diastopores simples*, M.-Ed.).

25. „ SIMPLEX, Busk, pl. xx. fig. 10.

PATINELLA, Gray.

26. „ PROLIGERA, Busk, pl. xix. fig. 1; pl. xx. fig. 3.

DISCOPORELLA, Gray.

27. „ HISPIDA, Johnst. (?), pl. xviii. fig. 5.
28. „ GRIGNONENSIS (?), M.-Ed., pl. xx. fig. 4.

DEFRANCIA, Bronn.

29. „ STRIATULA, Busk. pl. xvii. fig. 5 ? = *D. Michelinii*, Hag. = Cretaceous *Ceriopora diadema*, Goldf. = Cretaceous *D. Brongniarti*, M.-Edw.

FUNGELLA, Hagenow.

30. „ QUADRICEPS, Busk, pl. xvii. fig. 3.
31. „ MULTIFIDA, „ „ „ 4 = *Frondipora Marsillii*, Mich.
32. FUNGELLA INFUNDIBULATA, Busk, pl. xvii. fig. 6.

HETEROPORA, Blainv.

33. „ PUSTULOSA, Busk, pl. xx. fig. 1; pl. xix. fig. 6 = ? *H. tortilis*, Lonsd. = ? *Multizonopora ramosa*, D'Orb. = ? *H. intricata*, Mich. = ? *Entalophora irregularis*, D'Orb.
34. HETEROPORA CLAVATA, Goldf. sp., pl. xix. fig. 7 = *Ceriopora clavata*, Goldf. = *Heteropora anomolopora*, Rss. = *Ceriopora theleoidea* ? Hag.
35. HETEROPORA RETICULATA, Busk; no fig = *Ceriopora dichotoma*, Goldf. = *Heteropora dichotoma*, Hag.

36. HETEROPORA LÆVIGATA, Busk (D'Orb. sp.), pl. xix. fig. 5 = *Ceriopora dichot.* Goldf. = *Zonopora levigata*, D'Orb. = *Multizonopora ligeriensis*, D'Orb.

HETEROPORELLA, Busk = *Reptomulticava* (?), D'Orb.

37. „ RADIATA, Busk, pl. xix. fig. 2.
38. „ PARASITICA, „ pl. xxii. fig. 5.

THEONOIDEÆ, Busk.

'*Zoarium* massive, subglobose, or irregular; cells contiguous, crowded.' —Busk, 'C. P.' p. 127.

ALVEOLARIA, Busk.

39. „ SEMIOVATA, Busk, pl. xix. fig. 4; pl. xxi. fig. 3, section = *Blumenbachium*, Sowerby.

FASCICULARIA, Milne-Ed. = Theonoa (sp.), S. Wood; Meandripora, D'Orb.; Apsendesia, (pars) Blainv.

40. FASCICULARIA TUBIPORA, Busk, pl. xxi. fig. 1.
41. „ AURANTIUM, M.-Ed., pl. xxi. fig. 2 = *Apsendesia cerebriformis* ?, Blainv.

'Bryozoa (Polyzoa) from the Pliocene of Bruccoli (Sicily).'

The following list of species is compiled from one of the earliest and most important papers of Mr. A. W. Waters, as published in the Transactions of the Manchester Geological Society, vol. xiv. p. 465, read May 1878. In it Mr. Waters describes—some of which are figured—43 species of Polyzoa, and besides the synonyms he has given some account of their range in space and time. As the geological horizons of the Pliocene beds are almost or about the same horizon as our own English Crags, I look upon Mr. Waters's paper as a fit sequel to that of the work of Mr. Busk. I have not generally made any special point of dealing with the history or sequence of the geological horizons in which Polyzoa have been found, but it may perhaps be well just to give the section, as furnished by Dr. Fuchs, of these peculiar beds. They are given in descending order:—

(*a*) Upper Pliocene sand, gravels and limestone, Foss.: *Cerithium vulgatum*, *C. scabrum*, *Murex trunculus*, *Rissoa*, *Turbo*, *Trochus*, *Monodonta*, *Ostrea*.
(*b*) Yellow sands without fossils.
(*c*) Blue marl, *Buccinum semistriatum*, *Dentalium elephantinum*, &c.
(*d*) Bryozoa beds, Corals, Brachiopoda, *Pecten opercularis*, &c.

From the works of Seguenza it seems that the Bryozoa described by Manzoni from Sicily and Calabria, are also Lower Pliocene. I have given the original arrangement of Mr. Waters, and as the work was completed before the publication of Mr. Hincks's work, I have been more desirous to give Mr. Waters's opinion of the fossils rather than the mere identification and range of his species.

Cheilostomata.

1. SALICORNARIA FARCIMINOIDES, Ell. & Sol. = *S. sinuosa*, Hassall; *Vincularia* and *Cellaria marginata*, Goldf.

Range from Bartonian: Up. Eocene, North Italy; Oligocene, North Germany; Miocene, Austria-Hungary. Pliocene: Italy—common in

Sicily, about 30 localities. Coralline Crag, England. Recent: generally distributed. Characters vary.

2. MEMBRANIPORA BIDENS, Hagenow=*Cellepora hippocrepis*, Reuss? *M. Rosselli*, Manz. '4th Contr.'

Range from Maestricht: Up. Miocene, Aust. & Hung., English Crag.

2*a*. M. LACROIXII, Sav.: Miocene, Aust. and Hung. *M. Savartii*, allied, from Eng. Crag.

3. M. ANDEGAVENSIS, Mich., var. papyracea, Waters (fig. 3, plate), Bruccoli.

4. M. ANGULOSA, Rss.

Range from Bartonian: Miocene; Pliocene; Living, Mediterranean. 'There are probably a number of species which should be reduced to synonyms of this form, and it should be noticed that in the Chalk there are several so-called Escharæ described, which have cells like the above, but which would now be called Biflustra.'—Waters. Even the name Biflustra is now become obsolete.

5. LEPRALIA CILIATA, Pall.=*Cellepora crenilabris*, Rss.

Range from Miocene: Pliocene. Living, widely distributed (fig. 2, plate).

6. L. MORRISIANA, Busk.

Range from Pliocene: Cor. Crag; Leghorn; (Manzoni, '2nd Contrib.'). Allied sp., *L. pleuropora*, *inamœna*?, Rss.

7. LEPRALIA VULGARIS, Moll. (fig. 22, plate) =*Cellepora otophora*, Rss. *Lepralia* id., Rss.? *L. tumida*, Manz. *L. intermedia*, Rss.

Range from Miocene: Aust. and Hung.; Oligocene. Varieties: Pliocene, Castrocaro; Living: Madeira; Mediterranean.

8. L. COCCINEA, Aud.=*L. Ballii*, Johnst. Miocene of Eisenstadt (Hungary), Pliocene. Living.

9. L. INNOMINATA, Couch. Pliocene: rare at Castrocaro; Crag; Quaternary, A. W. W.

10. L. ARRECTA, Rss.; *Cellepora* id., and *Lepralia* id., Rss. Miocene: Eisenstadt.

11. L. ANSATA, Johnst., var. *porosa*, Rss.=*Lep. unicornis*, 'Crag Pol.' Oberoligocene of Doburg; Miocene, Aust. and Hung., Crag (as *unicornis*).

12. L. AURICULATA, Hass. One specimen, Bruccoli.

13. L. " var. *Leontiniensis*, Waters, (fig. 5, plate), Bruccoli.

14. L. CUPULATA, Manz. (fig. 6, plate), '3rd Contribution.' Miocene, Pliocene. Living.

15. L. BOWERBANKII, Busk, 'Crag Pol.;' Manzoni, '1st Contr.' Coral. Crag, Eng. and North Italy.

16. L. RESUPINATA, Manzoni (fig. 7, plate). Pliocene, Castrocaro.

17. L. SCRIPTA, Rss. = *L. megacephala*, Rss. Miocene, Hungary; Pliocene, Tuscany and Sicily. Living.

18. L. PALLASIANA, Moll.

'Probably several fossil species are *L. Pallasiana*, which have received other names.'—A. W. W. Known range, C. Crag, Sicily.

19. CELLEPORA CORONOPUS, S. Wood. Pliocene, C. Crag. Living.

20. C. TUBIGERA, Busk (figs. 20, 21, plate). Pliocene. Living, Brit. and Foreign Coasts, Mediterranean.

21. C. RAMULOSA, Linn. Pliocene, Cor. Crag. Living: Scandinavia; Naples, 40 fathoms.
22. HIPPOTHOA CATENULARIA, Jameson. Pliocene. Living.
23. ESCHARA LUNARIS, Waters (fig. 9, plate), Bruccoli.

'I believe that it is the same as *Porina labiata*, Röm. The name is given from the semilunar pore, which occurs frequently in *Lepralia*, but there are a few Escharæ with it. This would be called *Porellina ciliata* by Smitt.'—Waters. Pliocene. Living: Naples, 40 fath.

24. ESCHARA CERVICORNIS, Ell. and Sol. Pliocene. Living.
25. E. BIAPERTA, Mich., forma *Eschariformis*, Wat. (fig. 8, plate), Bruccoli.
26. E. PERTUSA, M.-Ed. (fig. 4, plate). Miocene, Doué. Pliocene: Crag.
27. E. FOLIACEA, Lam., var. *fascialis*, Waters. Pliocene.
28. BIFLUSTRA RYNCHOTA, Waters (fig. 1, plate), Bruccoli.
29. RETEPORA CELLULOSA, Linn. Miocene, Pliocene. Living, 'having a wide range.'
30. MYRIOZOON TRUNCATUM, Pall.=*Vaginopora polystigma*, Rss. *Myriozoon punctatum*, Rss. Miocene (as *punctatum*), Reuss.; Pliocene, Manzoni. Living, Mediterranean, com.
31. CUPULARIA REUSSIANA, Manzoni=*Cupularia doma*, D'Orb.

Cyclostomata.

32. DIASTOPORA FLABELLUM, Rss.=*D. simplex*, Busk (non D'Orb.). Miocene, Pliocene.
33. ALECTO MAJOR, Lonsd.=*A. repens*, S. Wood (Waters). Pliocene. Living, Arctic Sea.
34. PUSTULOPORA PROBOSCIDEA, M.-Ed. Bruccoli. Living: Shetland, Medit., Naples 30 fath.
35. P. RUGOSA, D'Orb.=*Entalophora*, id , D'Orb.; *Pustulopora rugulosa*, Manz. CHALK, stage 22, as *rugosa*. Miocene.
36. DISCOPORELLA MEDITERRANEA, Blainv. (figs. 11, 12, plate) = *Lichenopora* id., Blainv.
37. D. RADIATA, Aud.=*Discosparsa patina*, Heller.
38. DIASTOPORA CUPULA, D'Orb. (figs. 13, 14, plate) = *Discosparsa cupula*, D'Orb.
39. FRONDIPORA RETICULATA, Blainv., forma *verrucosa*, Waters, Bruccoli.
40. MESENTERIPORA, sp. (figs. 17 to 19, plate).
41. HORNERA FRONDICULATA, Lamx.=*H. affinis*, Milne-Ed.=*H. andegavensis*, Michelin. Pliocene. Living: Naples, in the deeper dredgings.

Of fig. 16, plate, Mr. Waters says:—'This seems the same as Manzoni ('Bry. de Castrocaro') has figured as *Aetea sica*, but I do not see from his figure why he does not call it *Alecto*, and believe it is the same which usually grows with more cells along the line of growth, and which he figures as *Alecto repens*.' There is no doubt in my mind but that both the figures of Mr. A. W. Waters, and also of Manzoni, are indicative of true *Stomatopora* (Alecto), but I did not suppress the name out of deference to so good a worker, nevertheless I doubted the affinity in the first part of this Report (see Aeteidæ). In his description of the plate vi. fig. 69 (fig. 5, plate vii.) Manzoni says '*Ætea sica*, Couch=*Alecto parasita*, Heller.'

'Italian Pliocene Bryozoa.'—Manzoni.

In the earliest of Dr. Manzoni's writings, entitled 'Briozoi plioceni italiani,' the author describes seventy-four species of Cheilostomatous and three Cyclostomatous Polyzoa. The work was published in 1869 and 1870, and was fully illustrated, as all Dr. Manzoni's works are. I have not these papers by me, and I can only give the list as supplied by Miss E. C. Jelly. Many of the names will be familiar to the student of the 'Crag Polyzoa,' but twenty-seven are new. I wish to preserve the divisions of the author, I., II., III., IV.

I.

I. Sub-Order Cheilostomata, Busk.

1. Membranipora Reussiana, Manz.
2. Lepralia rudis, Manz.
3. ,, umbonata, Manz.
4. ,, Bowerbankiana ?, Bk.
5. ,, lata, Bk.
6. ,, venusta, Eichwald.
7. ,, disjuncta, Manz.
8. ,, violacea, Johnst.
9. ,, tetragona, Rss. (Cellepora), 'Fos. Pol. Wien. Beck.' p. 78.
10. Lepralia spinifera, v. *unicornis*, Johnst.
11. ,, utriculus, Manz.
12. ,, innominata, Couch.
13. Cellepora scruposa ?, Bk.
14. ,, punctata, Manz.
15. Cupularia umbellata, Defr.
16. ,, canariensis, Bk.
17. ,, Reussiana, Manz.
18. Lunulites Androsaces, All.

II.

19. Membranipora exilis, Manz.
20. ,, andegavensis, Mich., 'Ic. Zoo.' p. 329.
21. ,, oceani, D'Orb., 'P. Fr.'
22. ,, Lacroixii, Sav. = M. Savartii, Aud.
23. Biflustra delicatula, Bk.
24. Lepralia decorata, Rss., 'Wien. Beck.' p. 89.
25. ,, Morrisiana, Bk.
26. ,, mamillata, S. Wood.
27. ,, Brongniartii, Aud.
28. ,, unicornis, Johnst.
29. ,, pertusa ?, Auctt.
30. Cellepora systolostoma, Men. (Coll. del R. Museo di Sc. Nat. di Pisa).
31. Cupularia intermedia, Michellotti.

III.

32. Lepralia scripta, Rss., 'Wien. Beck.' p. 82; ibid. 'Deut. Oberol.' p. 29; ibid. 'Deut. Septa.' p. 50.
33. Lepralia pteropora, Rss., 'Wien. Beck.' p. 81; ibid. von Crosara, p. 45.
34. Lepralia linearis, Hass. (*Heventia*, Gray).
35. ,, peregrina, Manz.
36. ,, fulgurans, ,,
37. ,, streńua, ,,
38. ,, papillifera, ,,
39. ,, ciliata, Pall.
40. ,, turgidula, Manz.
41. ,, elegantula, ,,
42. Lepralia delicatula, Manz.
43. ,, gibbosula, ,,
44. ,, annulatopora, ,,
45. ,, lucernula, ,,
46. ,, cupulata, ,,
47. ,, cheilostomata, ,,
48. ,, obeliscus, ,,
49. ,, scorpioides, ,,

IV.

50. Salicornaria farciminoides, Johnst., Manz. 'Saggio di Conch. Foss. Subalp. 1868,' p. 69.
51. Salicornaria cuspidata, Manz.
52. Hippothoa catenularia, Flem., D'Orb. 'Pal. F.' p. 383.
53. „ flagellum, Manz.
54. Membranipora annulus, Manz.
55. „ pedunculata, Manz.
56. „ reticulum, Mich. (non Blainv.).
57. „ angulosa, Rss., 'Wien. Beck.' p. 93; ibid. 'von Crosara,' p. 41.
58. „ subtilimargo, Rss., 'Oberol.' p. 17.
59. „ lineata, Bk.
60. „ Rosselii, Aud.
61. „ Smittii, Manz.
62. Lepralia ligulata, Manz. (= Cheilostoma).
63. Cellepora ramulosa, Linn.
64. „ coronopus, S. Wood; Busk, 'Crag' p. 57.
65. „ tubigera?, Busk.
66. „ pumicosa, Linn.
67. „ pulchra, Michellotti.
68. „ paucioscülata, „
69. „ Hassallii, Johnst.
70. Eschara Hellerii, Manz.
71. „ foliacea, Lamk.
72. Retepora cellulosa, Lamk.
73. Lunulites quadrata, Rss., op. cit. p. 66.
74. Cupularia bidentata, Rss., op. cit. p. 65.

II. Sub-Order Cyclostomata, Busk.

1. Stomatopora (Bronn), Taurinensis, Manz.
2. Idmonea serpens, Linn.
3. Discoporella verrucaria, Linn. = [1] *Discorparsa patina*, Lamk.

'I. Briozoi del Pliocene Antico di Castrocaro,' Manzoni.

Scrupocellaria, V. Bened.
1. „ elliptica, Rss., Tab. I. fig. 1.

Salicornaria, Cul.
2. „ farciminoides, Johnst., Tab. I. fig. 2.

Myriozoon, Donati.
3. „ truncatum, Pallas, Tab. I. 3 to 3*a*.

Hippothoa, Lamx.
4. „ divaricata, Lamx., Tab. I. fig. 15.
5. „ flagellum, Manz., Tab. I. fig. 14.

Aetea, Lamx.
6. ? „ sica, Couch, Tab. VII. fig. 69.
7. „ anguina, Hincks, Tab. VI. fig. 70.

Terebripora, D'Orb.
8. „ Archiaci, Fischer, Tab. VI. fig. 68.

[1] Is not this a mistake of the printer for Discosparsa?

MEMBRANIPORA, Blainv.

9. „ CATENULARIA, Jameson, Tab. I. fig. 8.
10. „ ANGULOSA, Rss., Tab. I. fig. 14 = *M. antiqua*, Busk = *Mollia antiqua*, Smitt.
11. „ APERTA, Busk., Tab. I. fig. 4.
12. „ TRIFOLIUM, S. Wood, Tab. I. fig. 7.
13. „ IRREGULARIS, D'Orb., Tab. I. fig. 5 = *M. trichophora*, Busk.
14. „ LINEATA, Linn., Tab. I. fig. 6.
15. „ FLEMINGII, Busk, Tab. II. fig. 21.
16. „ ANNULUS, Manz., Tab. I. figs. 9, 9*a*, 9*b*, 9*c*.
17. „ CALPENSIS, Busk, Tab. I. fig. 10.
18. „ HOLOSTOMA, S. Wood, Tab. I. fig. 12.
19. „ ROSSELII, Aud., Tab. II. fig. 15.
20. „ BIDENS, Hag., Tab. II. fig. 16.

LEPRALIA, Johnston.

21. „ DECORATA, Reuss, Tab. II. figs. 18*a*, 18*b*.
22. „ COCCINEA, Johnst., Tab. II. fig. 19.
23. „ FULGURANS, Manz., Tab. II. fig. 20.
24. „ STRENUIS, Manz., Tab. II. fig. 20.
25. „ INNOMINATA, Couch, Tab. VII. fig. 85.
26. „ SCRIPTA (?), Reuss, Tab. II. figs. 25, 25*a*.
27. „ SURGENS, Manz., Tab. II. fig. 22.
28. „ ANSATA, Johnst., Tab. II. fig. 24–24*a*.
29. „ RESUPINATA, Manz., Tab. II. fig. 26.
30. „ BRONGNIARTII, Aud., Tab. II. fig. 27; Tab. IV. fig. 54.
31. „ BIAPERTA, Michelin, Tab. II. fig. 28.
32. „ PLANATA, Manz., Tab. III. fig. 29.
33. „ MICANS, „ Tab. III. fig. 32*a*.
34. „ SCHIZOGASTER, Rss., Tab. III. fig. 34.
35. „ MARIONENSIS, Busk, Tab. III. fig. 39.
36. „ VIOLACEA, Johnst., Tab. IV. fig. 45*a*.
37. „ OTOPHORA, Rss., Tab. III. fig. 30–30*a*.
38. „ CILIATA, Pallas, Tab. III. fig. 34.
39. „ CRASSILABRA, Manz., Tab. III. fig. 38.
40. „ TUMIDA, „ „ figs. 33 and 33*a*.
41. „ INGENS, „ Tab. IV. fig. 44.
42. „ ANNULATOPORÆ, „ „ fig. 42.
43. „ MALUSII, Aud., „ fig. 45.
44. „ DISJUNCTA, Manz., Tab. III. fig. 35*a*.
45. „ CRIBRILINA, „ „ fig. 40.
46. „ VASCULA, „ Tab. V. fig. 56.
47. „ RARECOSTATA, Reuss, Tab. VI. fig. 76.
48. „ VENUSTA, Eichwald, Tab. IV. fig. 50.
49. „ REUSSIANA, Busk, Tab. VI. fig. 55.
50. „ SQUAMOIDEA, Reuss, Tab. IV. figs. 46 and 46*a*.
51. „ OBVIA, Manz., Tab. VI. figs. 44–44*a*.
52. „ HAUERI, Reuss, Tab. V. fig. 55.
53. „ LINEARIS, Hassall, Tab. III. fig. 37.
54. „ RETICULATA, Busk, Tab. III. fig. 36–36*a*.
55. „ CUCULLATA, Busk, Tab. IV. fig. 47.
56. „ PERTUSA, Johnst., „ fig. 48.

57. LEPRALIA SYSTOTOSTOMA, Manz., Tab. IV. figs. 49–49*a*.
58. „ CHILOPORA, Rss., „ fig. 54.
59. „ TUBA, Manz., „ fig. 52–52*a*.

CELLEPORELLA, Norman.

60. „ CASTROCARENSIS, Manz., Tab. V. fig. 57.

CELLEPORA.

61. „ TUBIGERA, Busk, „ fig. 60–61.
62. „ SYSTOLOSTOMATA, Manz., „ fig. 58.
63. „ RETUSA, Manz., „ fig. 59.
64. „ RAMULOSA, Linn., „ fig. 62.

ESCHARA, Ray.

65. „ FOLIACEA, Lk., „ fig. 66.
66. „ COLUMNARIS, Manz., „ fig. 65.
67. „ LICHENOIDES, Lamk., „ fig. 64.
68. „ SEDGWICKII, M.-Ed., „ fig. 63.
69. „ CERVICORNIS ?, Lamk.

BIFLUSTRA, D'Orb.

70. „ SAVARTII, Aud., Tab. II. fig. 17.

RETEPORA IMPERATO.

71. „ ? sp., Tab. VII. fig. 84.

CUPULARIA, Lamx.

72. „ UMBELLATA, Def. = *C. intermedia*, Mich., Tab. V. fig. 67.

CYCLOSTOMATA.

ALECTO, Lamx. (*Stomatopora*).

1. „ CASTROCARENSIS, Manz., Tab. VI. fig. 71.
2. „ REPENS, S. Wood, „ „ „ 72.
3. „ PARASITA, Heller, „ VII. „ 69.

IDMONEA, Lamx.

4. „ INSIDENS, Lamx. „ VII. „ 78.
5. „ SERPENS, Linn. „ VI. „ 78.

HORNERA, Lamx.

6. „ FRONDICULATA, Lamx. „ VII. „ 80.

PUSTULOPORA, Blainv.

7. „ ? sp. „ VII. „ 82.

TUBULIPORA, Lamk.

8. „ FLABELLARIS, Fabr. „ VI. „ 73.

DIASTOPORA, Lamx.

9. „ PATINA, Lamx. „ VII. „ 77.
10. „ STRIATA, J. Haine (*Berenicea*), Tab. VI. fig. 74; Tab. VII. fig. 79.
11. „ EXPANSA, Manz., Tab. VII. fig. 85.

CERIOPORA, Goldf.

12. „ GLOBULUS, Reuss, „ VII. „ 81.

HETEROPORELLA, Busk.

13. „ RADIATA ? Busk, Tab. VI. fig. 75.

'Post-Tertiary Polyzoa.'

In the Catalogue of Western Scottish Fossils, compiled by James Armstrong, John Young, and David Robinson (Glasgow, 1876), the authors give a list of species found in the Glacial Beds of Scotland. The authors were assisted in this work by the Rev. A. M. Norman, whose valuable labours on the group, previously published in the Reports on the Shetland dredgings, prove how fit he was to help in this special work. There is still a large mass of material in the hands of Mr. David Robinson, placed there by my friend Mr. T. Steel, late of Greenock; and it is to be hoped that if Mr. Robinson's remarks have not yet been, that they will soon be, published. These also were from the Garvel Park Beds. Unlike other lists, I have re-arranged the generic names so as to bring it into accord with the arrangement of the Rev. T. Hincks.

CHEILOSTOMATA, Busk.

CELLULARIA, Pallas.

1. ,, PEACHII, Busk. Post-Tertiary and Glacial deposits, Scotland; Garvel Park.

MENIPEA, Lamx.

2. ,, TERNATA, var. Ellis and Sol. Garvel Park.

SCRUPOCELLARIA, Van. Ben.

3. ,, REPTANS, Linn. Post-Tertiary and Glacial deposits, Scotland; Duntroon, Paisley.
4. ,, SCRUPOSA, Linn. Post-Tertiary and Glacial deposits, Scotland; Caithness
5. ,, SCABRA, Van. Ben.
Var. ELONGATA, Smitt. Garvel Park.

CABEREA, Lamx.

6. ,, ELLISII, Fleming. Garvel Park.

BUGULA, Oken.

7. ,, AVICULARIA, Pallas. Duntroon.

MEMBRANIPORA.

8. ,, FLEMINGII, Busk. Garvel Park; Lochgilp.
9. ,, TUBERCULATA, ,, ,, ,,
10. ,, ? UNICORNIS, Flem. Paisley; Dalmuir; Duntroon.
11. ,, CATENULARIA, Jamieson = *Hippothoa* of authors. Dalmuir; Duntroon.

CRIBRILINA, Gray.

12. ,, ANNULATA, Fabr. Garvel Park.

PORINA, D'Orbigny.

13. ,, TUBULOSA, Norman. Garvel Park.

SCHIZOPORELLA.

14. ,, HYALINA, Linn.
15. ,, SIMPLEX, Johnst. Caithness, in Boulder Clay.
16. ,, SPINIFERA, ,, Dalmuir.
17. ,, CRUENTA, Norman. Garvel Park.

HIPPOTHOA, Lamx.

18. ,, DIVARICATA, Linn. Caithness, in Boulder Clay.

LEPRALIA, Johnst.

19. „ PERTUSA, Esper. Dalmuir.

UMBONULA, Hincks.

20. „ VERRUCOSA, Esper. Dalmuir; Duntroon; Garvel Park.

PORELLA, Gray.

21. „ CONCINNA, Busk. Garvel Park; Lochgilp.
22. „ STRUMA, Norman. „ „

SMITTIA, Hincks.

23. „ CRYSTALLINA, Norman. Garvel Park.

MUCRONELLA, Hincks.

24. „ PEACHII, Johnst. Cumbrae College; Caithness, in Boulder Clay.
25. Var. LABIOSA, Busk. Caithness, in Boulder Clay.

CELLEPORA, Fabr.

26. „ PUMICOSA, Linn. „ „ „

CYCLOSTOMATA, Busk.

CRISIA, Lamouroux.

1. „ EBURNEA, Linn. Dalmuir, Lochgilp, Crinan, Duntroon, Paisley, and Garvel Park.
2. „ DENTICULATA, Linn. Caithness, in Boulder Clay.

IDMONEA, Lamx.

3. „ ATLANTICA, Forbes. The most important of individuals in Garvel Park beds.

TUBULIPORA, Lamk.

4. „ FLABELLARIA, Fabr. Dalmuir.
5. „ PHALANGEA, Couch. Dalmuir, Duntroon, Garvel Park.
6. „ ? SERPENS, Linn (*Idmonea*). Dalmuir, „ „

DIASTOPORA, Lamx.

7. „ OBELIA, Flem.

DISCOPORELLA, Gran. (*Lichenopora*).

8. „ HISPIDA, Flem. Paisley.
9. „ GRIGNONENSIS, Busk.
10. „ FLOSCULUS, Hincks = *Lichenopora radiata*. Garvel Park.
11. „ RADIATA, Busk. Garvel Park.

BIBLIOGRAPHY.

It may be that the student, in casting his eye over the following brief bibliographical notes, may detect an absence of certain names which are generally included in a section like the present one. I did not, it is true, seek to give a full list of authors, but in selecting the works now given I had more regard for special work than for furnishing a list of names in which remarks on the Class Polyzoa may be found, but in which no special plan of working is adopted. It was to the simple memoirs, whether brief or exhaustive, that I desired to direct attention, and I am not aware that I have overlooked any special papers, or authors. If I have sinned on this score, I shall be glad if notice of the omission is given to me, and I hope also that authors will forgive me if I have neglected to furnish notes on their labours. I only profess to give a bibliography of works on species found in the Cretaceous and Tertiary Rocks.

GEORGE BUSK.

1852. Catalogue of Marine Polyzoa in the collection of the British Museum. 12mo. London. Parts I. and II. Containing references to fossil species.
1859. Monograph of the Fossil Polyzoa of the Crag. Printed for the Palæontographical Society.
1866. Descriptions of Three Species of Polyzoa from the London Clay at Highgate, in the Collection of N. T. Wetherell, F.G.S., 'Geol. Mag.' vol. iii. No. XXV. July.
1875. Cyclostomatous Polyzoa. Part III. Brit. Museum Catalogue. Contains references to Fossil species.

ROBERT ETHERIDGE, Jun., F.G.S.

1875. On the Occurrence of a Species of *Retepora* allied to *R. phœnicea*, Busk, Tert. Beds. of Schnapper Point, Hobson's Bay, Victoria. 'Trans. R. Soc. Vict.' vol. xi. pp. 13, 14.
1876. Post-Tertiary Polyzoa. 'Geol. Mag.' Dec. 2, vol. iii. Prof. Busk describes with a figure a new species from the Post-Tert. Clays, Carsl., *Membranipora Etheridgii*, Busk.
1877. A Synopsis of the known Species of Australian Tertiary Polyzoa. Read before the Roy. Soc. New South Wales, Sept. 1877. Pp. 15, 8vo. Sydney.

In this synopsis Mr. Etheridge gives very full references to the bibliography and species described by various authors up to date. I have given elsewhere a list of Mr. Etheridge's species as found in the synopsis. Some of the species have been described or referred to by Mr. Waters in his various papers on 'Australian Fossil Bryozoa (Polyzoa.).'

J. W. DAWSON.

1869. Additional Notes on the Post-Pliocene Deposits of the St. Lawrence Valley. 'Canad. Nat.' vol. vi. pp. 23, 39, with sixteen engravings.

The author in the above describes and figures the Foraminiferæ and Bryozoa of the Post-Pliocene deposits of Lower Canada. He enumerates six species of Polyzoa, of which *Lepralia quadricornis* is described as new.

W. M. GABB and G. H. HORN.

1862. Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America. 'Journ. Acad. Nat. Sci. Philad.' vol. v. 2nd series, pp. 111–179; three plates.

FRIEDRICH V. HAGENOW.

1846. 'Bryozoen' in Geinitz, Grundriss der Versteinerungs-Kunde. 8vo. Dresden.
1851. Die Bryozoen der Maestrichter Kreidebildung. Naturwissensch. Von Fischer in Cassel.

Rev. THOMAS HINCKS.

1880. British Marine Polyzoa. London: John Van Voorst, two vols.—one text, the other plates.
1879.–1884. Various Papers and Contributions to General History of the Polyzoa: Annals and Mag. Nat. History, vols. issued during these years.—Treat chiefly of Recent species, but contain references to Fossil also.

P. H. MACGILLIVRAY, M.A., M.R.C.S.

1860. Notes on the Cheilostomatous Polyzoa of Victoria, and other parts of Australia. 'Trans. Phil. Institute Victoria' vol. iv. part ii., pp. 159–168. plates 2, 3.

1860. On two New Genera of Polyzoa. 'Trans. Roy. Soc. of Victoria.' These are DIPLOPORA = *Membranipora*, and DENSIPORA CORRUGATA = *Heteropora cervicornis*, D'Orb and Waters.

1881. ? On some New Species of Catenicella and Dictyopora; and on Urceolipora, a New Genus of Polyzoa. 'Trans. Roy. Soc. Victoria.' I refer to these papers because it will be possible to identify the recent with fossil species of Australian Polyzoa.

WILLIAM LONSDALE.

1845. Account of twenty-six species of Polyparia, obtained from the Eocene Tertiary Formation of North America. 'Quart. Jour. Geol. Soc.' vol. i. pp. 509–533. Seventeen engravings. Five Corals and eleven Polyzoa.

" Account of six species of Polyparia, obtained from Timber Creek, New Jersey. Five species of Polyzoa (Cretaceous), *Op. cit.* vol. i. pp. 65–75. Six engravings.

" Account of ten species of Polyparia obtained from the Miocene Tert. Formations of North America. *Op. cit.* vol. i. pp. 495–509. Ten engravings. Seven species are Polyzoa.

1850. Descriptions of Polyzoa in Dixon's 'Fossils of Sussex.'

S. G. MORTON.

1834. Synopsis of the Organic Remains of the Cretaceous Group of the United States. This book is referred to both by Lonsdale and Messrs. Gabb & Horn, in their descriptions of American Cretaceous Polyzoa.

Dr. A. MANZONI.

1869. Briozoi pliocenici italiani. Four contributions on Italian Pliocene Bryozoa, in which the author describes seventy-seven species and gives figures of many. Sitz. der K. Akad. d. Wissensch.

1871. Supplemento alla dei Briozoi Medit. Pp. 1–10. Three plates. *Op. cit.*

1875. I Briozoi del pliocene antico di Castrocaro. (Bryozoa of the Older Pliocene of Castrocaro, Bologna). This work is, I believe, now out of print. Pp. 64. Seven plates, 4to.

1877. I Briozoi Fossili del Miocene d' Austria ed Ungheria. Parte ii. Celleporidæ, Escharidæ, Vincularidæ, Selenaridæ. (Miocene Bryozoa, Austria and Hungary). Denkschr. K. Ak. Wiss. Wien, bd. xxxvii. abth. 2, pp. 49–78. Seventeen plates.

1878.[1] Fossil Bryozoa of Aust. and Hungary. Part III. Cyclostomata. A continuation of the work of Reuss, which forms the first of this series. *Op. cit. id.*, bd. xxxviii. pp. 1–24. Plates i.–xviii.

" 'Bryozoaries du Pliocène de l'Ile de Rhodes.' Mémoires de la Société Géolog. de France. Paris.

OTTOMAR NOVÄK.

1877. Ćretaceous Bryozoa of Bohemia (Beitrag zur Kenntniss der Bryozoen, &c). Denkschr. K. Ak. Wiss. Wien, bd. xxxvii. abth. ii. pp. 72–126. Ten plates. 'Geological Record,' 1878. Pub. 1882.

D'ORBIGNY.

1839. Voyage dans l'Amérique Mérid. vol. iv.; plate, Zoophytes.

1840.–1853. Paléontologie Française, Terr. Crétacés, v.

1851. Zoological Researches, &c.

Dr. A. E. REUSS.

1845–6. Die Versteinerungen der Böhmischen Kreide-Formation.

1847. Fossilen-Polyparien des Wiener Tertiarbeckens. 4to, Wien.

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[1] Of this work I seem not to have furnished any account. See *ante*, brief note from *Geol. Record.*

Professor RITTER VON REUSS.

1874. Die fossilen Bryozoen, &c (Fossil Bryozoa of the Austro-Hungarian Miocene). Sitzb. K. Ak. Wiss. Math. Naturw. Classe, abth. i. bd. lxviii. hefte 3–5, pp. 219–222. A brief notice of memoir which was to appear in the Denkschriften.

„ Paläontologische Studien. (Palæontology of the Older Alpine Tertiaries.)

„ Miocene Bryozoa of Austro-Hungary, Part I. Denkschr. K. Ak. Wiss. bd. abth. i. pp. 141–190 (plates 1 to 12). Describes ninety-five species, of which forty-one are new *Lepraliæ* and two are new *Membraniporæ*. (This work was completed by Dr. Manzoni, to whose name reference can now be made.)

FRIEDRICH ADOLPH ROEMER.

1863. Die Polyparien des Norddeutschen Tertiar-Gebirges. Abdruck aus Palæontographica. Cassel, Verlag von Fischer.

Captain CHARLES STURT.

1833. Two Expeditions into the Interior of South Australia. London, 2 vols. 8vo.; vol. ii. pp. 253, 254 (plate 3).

Tertiary Polyzoa in Australia were first collected by Sturt; but 'the reference of his specimens to species at that time known as European . . . will not, I think, stand.'—'Synopsis,' R. Etheridge, jun.

Dr. STOLICZKA.

1864? Austrian Novara Expeditions to Australia. In one of the vols. Dr. Stoliczka describes 'Fossile Bryozoen aus dem Tertiaren Grünsandstein der Orakei Bay, Auckland,' pp. 87–158.

A. WILLIAM WATERS, F.G.S.

1877. Remarks on the Recent Geology of Italy. 'Transactions of the Manchester Geological Society,' 1877. Paper read June 26.

In this paper Mr. Waters gives some account of the Bryozoa Limestone of Calabria, with lists and range of species. No descriptions or plates.

1878. On Bryozoa. 'Proceedings of the Literary and Phil. Soc.' vol. xvii. No. 10, 1877 and 1878; Manchester Micro. and Nat. Hist. Soc. Paper read March 1878.

In this paper Mr. Waters treats of the structure of the Polyzoa, more particularly of the character of the cell and the minute details in connection with its structure, for the purpose of comparison and study of fossil species.

1878. Bryozoa (Polyzoa) from the Pliocene of Bruccoli (Sicily). 'Proceed. Manchester Geol. Soc.' Paper read May 1878.

In the Sicilian deposits the débris closely resembles that of the Crag. From the Bruccoli bed Mr. Waters describes forty-three species of Polyzoa —thirty-two species of *Cheilostomata* and eleven of *Cyclostomata*. One plate of illustrations.

1878. On the Use of the Opercula in the determination of the Cheilostomatous Bryozoa. 'Proceedings. Lit. and Phil. Soc.' vol. xviii. No. 2, Sessions 1878–9. Paper read Oct. 1878. One plate, thirty-seven figures.

1879. Bryozoa (Polyzoa) of the Bay of Naples. 'Ann. Mag. Nat. History,' ser. v. vol. iii. 1879, Jan., plates viii. to xi.; Feb. 1879, plates xii. to xv.; March, 1879, plates in previous parts; April, 1879, 'Cyclostomata' plates xxiii., xxiv.

Professor G. SEQUENZA.

1879–80. 'Bryozoa,' in his work entitled 'Le formazioni terziarie nelle provincia di Reggio.' Ten of the species described as new by the Professor critically revised, and the new names are replaced by old and well-known forms, by Rev. T. Hincks. 'Ann. Mag. Nat. Hist.' April 1884.

In this series of papers Mr. Waters not only refers his species to recent types, but identifies some of the Bay of Naples Polyzoa as recurrent species which date back to Miocene and Eocene times, and some few to the Chalk. This is a valuable contribution to the history not only of recent but of Fossil Tertiary species.

1880. On the terms 'Bryozoa' and 'Polyzoa.' 'Ann. Mag. Nat. Hist.' Jan. 1880.
1879? On the occurrence of Recent Heteropora. 'Journ. Roy. Micr. Soc.' Paper read May 1879.

In this paper Mr. Waters makes some reference to the zoological position of Heteropora, and refers D'Orbigny's *Plethopora cervicornis*, D'Orb., to Heteropora.

1881. On Fossil Cheilostomatous Bryozoa from South-West Victoria, Australia. Plates xiv., xviii. 'Quart. Jour. Geol. Soc.' vol. xxxvii. p. 309.

In this paper Mr. Waters describes seventy-two species or varieties of Polyzoa, many of which are new. As the whole of the species described may be found included in the lists in the first part of the present Report, it will not be considered as any slight to the author in only mentioning the titles now.

1882. On Fossil Cheil. Bry. from Mount Gambier, South Australia, 'Quart. Jour. Geol. Soc.' vol. xxxviii. p. 257, plates vii. to ix.
" On Cheilostomatous Bryozoa from Bairnsdale (Gippsland), 'Quart. Jour. Geol. Soc.' ibid. p. 502.
1883. Fossil Cheilostomatous Bryozoa from Muddy Creek, Victoria, &c., 'Quart. Jour. Geol. Soc.' vol. xxxix. p. 423, pl. xii.

In this paper Mr. Waters gives diagrams of the 'globolus' of *Catenicella*, with a new nomenclature of the parts of the *zoœcia* of species—a valuable addition to structural knowledge of these peculiar forms, and will help in the placement of the group. It is only recently that Fossil *Catenicella* has been discovered.

H. WATTS.

1865. On Fossil Polyzoa. 'Trans. Roy. Soc. of Victoria,' vol. vi. pp. 82–84.

C. S. WILKINSON, F.G.S.

1864. Report on the Cape Otway District. Pp. 21–28.

Reports of the Director of the Geological Survey of Victoria, containing references to Polyzoa. As the reports contain very meagre references to fossil Polyzoa, it seems to be useless to multiply names of papers, &c. Mr. Robert Etheridge's (jun.) 'Synopsis,' referred to under his name, contains ample references to, I believe, every important paper, including and in addition to the Australian papers already given.

Rev. J. E. TENISON WOODS.

1859. Remarks on a Tertiary Deposit in South Australia. 'Trans. Phil. Institute, Victoria,' vol. iii.
1860. On the Tertiary Deposits of Portland Bay, Victoria. *Op. cit.* vol. iv. plate ii. pp. 169–172. In both these papers the author refers to Polyzoa.
" On Some Tertiary Rocks in the Colony of S. Australia. 'Quart. Jour. Geol. Soc.' London, vol. xvi. pp. 253–261. As an appendix to this work Mr. George Busk furnished a list of Fossil Polyzoa; but as there were no descriptions, and as the names were in MS., but very few have been retained by Mr. Waters.

1862. Geological Observations in S. Australia. London, 1863, 8vo. In this work Polyzoa are referred to—fifteen genera and thirty-seven species.
1865. On some Tertiary Deposits in the Colony of Victoria, 'Quart. Jour. Geol. Soc.'
" On some Tertiary Foss. in S. Australia. 'Trans. Roy. Soc. of Victoria,' vol. vi. pp. 3–6 (plate). Both of these papers contain references to Polyzoa.
1877. On some Tertiary Australian Polyzoa. 'Journ. Roy. Soc. New South Wales,' vol. x. p. 147.

SEARLES WOOD.

1850. Descriptive Catalogue of the Zoophytes of the Crag. 'Ann. Mag. Nat. Hist.' xiii. p. 10, &c.

S. WOODWARD.

1833. Outlines of the Geology of Norfolk. 8vo, Norwich. Mentions a few species of Polyzoa.

Twelfth Report of the Committee, consisting of Professors J. PRESTWICH, W. BOYD DAWKINS, T. MCK. HUGHES, *and* T. G. BONNEY, Dr. H. W. CROSSKEY (*Secretary*), Dr. DEANE, *and* Messrs. C. E. DE RANCE, H. G. FORDHAM, J. E. LEE, D. MACKINTOSH, W. PENGELLY, J. PLANT, *and* R. H. TIDDEMAN, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.*

THIS Committee is continuing its researches into the distribution, position, and general characteristics of the Erratic Blocks of England, Wales, and Ireland, and is preparing a connected account of the general results obtained, which it hopes to be able to submit at an early meeting of the Association.

Meanwhile, the following details respecting newly observed erratic blocks are recorded.

Essex: Newport.—Mr. George Linney, of Saffron Walden, has furnished an account of a large erratic now standing on the high road from Cambridge to Bishop's Stortford, about 225 yards south of the entrance to the Sholgrove demesne, on the side nearest to Newport, and about a mile from Audley End station.

The dimensions above ground are, height 6 ft.; width, at top 3 ft. 6 in., at base 6 ft.; thickness 2 ft.

The general shape is irregular, but the sides are nearly flat. Height above the sea-level about 180 ft.

It is composed of millstone grit. This boulder has no local history, except that a vague tradition exists that it was placed in its present position as a mark for a Lepers' Hospital, which was done away with by Henry VIII.

Warwickshire.—Mr. Fred. Martin has drawn up the subjoined account of erratic blocks which have been exposed during the process of enlarging the West Suburban Railway, which runs from New Street, Birmingham, through Edgbaston to King's Norton, a distance of about $5\frac{1}{2}$ miles.

The cuttings generally are through drift, composed of varying proportions of sand, clay, and gravel, resting on a fairly regular surface of the New Red Sandstone rock of the district. Except near King's Norton, this drift, so far as it has been exposed by these excavations, is entirely free from erratic blocks, the largest stones not averaging more than 3 in. or 4 in. diameter.

At a point on the railway near the village of Stirchley, about 4½ miles from Birmingham, the drift is composed of a tenacious marly clay unstratified, and with very sparsely scattered Bunter pebbles. A few erratic blocks (presently to be catalogued), averaging in size about 1 ft. 6 in. × 1 ft. × 1 ft., were found, mostly of a felsitic rock.

About 50 yards to the south of this point, the nature of the drift changes to a dark red clay with angular gravel, which gravel consists mostly of fragments of broken-up slate. This angular gravel overlies a dark red clayish gravel made up of Bunter pebbles, but having no angular fragments.

Below these gravels is a band of pale-coloured loose sand, about 2 feet thick, and much contorted.

Below this again is a sandy gravelly clay resting immediately upon a green shale or marl, the basal bed of the Keuper. All these gravels contain erratic blocks in large numbers.

About a quarter of a mile from this point a few erratic blocks have been obtained from a matrix of very sandy clay, interstratified with beds, about two or three inches thick, of a more gravelly clay, and containing rounded pebbles, and angular fragments of coal shale, carboniferous grit, &c., besides small blocks of the basal rock of the Keuper above mentioned.

At this point in a dell at the side of the railway is a large felsitic boulder (No. 2 in the subjoined list), measuring 6 ft. 3 in. × 4 ft. 9 in. × 3 ft. 9 in.: only about one-third of it is visible above ground, the rest being buried in clay. The ground was dug away from it in order that a photograph might be taken, but was subsequently put back again.

Near the junction of the new railway with the main line to Gloucester is another large boulder (No. 1 in subjoined list), measuring 9 ft. × 8 ft. × 3 ft., and is at the time of writing this paper lying in its original position, about 9 ft. below the surface.

The earth being removed from round it to a depth of 6 ft., a very good photograph was obtained.

The erratic blocks found in these gravels vary in cubic capacity from 1 to 216 cubic ft., and include shales, slates, ashes, felsites, pure quartz, carboniferous sandstone and grit, though the majority of them are felsitic, and derived from the neighbourhood of the Arenig and Berwyn Hills of North Wales.

A few of these blocks, more especially those derived from slate rocks, retain ice-markings and smoothing.

The majority of them, however, have rough surfaces with no ice-markings of any kind.

Subjoined is a list of the chief erratic blocks found in the above Stirchley gravels, which have been examined and identified by Dr. Lapworth.

1. Rough, bluish-green, felspathic ash, with crystals of felspar; no striæ, no smoothing. Size, 9 ft. × 8 ft. × 3 ft.

2. Rough, amygdaloidal or brecciated green felstone; no smoothing, no striæ. Size, 4 ft. 9 in. × 6 ft. 3 in. × 3 ft. 9 in.

3. Coarse felsitic ash; no striæ, no smoothing. Size, 4 ft. 6 in. × 4 ft. × 2 ft. 6 in.

4. Pale felspathic rock, probably an altered ash or fault rock from Arenig; no striæ, no smoothing. Size, 3 ft. × 2 ft. × 1 ft. 6 in.

5. Very coarse streaked volcanic ash, with crystals of felspar; no striæ, no smoothing. Size, 3 ft. 6 in. × 3 ft. × 2 ft.

6. Dense felspathic ash with crystals of orthoclase; no striæ, no smoothing. Size, 3 ft. × 2 ft. × 2 ft.

7. Altered felspathic ash with crystals of orthoclase; no striæ, no markings. Size, 2 ft. 6 in. × 2 ft. × 1 ft. 9 in.

8. Ironstained greenish grit with enclosures of shale. Size, 2 ft. × 1 ft. 6 in. × 1 ft.

9. Rough felspathic rock with enclosures of grey felspar; no striæ, no smoothing. Size, 2 ft. 6 in. × 2 ft. × 1 ft. 6 in.

10. Felspathic ash; altered, from Arenig; no striæ, no smoothing. Size, 1 ft. 6 in. × 1 ft. 6 in. × 1 ft.

11. Well-bedded striped mudstone flag, probably of Silurian age. Size, 1 ft. 6 in. × 1 ft. × 3 in.

12. Fragments of slate showing ice-groovings and smoothing; probably Silurian blue mudstone from the Berwyn Hills.

Report upon National Geological Surveys: Part I., Europe. By W. Topley, *F.G.S., Assoc. Inst. C.E., Geological Survey of England and Wales.*

Introduction.

In the following pages a brief account is given of the organisation and publications of the chief Geological Surveys [1] in Europe. The statements are taken from official sources, or from an inspection of the publications.

Information has been kindly supplied by the directors of the following surveys—Austro-Hungary, Bavaria, Belgium, Italy, Norway, Portugal, Saxony, Spain, Sweden, Switzerland; most of these have since corrected the proofs of the parts of this Report referring to their respective surveys.[2]

In the preparation of this report my colleague Mr. W. H. Dalton has given me much assistance; my thanks are also due to Professor G. A. Lebour, Mr. W. Rupert Jones, and Mr. F. W. Rudler.

The libraries of the Geological Survey (Museum of Practical Geology), and of the Geological and Geographical Societies, contain a large collection of the maps and other publications of the various surveys (see the 'Catalogues' of those libraries). The more important publications are noted as they appear in the 'Quarterly Journal of the Geological Society' (November number of each year), the 'Proceedings of the Royal Geographical Society,' and in 'Petermann's Mittheilungen' (Gotha). The 'Geological Record' gives descriptions of maps published in and since 1874.

The official title of the Survey is first given, with the place of the head office, which is also the place of publication unless otherwise stated.

[1] The exact equivalent of the English term '*Survey*' is not used on the Continent; it is that of *Committee*, *Commission*, *Inquiry*, *Institute*, or *Service*.

[2] Some corrections and additions, including those thus supplied, have been made since the Report was read at Montreal.

The mode of issue varies greatly, and therefore the exact titles of the publications are given, as far as possible.

For information upon Topographical Surveys reference may be made to the 'Notes on the Government Surveys of the Principal Countries of the World,' prepared at the Intelligence Branch of the War Office, London, and published in 1883 (price 6*s*.). This gives the scales of all the chief maps; plates, with descriptions, of the various signs employed; full tables of all measures of length and surface, with their English equivalents. Brief mention is sometimes made of the Geological Surveys.

In the following pages the natural scale of maps is given, this being the method almost universally adopted on the Continent. The following table gives the equivalents, in English inches, of the scales referred to:—

Natural Scale.	Inches to one Mile.	Countries.
1 : 10,000	6·336	Upper Silesia, Italy (part).
1 : 10,560	6·000	United Kingdom (part).
1 : 20,000	3·168	Belgium.
1 : 25,000	2·534	Prussia, Saxony, Alsace-Lorraine, Italy (part)
1 : 50,000	1·267	Sweden (part), Italy (part).
1 : 63,360	1·000	United Kingdom (part).
1 : 75,000	·845	Austria and Hungary.
1 : 80,000	·792	France.
1 : 100,000	·633	Italy, Norway, Switzerland, Bavaria.
1 : 144,000	·440	Austria and Hungary.
1 : 200,000	·317	Netherlands, Finland, Sweden (part).
1 : 400,000	·159	Spain.
1 : 420,000	·150	Russia.

The meridian adopted for the maps varies much.[1] As a rule it is that of the capital of the country. The exceptions to this are the maps of Germany and some of Norway, where the meridian is Ferro, and Switzerland, where it is Paris. Paris has been taken as the meridian for the map of Europe, now being prepared by a committee of the International Geological Congress; scale 1 : 1,500,000. This map, in 49 sheets, will be based upon those of the Geological Surveys hereafter described.

The International Geodetic Congress at Rome in 1883 recommended the adoption of Greenwich as the universal meridian. The Congress met at Washington in October 1884, when the provisional resolution passed at Rome was confirmed.

On the Continent a large number of official and semi-official publications have been made by Government mining engineers and others; but these are not here included unless they form part of a systematic survey or give the main results of such survey.

The earliest detailed survey is that of the United Kingdom, 1832. In all its essential characters this is now much the same as when left by its founder, Sir H. de la Beche, and probably no other survey yet rivals it in the variety and completeness of its publications. Many of the more important Continental surveys have been commenced during the last 15 years.

Much difficulty has been felt in deciding what small general maps should be mentioned. The Catalogues already referred to give the titles of many of them. For the most part those only are here mentioned

[1] The relations of the Meridians to that of Greenwich which are given in this Report, are taken from the *Notes on Government Surveys* referred to above.

which are official, or which are reductions of official maps; and of these the notices are necessarily incomplete.

Some interesting results come out from this investigation as regards the relative amount of work done by private and official geologists. In England the foundations of the survey, and in fact of all detailed field geology, were laid by private workers, and a very large proportion of English geological literature has always come from them. On the Continent this has rarely been so; nearly all the surveys are directly due to the Governments, and much of the geological literature comes from those connected with the surveys, or from official mining engineers. There, also, many professors of geology are connected with the surveys; this is not now the case in England, although many of its professors have at one time served on the staff.

The publications of the English Survey are confined to questions relating to its work and progress; but this is not always the case abroad. The staffs of the Austrian and Prussian Surveys have always been active in working at the geology of districts outside their own special areas, which are by no means small. The best work of late years relating to the geology of Turkey and Greece has been done by officers of the Austrian Survey.

Alsace-Lorraine.

Commission für die Geologische Landes-Untersuchung von Elsass-Lothringen (Strasburg).

The director is E. Cohen. The map—'Geologische Specialkarte von Elsass-Lothringen,' is on the scale of 1 : 25,000.

The publications are 'Abhandlungen,' with atlas, dating from 1875; the first volume contains a Bibliography of the geology of Alsace-Lorraine, by E. W. Benecke and H. Rosenbusch, pp. 77.

A map of the environs of Strasburg—'Geologische Karte der Umgegend von Strassburg,' by E. Schumacher, 1 : 25,000, 1883—gives special agricultural information, like the maps near Berlin (see p. 230).

Austro-Hungary.

Kaiserlich-Königliche Geologische Reichsanstalt (Vienna).

This Survey was established in 1849, with W. von Haidinger as director; he was succeeded in 1867 by F. Ritter von Hauer.[1] Dionys Stur has been vice-director since 1877.

The field work of the survey, which is mostly done on the scale of 1 : 25,000, is at present divided into four sections:—(1) under G. Stache, in Tirol; (2) under E. von Mojsisovics, in N. Styria; (3) under C. M. Paul, in the Galician Carpathians; (4) under E. Tietze, in the western and north-western parts. There is a large staff of assistant geologists and others.

There are in all about twenty-three official topographical maps of Austro-Hungary or of parts of it, on scales from 1 : 12,500 downwards. These are all being absorbed in the 'Neue Special-Karte,' scale 1 : 75,000, on which the geological information is published; the complete map

[1] Resigned early in 1885.

will be in 715 sheets, of which 270 are published with the geology, dating from 1870.

The meridian is Ferro, 18° 9′ W. of Greenwich. The heights are given in metres; there are contour-lines at intervals of 50 metres. The sheets are not quite rectangular, the right and left edges being always meridian lines, 30′ apart.[1]

The maps are denoted by a double system of numbering—Vertical (*Colonne*) (I to XXXV) and Horizontal (*Zone*), 1 to 37.

The 270 sheets now published are thus grouped:—

Upper and Lower Austria	38 sheets
Moravia and Silesia	30 "
Tyrol	37 "
Illyria, Styria, and Salzburg	45 "
Galicia and Bukowina	101 "
Hungary	12 "
Bohemia	7 "
	270 "

The prices vary from 1 to 8 fl. (2 to 16 sh.).

A smaller map, scale 1 : 144,000, is also published, of which 158 sheets are issued. This map is divided into various provinces. The sheets now published are as follows, the prices varying from 1 to 6 fl.:

Austria above and below the Ems	29 sheets
Salzburg	13 "
Styria and Illyria	36 "
Bohemia	38 "
Hungary	42 "
	158 "

The following general maps are issued:—

Hungary	18 sheets
Lombardy and Venetia	4 "
Transylvania	4 "
Banat	4 "
Slavonia and the Frontier	1 "
Bosnia and Herzegovina	7 "
Dalmatia	2 "

The publications of the survey, other than maps, are:—

'Abhandlungen der k. k. geol. Reich.', of which ten volumes have appeared, dating from 1852, price, 23 to 70 fl.; some cf these contain maps on a large scale; 'Jahrbuch,' from 1850; 'Verhandlungen,' from 1867. A 'General-Register' of the 'Jahrbuch' is published.

Numerous memoirs, stratigraphical and palæontological, from the 'Abhandlungen' are separately issued.

Several semi-official memoirs, with large maps or special maps, are published by officers of the survey, the most important being:—

V. Mojsisovics, 'Dolomitriffe von Südtirol und Venetien,' 2 vols. 1879, price, 19 fl. Map, in 6 sheets (1 : 75,000), separately issued.

V. Mojsisovics, Tietze, and Bittner, 'Grundlinien der Geologie von Bosnien-Hercegovina, 1880, price, 12 fl. Map, 1 : 576,000.

V. Hauer, 'Geol. Uebersichtskarte der österr.-ungar. Monarchie,' 12 sheets, 1 : 576,000; 45 fl.

V. Hauer, smaller map of the same, 1 : 2,016,000, 4th ed. 1884; 6 fl.

[1] This most convenient arrangement is also adopted in the maps of Prussia and Saxony.

Bohemia.—This is a section of the Austrian Survey, under the control of Anton Fritsch; the maps are those of the 'Neue Special-Karte,' scale 1 : 75,000, referred to above. The text is included, as 'Geologische Abtheilung,' in 'Archiv der Naturw. Landesdurchforschung von Böhmen,' with plates and extra maps on various scales.

Hungary.—This Survey was established as a section of the Austrian Survey in 1868, but was soon after made a distinct body under the title 'Königliche ungarische geologische Anstalt;' its head-quarters and the place of publication is Budapest. But it is still in connection with the central institution at Vienna, and an abstract of its work appears in the Verhandlung.

The first director was Max von Hantken, who was succeeded in 1882 by Johann Böckh. The survey is done on the scale of 1 : 28,800.

The publications date from 1871. These are in Hungarian, but a German version is given in 'Mittheilungen, aus dem Jahrb. k. u. geol. Anstalt,' dating from 1872. About 22 sheets of the map are published.

Bavaria.

Bureau der Geognostischen Untersuchung des Königreichs Bayern (Munich).

The survey was commenced in 1851, under C. W. von Gümbel, the present director. The publications date from 1858; they have been issued at Gotha, but in future will be published at Cassel.

The field work is done on various scales, from 1 : 5,000 to 1 : 25,000; the publication is usually on the scale of 1 : 100,000, but in special cases 1 : 50,000.

Two meridians are used on the maps—Ferro (18° 9′ W. of Greenwich) and Munich (11° 36′ E. of Greenwich). The maps are not contoured.

Explanations of separate sheets are not published, but the maps are grouped, for purposes of explanation, as follows:—

1 'Geognostische Beschreibung des bayerischen Alpengebirges und seines Vorlandes' (southern frontier), 5 maps. 96 marks. 1861.

2. 'Geog. Besch. des ostbayerischen Grenzgebirges' (Bayreuth, Ratisbon, Passau), 5 maps. 108 marks. 1868.

3. 'Geog. Besch. des Fichtelgebirges und Frankenwaldes' (N. of Bayreuth), 2 maps. 70 marks. 1879.

There is no official general map; but the director has published the following, without text:—'Geog. Uebersichts-Karte des Königreichs Bayern,' Munich, 1858, 1 : 500,000. Price 17·20 marks.

Belgium.

Service de la Carte Géologique de la Belgique (Brussels).

This survey is conducted as a part of the 'Musée Royal d'Histoire Naturelle de Belgique' (Brussels). The work is executed under the 'Commission de Contrôle de la Carte Géologique de la Belgique,' composed of five members of the Royal Academy of Belgium, with M. J. Stas as president. The surveying work is done under the direction of Ed. Dupont, with three 'conservateurs' and eleven assistants. A peculiar feature of this survey is that each main division of the geological series is traced out completely by one man, so that an index map of progress is also a geological index map.

The map is on the scale of 1 : 20,000, with contours at 5 metres interval on the left bank of the Meuse, and at 10 metres on the right bank. The map is in 72 main divisions ('planchettes'); each containing, when complete, 8 sheets ('feuilles'); in all there will be 430 sheets. The meridian is Paris, 2° 20′ E. of Greenwich. Each sheet is accompanied by 'Texte explicatif.'

The maps give the nature of the soil, and note, by dark shades of colour, the actual areas at which solid rock is exposed. Six sheets are published, dated 1882 and 1883.

The memoirs issued by the Musée Royal (to which the Survey is now attached) are in two forms, dating from 1877 :—

'Annales du Musée R. d'Hist. Nat. de Belgique,' in fol., each volume with atlas; and 'Bulletin,' in 8vo. The former is divided into four series —palæontology, lithology, stratigraphy, existing fauna.

Before the establishment of the existing Survey another had been in existence, conducted by a Committee of which M. Jochams was president. It was founded, in 1878, under the control of the 'Ministère de l'intérieur;' this is stated on each publication, which may thus be distinguished from the publications of the existing Survey, the latter being headed 'par ordre du Gouvernement.'

About 20 maps were published (1879–81), each with text; 18 were by O. v. Ertborn and P. Cogels. Both Surveys have used the same topographical map.

A general map—' Carte Géologique de la Belgique, exécutée par ordre du Gouvernement,' scale 1 : 160,000—was prepared by André Dumont from 1836 to 1854, and was published in 1854. A new issue of this was made in 1877, in two editions—soil and rock, price 40 francs each map. This map was accompanied by Memoirs. Those on the 'Terrains ardennais et rhénan' were published by Dumont in the *Mém. Acad. Roy. Belgique*, 1847 and 1848; those on the 'Terrains crétacés et tertiaires,' prepared by Dumont and edited by M. Mourlon, are published in four vols. 8vo. 1878–1882.

A reduction (not official) of Dumont's map, scale 1 : 380,000, showing the beds below the Hesbayen and Campinien, was published in 1877 by Lelorrain and E. Henry.

FINLAND.

Finlands Geologiska Undersökning (*Suomenmaan Geologillinen Tutkimus*) (Helsingfors).

This survey was commenced in 1865, under the Department of the Administration of Mines, on the scale of 1 : 200,000; the director being K. Ad. Moberg.

The publication commenced in 1879; five sheets, in the neighbourhood of Helsingfors, were issued up to 1882. There are descriptions ('Beskrifning') to the sheets. All the superficial deposits are shown.

The explanations on the maps are given in Finnish and Swedish; the 'Beskrifning' is in Swedish.

The meridian is Helsingfors, 25° 12′ E. of Greenwich.

France.

Service de la Carte Géologique détaillée de la France (Paris).

The origin of this survey may be traced to the Paris Exhibition of 1855, when, under the direction of Dufrénoy and Élie de Beaumont, twenty maps (scale 1 : 80,000), were coloured geologically in MS. and exhibited. These maps, with others, amounting in all to about sixty, all in the N. and N.W. of France, were again presented at the Paris Exhibition of 1867.

The recognition of the value of such maps, and the fact that similar surveys were in progress in neighbouring countries, led to the establishment of the existing geological survey in 1868, with Élie de Beaumont as director. On his death, in 1875, M. Jacquot became director.

The map employed is the 'Carte Topographique de l'État-Major,' scale 1 : 80,000. The meridian is Paris, 2° 20′ E. of Greenwich. The map of France is in 258 sheets; Corsica in sheets, 259–267. It has hill-shading without contours; heights in metres.

Each map is accompanied by an 'Explication' printed on one side only, to be attached to the map if desired; some sheets also by plates containing longitudinal and vertical sections and photographs.

A very elaborate system of signs has been employed on the maps, for distinguishing minute varieties of rocks, soils, ores, mineral springs, &c. The number of these signs is 1,113. In addition to these many subordinate signs have been devised, further explaining or modifying the others.[1]

As the work progresses it will be reduced and published on the scale of 1 : 320,000; this will be in 32 sheets; Corsica in sheet 33. Each sheet of this map will include 16 sheets of the larger scale.

The publication of the maps commenced in 1873, with sheet 48, Paris; the explanation of this being 'Cahier I.' About 67 sheets are issued (to February 1885), chiefly in the north.

In addition to the explanations of sheets there are 'Mémoires'; No. 1, 'Pays de Bray,' by De Lapparent, was published in 1873; No. 2, 'Mineralogie Micrographique,' by Fouqué and Levy, in 1879. There are also special monographs on the coalfields—Brioude and Brassac, Langeac, and the Loire.

The foregoing statements refer only to the existing survey, but there were official publications of earlier date.[2] In 1822, incited thereto

[1] All these signs, &c., are fully explained in pamphlets issued in 1874, 'Généralités' A, B, C, and D. See also De Chancourtois, *Ann. Mines*, ser. 7, t. v. 1878.

[2] A notice of the various geological maps of France was given, by Professor G. A. Lebour, in the *Geographical Magazine*, vol. iii. p. 47, 1876.

by the publication of Greenough's 'Geological Map of England and Wales' (1819–20), a survey was commenced by Dufrénoy and Élie de Beaumont, under the direction of Brochant de Villiers. From 1822 to 1825 the surveyors were studying field geology in England. In 1825 the work was commenced in France, De Beaumont taking the east, Dufrénoy the west. There were two assistants, and the survey was completed in 1830.

The map, 'Carte Géologique de la France,' is in 6 sheets, scale 1 : 500,000. It was published in 1840–42; the two volumes of 'Explication' in 1841 and 1848.

A reduction of this map ('Tableau d'Assemblage'), scale 1 : 2,000,000, was published in 1841.

There are a large number of maps and memoirs of Departments, of which great use is made by the surveyors. Some are by private geologists, but most are by official mining engineers. These maps are on various scales; some, as that of the Pas de Calais (by Du Souich, 1851) on the full scale of 1 : 80,000.

A Geological Map of France in 48 sheets, scale 1 : 500,000, is in preparation by C. Vasseur and L. Carez.

Italy.

Reale Comitato Geologico d'Italia (Rome).[1]

This survey was commenced in 1868, when the capital was Florence. It was directed by a committee of Professors at Universities and Engineers of Mines. In 1873, when the chief office and place of publication were transferred to Rome, the staff was reorganised; the *Comitato* (with Professor Meneghini as president) retained mainly a consulting power, the real chief of the survey being F. Giordano, the present director. The staff consists of 7 geologists, 3 assistants, and a palæontologist.

The systematic and detailed investigation of the country dates from 1877, and was commenced in Sicily; in 1879 the survey was extended to the Apuan Alps and the Roman Campagna. The scale adopted for the survey is usually 1 : 50,000; areas of special interest, such as those mentioned above, are surveyed on the scale of 1 : 25,000. Recently some surveys have been made on the scale of 1 : 10,000—of Elba, Ischia, and the environs of Rome.

A general map (1 : 1,111,111) was published in 1881: another, on the scale of 1 : 500,000, is now in preparation, Sicily being published (1883).

The systematic publication of the survey map will be on the scale of 1 : 100,000, in 277 sheets, those of Sicily being nearly ready for issue.[2]

Districts of special importance will be published on the scale of 1 : 25,000, with contours; Elba, in two sheets, is now ready.

In the topographical maps prepared by the Italian Government (of which there are 18, on various scales), the meridian is reckoned from Rome (Monte Mario), which is 12° 28′ E. of Greenwich. There is a topographical map, prepared by the Austrian Government, on the scale of 1 : 75,000, in which the meridian is reckoned from Ferro; but this map is not used by the Geological Survey.

[1] For a fuller account of this Survey, see *Nature*, Nov. 24, 1881.

[2] Four sheets, with a sheet of sections, were published at the end of 1884.

The publications comprise the 'Bollettino,' (in 8vo.), dating from 1870, of which fourteen volumes are published; and 'Memorie' (in fol.), dating from 1871, of which two volumes are published. These volumes contain numerous maps, on various scales, and plates of fossils. Many of the authors of papers here published are not connected with the survey; but, as a Geological Society was founded for Italy in 1881, the survey publications will probably in future be more purely official.

Several semi-official maps are issued. Three are by Prof. Capellini, a member of the *Comitato.* These are—the Bolognese Apennines; Leghorn (each 1 : 100,000); Gulf of Spezia (1 : 50,000).

NETHERLANDS.

Commissie voor de Geologische Kaart van Nederland (Haarlem).

An official survey of this country was made by W. C. H. Staring, and published ('Geologische Kaart van Nederland') at Haarlem, in 27 small sheets; 1858–67 with explanation. The scale is 1 : 200,000; the meridian Amsterdam, 4° 55′ E. of Greenwich. The map shows 13 varieties of alluvium, 8 of diluvium, 16 of Pliocene—Eocene, with other rocks down to Devonian.

Another map (? not official) has been published by Kruijder, in six sheets, 1880.

NORWAY.

Geologiske Undersögelse (Christiania).

The geological investigation of this country is in two parts. That of Southern Norway, under the direction of Th. Kjerulf, dates from 1858; that of Northern Norway, under the direction of T. Dahll, dates from 1866, and was completed in 1878. For the former there are two assistants, with extra help during the summer.

The surveying work is done on various scales—for the most part 1 : 100,000, but some 20/, 50/, and 200,000. For the last the meridian is Ferro; for the others it is Christiania, 10° 43′ E. of Greenwich.

The published map of Southern Norway, in rectangular sheets, is on the scale 1 : 100,000, with contours at 100 feet (1 Norwegian foot= 12.35 English inches). Seventeen sheets are published, dating from 1876. These are grouped as follows: Trondhjem and district, 8 sheets; Bergen, 2; Hamar, 2; Christiania and Fredrickstadt, 5. Each sheet is priced kr. 1·60 (1 kr. = 1*s.* 1¼*d.*).

A general map of part of Southern Norway (Diocese of Christiania, Hamar, and Christiansand) was published in 1856–65, by Th. Kjerulf and T. Dahll; scale 1 : 400,000; 10 sheets; with explanatory pamphlet in French; in this the meridian is Ferro.

A general description of Southern Norway with atlas and map ('Geologiske Oversigtskarte,' 1 : 1,000,000), was published by Th. Kjerulf in 1879. (German translation, by Dr. A. Gurlt, in 1880). A map of Northern Norway ('Geologisk Kart over det Nordlige Norge') on the same scale, was published in 1879 by T. Dahll.

There is no regular publication of memoirs and papers of the survey; but they appear in 'Nyt magazin for naturvidenskab,' and in other journals, transactions, and University treatises. The collection made by the survey is at present deposited in the Mineralogical Cabinet of the University of Christiania.

PORTUGAL.[1]

Secção dos Trabalhos Geologicos de Portugal (Lisbon).

This survey was commenced in 1857 (as Commissão Geol. de Portugal). It was reorganised with the existing title in 1869, under the direction of Carlos Ribeiro; he was succeeded, in 1883, by J. F. N. Delgado.

The work is now done on the scale of 1 : 100,000; with occasional enlargements to double this scale. There are contours at intervals of 25 metres. The map will be in 37 sheets, longitude reckoned from Lisbon, 9° 9′ W. of Greenwich. The topographical map is not yet complete, and none of the sheets are published with the geology.

Several memoirs have been published, dating from 1865; and also a general map—'Carta Geologica de Portugal,' by C. Ribeiro and J. F. N. Delgado, scale 1 : 500,000; 1876 (now out of print).

PRUSSIA.

Königliche Geologische Landes-Anstalt und Bergakademie zu Berlin (Berlin).

The publications of this survey date from 1870; the director is W. Hauchecorne.

The map—'Geologische Special-Karte von Preussen und den Thüringischen Staaten' is on the scale of 1 : 25,000; with hill-shading, and contours at intervals of 5 metres.

It is divided into 88 'Grad-Abtheilungen;' each subdivided into 60 'Blättern,' excepting on the frontier and sea-board, where some sheets are absent. Each complete 'Grad-Abtheilung' contains exactly 1° of long. and 1° of lat.; each 'Blatt' contains 10′ of long. and 6′ of lat.; the sheets are therefore not quite rectangular. The longitude is reckoned from Ferro, 18° 9′ W. of Greenwich.

The publication takes place in 'Lieferungen,' each containing from three to nine maps of the same district, though not always in the same 'Grad-Abtheilung.' The 'Lieferungen' vary in price according to the number of maps included, averaging 2 marks per map with its 'Erläuterung.' The maps near Berlin are especially agricultural, minute variations of soil being indicated by signs; these form a special set of maps, in 27 sheets. In the coal districts two editions are issued, one showing the edges of the coal-seams beneath the newer rocks.

[1] The first part of the serial publication of this Survey has just been issued—'*Communicações da Secção dos Trabalhos Geologicos de Portugal*,' tom. 1, fasc. 1, 1885; 8vo. Lisbon. Some of the papers therein contained had been previously printed.

About 26 'Lieferungen' are issued, containing 142 sheets; which, for convenience of reference, may be grouped as follows:—

Berlin, Potsdam, &c.	27
Wettin, Jena, &c.	84
Wiesbaden, Frankfort, &c.	13
Saarbruck, &c.	18
	142

Although all maps fit into the complete system of 'Grad-Abth.' and 'Blatt.' the earlier sheets published have a different set of numbers. The position of each map however, and its relation to the new system of numbering, can be seen from the index-map on each 'Lieferungen.'

A descriptive text ('Erläuterung') is issued with each map.

There are also 'Abhandlungen,' dealing with special districts, palæontology, &c. These date from 1872. They contain numerous plates and maps, the latter being sometimes separately issued.

The 'Jahrbuch,' dating from 1880, contains shorter papers, reports &c.

A reduction of the above-mentioned map—'Geologische Karte der Provinz Preussen,' scale 1 : 100,000, is in course of publication.

Numerous general maps of Germany or of parts of it are published, the most important of which is that of H. von Dechen—'Geologische Karte der Rheinprovinz und der Provinz Westfalen,' in 35 sheets, scale 1 : 80,000. A continuation of this map, on the same scale, being a reduction of the new Prussian survey, is now being prepared. The Wiesbaden sheet (numbered 35) was issued in 1882.

Geological surveys of some German States have been made on the scale of 1 : 50,000, not all directly by the Government; but the great survey above described will probably absorb these, and will re-map the districts on the larger scale.

Amongst these local surveys are the following:—

Baden, made by Zittel and Sandberger.

Hesse. 'Geologische Specialkarte des Grossherzogthums Hessen und der angrenzenden Landesgebiete.' This survey, under the direction of R. Ludwig, is in eighteen sheets, with text. It was made by the 'Mittelrheinischer Geologischer Verein' (Darmstadt), and was published from 1856 to 1872.

Upper Silesia.—A 'Specialkarte der Oberschlesischen Bergrevier.' scale 1 : 10,000, is published by the 'k. Oberbergamt in Breslau'; in 'Lieferungen,' of ten or more sheets. The price of each sheet is 1½ mark.

Roumania.

Biuroului Geologicŭ Românŭ (Buchurest).

Established in 1882, under the direction of Gregoriŭ Stefănescu, for the purpose of providing materials for the International Geological Map of Europe. One Report has been published ('Anuarulŭ Biuroului Geologicŭ,' anulŭ 1882–1883, No. 1, pp. 114, 1884). The rocks contained within the kingdom which are briefly described in this Report, are:—Crystalline Schists (Archæan), Jurassic, Eocene, Miocene, Pliocene and Quaternary. This Report contains descriptions, with analyses, of mineral springs.

Russia.

This survey[1] was commenced in 1882; the director is B. Cheresheff.

The publications comprise Reports in 8vo., and Memoirs in 4to; the latter are illustrated by maps and plates; some of the Memoirs are descriptive of sheets of the maps, others of certain formations in various districts.

The Reports are in Russian only; the Memoirs have title in French ('Mémoires du Comité géologique'), and a translation or prècis in German.

The map is on the scale of 1 : 420,000; to be completed in 154 sheets; 3 sheets are published. The meridian is Pulkowa, 30° 19′ E. of Greenwich.

The map has explanations and title in French:—'Carte géologique générale de la Russie d'Europe.'

A map of the Urals, prepared by the mining engineers, has been published by A. Karpinsky—'Geologische Karte des Ostabhanges des Urals,' 3 sheets, 1884. Scale 1 : 420,000; with enlarged parts of 1 : 210,000.

Saxony.

Königliche Geologische Landesuntersuchung von Sachsen (Leipzig).

This survey dates from 1872; the publications from 1877.[2] The director has from the commencement been Hermann Credner. There are eight assistant geologists.

The scale for mapping and publication is 1 : 25,000; the meridian is Ferro, 18° 9′ W. of Greenwich. The maps—'Geologische Special-Karte des Königreiches Sachsen,' are contoured at intervals of 5 metres on the lowlands and 10 metres on the hills.

The division of the maps, as regards lines of latitude and longitude, is the same as in the Prussian maps. The maps of Saxony have a special numbering of their own, but most of those now published would be contained within Grad-Abth. 58 and 72 of the large Prussian map.

The maps show all the drift-deposits, the soils being sometimes noted and described in detail. In some cases a separate edition, showing only the solid rock, is issued. There are also special issues for certain mining districts.

Much attention is paid to the petrological variations in the crystalline rocks, these being noted by letters and signs.

Thirty-five sheets are published, all in the western part of Saxony, but those in the extreme south-west are not yet issued. The price of each sheet is 2 marks; of the accompanying 'Erläuterung' 1 mark.

A general map has been published by the director, 'Uebersichtskarte des Sächsischen Granulitgebirges und seiner Umgebung,' scale 1 : 100,000, 1884; price, with Erläuterung, 5 marks.

[1] For descriptions of this Survey, and of its publications, see *Nature*, vol. xxix. p. 93; xxx. p. 608; *Geol. Mag.*, dec. iii. vol. i., p. 84, 1884.

[2] Detailed descriptions of the work and publications of the Survey of Saxony have been published by the director (H. Credner) in *Mittheil. des Vereins für Erdkunde zu Leipzig*, 1877 and 1880.

Spain.

Comision del Mapa Geológico de España (Madrid).

The Commission was formed in 1849, with F. Luxan as director. At one time under the Statistical Department, it was, in 1870, placed with that of the Mining Engineers. The existing organisation and systematic publication date from 1873, when the present director, Manuel Fernandez de Castro, was appointed.[1]

The Government topographical map of Spain is on the scale of 1 : 50,000, with contours at 20 metres apart. This was commenced only in 1875, and few sheets are published; it will be completed in about 1,080 sheets; this map is not used by the Geological Survey. Maps published by F. Coello on the scale of 1 : 200,000, are those usually employed in the field work of the survey. The longitude in all is reckoned from Madrid, 3° 41′ W. of Greenwich.

The staff of the survey since 1873 has usually contained six mining engineers and seven or eight assistants.

The maps are issued on the scale of 1 : 400,000, with the reports on each province (see below).

The publications of the survey consist of the 'Boletin,' dating from 1874, and the 'Memorias,' dating from 1873.

Each volume of the 'Memorias' is devoted to the 'Descripción física y geológica' of a single province; mining is added in the title of some, and agriculture in others; these latter being those written by Daniel de Cortázar. The volumes, of from 200 to 400 pages, contain plates of fossils, sections, &c., and also the maps (1 : 400,000) already referred to.

The 'Boletin' contains shorter descriptions of special districts, translations of foreign memoirs on Spanish geology, &c. The maps here are on various scales. Altogether, since 1873, twenty-seven provinces have been described; eleven of them with maps of 1 : 400,000.

Descriptions of some provinces, with maps, were published before the reorganisation of the survey in 1873; some had maps of 1 : 400,000.

The palæontological work of the survey is scattered throughout the various volumes, but this is now being collected and separately issued.

The largest (and in some respects the best) general map of Spain and Portugal is that of De Verneuil and Collomb (1 : 1,500,000), published in Paris in 1864; and a 2nd edition, with text, in 1868 (now out of print). Another map (1 : 2,000,000) was published by F. de Botella, of the Spanish Survey, in 1881. The price of this is 15 francs; there is no text.

At the conclusion of the work of the survey, now approaching, a complete map of Spain, on the scale of 1 : 400,000, will be published, in sixteen sheets; the first sheet will probably be published in 1885.

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[1] A full account of this survey was published for the Mining Exhibition in Madrid, 1883—*Com. Mapa Geol. Españ., su origen, vicisitudes y circunstancias actuales*, with two index maps (*Boletin*, t. x.). An earlier publication—'*Memoria . . . . del Mapa Geol. España.*' 1876, Madrid, pp. 183, gives a full account of the geological literature of Spain (in provinces) and its foreign possessions.

SWEDEN.

Sveriges Geologiska Undersökning (Stockholm).[1]

This survey was commenced in 1858 with Alex. Erdmann as director. In 1869–70 the director was A. E. Törnebohm; he was succeeded in 1871 by the present director, Otto Torell.

The staff consists of twelve geologists, with some additional assistants during the summer months.

The survey is made on two scales; in the more populous districts, 1 : 50,000; in the mountainous districts, 1 : 100,000. In the former case the maps are published on that scale, in the latter the publication is on the scale of 1 : 200,000.

The meridian is Stockholm, 18° 3′ E. of Greenwich. The maps are not contoured, but numerous heights are given in Swedish and Norwegian feet (=12·35 English inches).

The publications date from 1862.

Of the sheets on the 1 : 50,000 scale (Ser. A, a) about 83 are published; these are numbered in the order of publication, irrespective of their relative positions. Each sheet is accompanied by a descriptive 'Beskrifningar.' The prices, for map and description, are 2 kronor) for the full sheets, 1 or $1\frac{1}{2}$ kroner for the coast sheets (1 kroner =1*s*. $1\frac{1}{4}$*d*).

Of the sheets on the scale of 1 : 200,000 (Ser. A, b) ten are published; each with 'Beskrifningar,' price $1\frac{1}{2}$ kroner.

All the maps give the distribution of the superficial deposits, but a few are published with special reference to these and to agriculture. That of the environs of Skottorp, scale 1 : 4,000, shows by signs the nature and composition of the soil in great detail. There are also some special maps referring to mining, &c.; these extra maps are in Ser. B.

A general map of Southern Sweden (south of lat. 59° 45′), on the scale of 1 : 1,000,000, will probably be published with a description during this year (1884).

In addition to the explanations of the maps there are memoirs in Ser. C ('Afhandlingar och uppsatsen') in 8vo. or 4to., with or without plates or atlas. Eighty of these are published, dating from 1863, at various prices up to 8 kroner. They refer to palæontology, stratigraphy, petrology, economic and theoretical geology; most are in Swedish, but a few are in French, German, or English.

A map of the iron district of Central Sweden, though not an official publication of the survey, should be mentioned here. This was prepared, by A. E. Törnebohm, for the Board of Swedish Ironmasters (Jernkontoret). It is in nine sheets (1879–82); each, with description, price 4 kroner. Its title is 'Geologisk Ofversigtskarta öfver Mellersta Sveriges Bergslag;' the scale is 1 : 250,000.

Another similar publication, also by Törnebohm, is 'Geologisk atlas öfver Dannemora Grufvor,' in 17 sheets, with description, 1878.

All the publications referred to are issued at Stockholm.

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[1] This survey is described in *La Carte géologique de la Suède et ses envois à l'Exposition Universelle de Paris en* 1878, *avec une description succincte des formations géologiques de la Suède.* 8vo. Stockholm, pp. 57, 1878.

Switzerland.

Beiträge zur Geologischen Karte der Schweiz (Matériaux pour la Carte Géologique de la Suisse) (Berne).

The present organisation dates from 1859, when the Federal Council offered to the Swiss Natural History Society a grant in aid of colouring geologically the topographical map ('Carte Dufour'). A geological commission of five members was then formed, with Bernhard Studer as president.

The map is in 25 sheets; three of the corner sheets are for title, index, &c. Eighteen sheets are published, those not yet issued being XIII., XIV., and XVIII., all in Central Switzerland.

The scale is 1 : 100,000; the meridian is Paris, 2° 20′ E. of Greenwich.

The text, chiefly in German, but partly in French and Italian according to the locality described, is contained in 'Lieferungen' 1–28, dating from 1862. Some of these describe one or more sheets of the map; others describe special districts, with maps on the scale of 1 : 50,000 or 1 : 25,000.

A general map, 'Carte Géol. de la Suisse,' was published by B. Studer and A. Escher von der Linth in 1853, scale 1 : 350,000; with text—'Geologie der Schweiz,' by B. Studer, 2 vols., 1851–53.

United Kingdom.

Geological Survey of the United Kingdom (London).

The founder of this survey was H. T. De la Beche, who before 1832 had coloured geologically the Ordnance one-inch maps of the South-West of England. In that year a small grant was made by the Government towards the cost of publishing these maps by the Ordnance Survey, but De la Beche also contributed money for the purpose. Subsequently De la Beche was definitely appointed to make a Geological Survey, under the direction of General Colby, then the head of the Ordnance Survey. The first result of this was the publication of the 'Report on the Geology of Devon, Cornwall, and West Somerset,' 1839, with the one-inch maps of the district.

About 1832 other geologists were surveying various districts upon the one-inch maps of the Ordnance Survey—William Smith in many parts,[1] and W. Lonsdale near Bath. H. Maclauchlan and J. R. Wright (both of the Ordnance Survey) mapped the Forest of Dean and the country around Ludlow respectively, W. Logan surveyed part of S. Wales; the information collected by these three observers was incorporated in the official geological maps.

In 1845 the Geological Survey was detached from the Ordnance Survey and was placed under the 'Office of Woods and Works;' in 1854 it became a branch of the 'Department of Science and Art.'

From about the year 1832 some officers of the Ordnance Survey in the N. of Ireland collected geological information, which was completed and published by Captain J. E. Portlock in 1843.

[1] Smith made a Geological map of Somersetshire upon the one-inch scale in 1799.

The geological survey of Ireland was commenced in 1845, with Captain H. James as director, the subsequent directors being T. Oldham, 1845; J. B. Jukes, 1850; E. Hull, 1869.

The survey of Scotland was commenced in 1854, and was made a distinct branch of the geological survey in 1867, with Arch. Geikie as director, succeeded in 1882 by H. H. Howell.

England, the original home of the Survey, was presided over by De la Beche as director till 1845, when A. C. Ramsay became director; he was succeeded in 1872 by H. W. Bristow, now the senior director.

The dates of appointment of the Directors-General are: H. T. De la Beche, 1845; Sir R. I. Murchison, 1855; A. C. Ramsay, 1872; Arch. Geikie, 1881.

Until 1845 the Survey was known as that of *Great Britain*; when the survey of *Ireland* was commenced, the original name was confined to that of Great Britain proper, the entire Survey being called that of the *United Kingdom*. In 1867 the title of Great Britain was discontinued entirely, this Survey being divided into those of *England and Wales* and *Scotland*.

The total number of the staff of the Geological Survey is now fifty-seven, distributed as follows: one Director-General, three Directors, three District Surveyors, fourteen Geologists, twenty-five Assistant Geologists, four Naturalists and Palæontologists, four Fossil Collectors, three General Assistants.

The survey of the greater part of England has been done on the 1-inch Ordnance maps (1 : 63,360). In the North of England the 6-inch maps (1 : 10,560) have been used, and much of the ground has been published on this scale. In the South of Scotland the 6-inch maps have been used; but in the North of Scotland the survey will be mainly on the 1-inch scale. In Ireland the 6-inch maps have always been employed for field work.

The contours on the 6-inch maps are usually at intervals of 100 feet up to 1,000 feet, above that at intervals of 250 feet. In the maps of Yorkshire the contours are more numerous. The old 1-inch maps, on which alone the geology is yet published, have no contours, but heights are marked in some districts.

In Ireland the drift has always been shown upon the 1-inch maps by 'stippling.' Originally no glacial drift was shown upon the English maps; but in 1871 the publication of *drift maps* was commenced, and two editions of many of the maps are now issued—*solid* and *drift*. In the East of England only the drift maps are issued, very little being here known of the solid geology.

At the end of 1883 the field survey of the original 1-inch map of England and Wales was completed; the survey of the drifts of the areas over which these are not yet mapped has been commenced.

In Ireland and Scotland there is only one system of numbering the maps. In England some maps are in *sheets*, some are divided into *quarter-sheets*. In the new maps of the Ordnance Survey the system of dividing into quarter-sheets will be discontinued. The maps and their divisions in the North of England are the same in the old and the new series, the numbering only being different; but in the South of England there is no relation between the boundaries of the old and the new maps.

In addition to the maps there are 'Horizontal Sections,' on the scale (for heights and distances) of six inches to a mile. These are published at 5*s*. each; many have 'Explanations,' price 2*d*. each.

The details of Coal Measures, Cliff Sections, &c., are given on sheets of 'Vertical Sections,' 3*s.* 6*d.* each.

An 'Index Map,' scale four miles to the inch (1 : 253,440) has been published of Wales and the adjacent districts, in six sheets, price 3*s.* 6*d.* each. An Index Map of the whole of England and Wales, upon the same scale, is now in progress.

In all maps of the United Kingdom the meridian is Greenwich.

The publication of the Maps of England dates from about 1839, those of Ireland from 1855, of Scotland from 1859.

The number of maps and sections published is shown in the following table[1]:—

—		England and Wales	Ireland	Scotland	Total
1-inch map (1: 63,360) (sheets or quarter-sheets in England and Wales)	Solid . . . . 183 Drift edition of solid map 49 Drift only . . . 12	244	180	33	457
6-inch maps (1 : 10,560)		216	10	128	354
Horizontal sections		129	30	9	168
Vertical sections		69	1	7	77
Total		658	221	177	1,056

The prices of the 1-inch maps are from 1*s.* 6*d.* to 8*s.* 6*d.* for England (a few detailed drift maps at higher prices); 1*s.* 6*d.* to 3*s.* for Ireland; 4*s.* to 6*s.* for Scotland; of the 6-inch maps, 4*s.* to 6*s.*

The 'Memoirs' of the Geological Survey date from 1845. Four volumes were consecutively numbered; vol. 1 and vol. 2 (in two parts) contain several papers. The other two volumes and all later 'Memoirs' are each confined to one subject or district.

Memoirs or Explanations of sheets of the map have been issued since 1859; those published are—for England, 49; Ireland, 92; Scotland, 17.

British fossils are described in 'Decades' (thirteen published, from 1849) and 'Monographs' (four published, from 1859).

'Mineral Statistics' were published annually from 1853 to 1882; but in 1883 the Mining Record Office, in which these were prepared, was removed to the Home Office, and the statistics are now issued as parts of the Reports of the Inspectors of Mines.

No official general map has been issued by the survey, but the following maps, on scales varying from seven to eleven and a half miles to the inch, have been published by the directors of the respective surveys; they are reductions of survey work to date: British Islands, by A. C. Ramsay, 1878; England and Wales, by A. C. Ramsay, 4th ed. 1879; Ireland, by J. B. Jukes, 1867; Ireland, by E. Hull, 1878; Scotland, by A. Geikie, 1876.

[1] A *Catalogue of the Publications of the Geological Survey of the United Kingdom* to 1884 has been issued, with index maps, pp. 95, price 1*s.*

Report of the Committee, consisting of Messrs. R. B. Grantham, C. E. De Rance, J. B. Redman, W. Topley, W. Whitaker, *and* J. W. Woodall, *with* Major-General Sir A. Clarke, Sir J. N. Douglass, Captain Sir F. O. Evans, Captain J. Parsons, Professor J. Prestwich, Captain W. J. L. Wharton, *and* Messrs. E. Easton, J. S. Valentine *and* L. F. Vernon Harcourt, *appointed for the purpose of inquiring into the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other Material in that Action. Drawn up by* C. E. De Rance *and* W. Topley, *Secretaries.*

The importance of the subject referred to this Committee for investigation is universally admitted, and the urgent need for inquiry is apparent to all who have any acquaintance with the changes which are in progress around our coasts. The subject is a large one, and can only be successfully attacked by many observers, working with a common purpose and upon some uniform plan.

The Committee has been enlarged by the addition of some members who, by official position or special studies, are well able to assist in the work.

In order fully to appreciate the influence, direct or indirect, of human agency in modifying the coast-line, it is necessary to be well acquainted with the natural conditions which prevail in the places referred to. The main features as regards most of the east and south-east coasts of England are well known; but even here there are probably local peculiarities not recorded in published works. Of the west coasts much less is known. It has therefore been thought desirable to ask for information upon many elementary points which, at first sight, do not appear necessary for the inquiry with which this Committee is entrusted.

A shingle-beach is the natural protection of a coast; the erosion of a sea-cliff which has a bank of shingle in front of it is a very slow process. But if the shingle be removed the erosion goes on rapidly. This removal may take place in various ways. Changes in the natural distribution of the shingle may take place, the reasons for which are not always at present understood; upon this point we hope to obtain much information. More often, however, the removal is directly due to artificial causes.

As a rule, the shingle travels along the shore in definite directions. If by any means the shingle is arrested at any one spot, the coast-line beyond that is left more or less bare of shingle. In the majority of cases such arresting of shingle is caused by building out 'groynes,' or by the construction of piers and harbour-mouths which act as large groynes. Ordinary groynes are built for the purpose of stopping the travelling of the shingle at certain places, with the object of preventing the loss of land by coast-erosion at those places. They are often built with a reckless disregard of the consequences which must necessarily follow to the coast thus robbed of its natural supply of shingle. Sometimes, however, the groynes fail in the purpose for which they are intended—by collecting an insufficient amount of shingle, by collecting it in the wrong places, or from other causes. These, again, are points upon which much valuable information may be obtained.

Sometimes the decrease of shingle is due to a quantity being taken away from the beach for ballast, building, road-making, or other purposes.

Solid rocks, or numerous large boulders, occurring between tide-marks, are also important protectors of the coast-line. In some cases these have been removed, and the waves have thus obtained a greater power over the land.

To investigate these various points is the main object of the Committee.

A large amount of information is already in hand, much of which has been supplied by Mr. J. B. Redman, who for many years has devoted special attention to this subject. Mr. R. B. Grantham has also made important contributions respecting parts of the south-eastern coasts.

But this information necessarily consists largely of local details, and it has been thought better to defer the publication of this for another year. Meanwhile the information referring to special districts will be made more complete, and general deductions may be more safely made.

As far as possible the information obtained will be recorded upon the six-inch maps of the Ordnance Survey. These give with great accuracy the condition of the coast, and the position of every groyne, at the time when the survey was made.

Appended is a copy of the questions circulated. The Committee will be glad of assistance, from those whose local knowledge enables them to answer the questions, respecting any part of the coast-line of England and Wales.

Copies of the forms for answering the questions can be had on application to the Secretaries.

Appendix—Copy of Questions.

1. What part of the English or Welsh Coast do you know well?
2. What is the nature of that coast?
   (*a*) If cliffy, of what are the cliffs composed?
   (*b*) What are the heights of the cliff above H.W.M.?
   Greatest; average; least.
3. What is the direction of the coast-line?
4. What is the prevailing wind?
5. What wind is the most important—
   (*a*) In raising high waves?
   (*b*) In piling up shingle?
   (*c*) In the travelling of shingle?
6. What is the set of the tidal currents?
7. What is the range of tide?
   Vertical in feet. Width in yards between high and low water.
   At Spring tide; at Neap tide?
8. Does the area covered by the tide consist of bare rock, shingle, sand, or mud?
9. If of shingle, state—
   (*a*) Its mean and greatest breadth.
   (*b*) Its distribution with respect to tide-mark.
   (*c*) The direction in which it travels.
   (*d*) The greatest size of the pebbles.
   (*e*) Whether the shingle forms one continuous slope, or whether there is a 'spring full' and 'neap full.' If the latter, state their heights above the respective tide-marks.
10. Is the shingle accumulating or diminishing, and at what rate?
11. If diminishing, is this due partly or entirely to artificial abstraction? (*See* No. 13.)
12. If groynes are employed to arrest the travel of the shingle, state—
    (*a*) Their direction with respect to the shore-line at that point.
    (*b*) Their length.
    (*c*) Their distance apart.

(d) Their height—
  (1) When built.
  (2) To leeward above the shingle.
  (3) To windward above the shingle.
(e) The material of which they are built.
(f) The influence which they exert.

13. If shingle, sand, or rock is being artificially removed, state—
  (a) From what part of the foreshore (with respect to the tidal range) the material is mainly taken.
  (b) For what purpose.
  (c) By whom—Private individuals. Local authorities. Public companies.
  (d) Whether half-tide reefs had, before such removal, acted as natural breakwaters.

14. Is the coast being worn back by the sea? If so, state—
  (a) At what special points or districts.
  (b) The nature and height of the cliffs at those places.
  (c) At what rate the erosion now takes place.
  (d) What data there may be for determining the rate from early maps or other documents.
  (e) Is such loss confined to areas bare of shingle?

15. Is the bareness of shingle at any of these places due to artificial causes?
  (a) By abstraction of shingle.
  (b) By the erection of groynes, and the arresting of shingle elsewhere.

16. Apart from the increase of land by increase of shingle, is any land being gained from the sea? If so, state—
  (a) From what cause, as embanking salt-marsh or tidal foreshore.
  (b) The area so regained, and from what date.

17. Are there 'dunes' of blown sand in your district? If so, state—
  (a) The name by which they are locally known.
  (b) Their mean and greatest height.
  (c) Their relation to river mouths and to areas of shingle.
  (d) If they are now increasing.
  (e) If they blow over the land; or are prevented from so doing by 'bent grass' or other vegetation, or by water channels.

18. Mention any reports, papers, maps, or newspaper articles that have appeared upon this question bearing upon your district (copies will be thankfully received by the Secretaries).

19. Remarks bearing on the subject that may not seem covered by the foregoing questions.

N.B.—Answers to the foregoing questions will in most cases be rendered more precise and valuable by sketches illustrating the points referred to.

Report of the Committee, consisting of Professors A. H. GREEN *and* L. C. MIALL *and* Messrs. JOHN BRIGG *and* JAMES W. DAVIS *(Secretary), appointed to assist in the Exploration of the Raygill Fissure in Lothersdale, Yorkshire.*

DURING the past year operations have been entirely suspended, to enable the proprietors of the quarry in which the fissure is situated to remove, by quarrying, a large mass of limestone, which greatly interfered with the work of excavation by your Committee. The removal of this limestone is now nearly completed, and it is hoped that in two or three months the examination of the fissure may be resumed. The importance of the work was sufficiently demonstrated in the report of last year, and your Committee suggest that the grant of 15*l.* should be renewed and increased to 20*l.* They wish to express their sense of the kindness of the proprietors, Messrs. Spencer, who have, at considerable cost and no small inconvenience, greatly facilitated the work of the Committee, besides reducing the cost of its future explorations.

Fourth Report of the Committee, consisting of Mr. R. ETHERIDGE, Mr. THOMAS GRAY, *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Earthquake Phenomena of Japan. Drawn up by the Secretary.*

DURING the last year, that is, from June 1883 to the end of May 1884, only thirty-nine earthquakes have been recorded in Tokio. In the three previous years during corresponding periods the number of records were 75, 57, and 28. Not only have the shocks been few in number, but they have also been unusually feeble. At the time when the greatest shocks occurred, which was at the end of December and in January, I was absent from Tokio on a visit to the Takashima Colliery, near Nagasaki, with the object of establishing an underground observatory.

Although, as these remarks indicate, my opportunities for the observation of earthquakes have been small, I am pleased to state that I have been singularly fortunate in obtaining a series of most interesting records, and at the same time have had leisure to work up a portion of the numerous observations which during the last few years have been steadily accumulating. A few of the results which have been obtained have already been communicated to the Seismological Society. These, together with others which yet remain for publication, are briefly as follows:

Determination of areas from which the shakings so often felt in North Japan emanate.

In my report to the British Association in 1882, I stated that I had sent bundles of postcards to all the important towns within a radius of sixty to one hundred miles of Yedo, with a request that every week one of these cards should be returned to me together with a statement of the earthquakes which had been felt. Subsequently the boundary of the postcard area was extended until it covered the whole of Japan north of Tokio. I did not extend the area far towards the south, because I quickly discovered that it was seldom that earthquakes originated in that direction whilst disturbances travelling from the north towards the south quickly died out as they reached heavy mountain ranges which in that part of the country had a strike at right angles to the direction in which the disturbances were travelling. At the end of September 1883, after exactly two years of observation, I ceased to supply my correspondents with postcards and commenced the arrangement and analysis of the accumulated material. From regular observers I found that I had received about 1,500 letters, whilst there were also a large number of others from casual correspondents. I also had the records of instruments placed in various parts of the country, and a very extensive series of diagrams and notes made by myself and others in Tokio and Yokohama.

In the two years I refer to, in North Japan and Yezo 387 earthquakes had been noted. Of each of these I was enabled to draw a map showing the area over which it had been felt, and to indicate approximately its origin. In the determination of origins I was greatly assisted by the records of instruments and the time observations which had been checked by daily time signals sent by the Telegraph Department from Tokio. One hundred and twenty-five of these maps drawn on a small scale

I am glad to have it in my power to say are now being published by the Seismological Society.

The results which these observations have given, although in certain cases only confirmatory of previous observations, may be epitomised as follows:—

1. Out of the 387 shocks, 254 have been local, the area shaken in some cases not exceeding 50 square miles. The remaining 133 disturbances each shook an area with an average diameter of 45 miles. A few of the larger shocks shook an area the radius of which was at least 150 miles. As the latter originated far out at sea their effects on the land were small. At least fifteen cases have occurred when an earthquake has been practically felt at the same time over two distant areas—observers in the intermediate areas not having felt any disturbance. The distance between such areas has been as much as 150 miles.

2. The area where the most earthquakes have been felt is along the line of the Tonegawa, especially near its mouth, which is one of the flattest parts of Japan. No less than eighty-four per cent. of all the earthquakes observed have originated beneath the Pacific Ocean, or on the land close to the sea-board.

The volcanic regions of Japan and the mountainous districts are singularly free from earthquakes.

Unless an earthquake is very severe it invariably grows feebler as it approaches the mountains and then dies out without crossing them. The mountains referred to are broad ranges, having peaks from 6,000 to 10,000 feet in height.

In many respects the distribution of seismic activity in Japan holds a close relationship to the distribution in South America. In the centre of Japan we have high mountain ranges consisting of granite, metamorphic slates and limestones, and old volcanic rocks, perforated by the vents from which materials have been ejected to form modern volcanoes.

The mountains to the eastward slope steeply beneath a deep ocean, whilst to the west there is a very gentle slope. The earthquakes chiefly originate on the steep slope beneath the deep ocean. In South America many of the destructive earthquakes appear to have had a similar origin.

3. Of the 387 earthquakes, 278 occurred during the winter months and 109 during the summer months. If, for convenience, we consider the intensity of an earthquake as being proportional to the area shaken, then the seismic energy of the winter months to that of the summer months is in the ratio of about 3 : 1.

In the whole of Japan on the average there is at least one shock per day, possibly two or three. This is a number which European seismologists, basing their calculations on catalogues (which for Japan are exceedingly imperfect), have given for the whole world.

4. Taking either the 387 earthquakes here referred to, or the records of earthquakes made during the last ten years in Tokio, by means of instruments working automatically, we find that their occurrence closely follows curves of temperature. A peculiarity is that the sinuses of the curves of mean monthly temperatures are generally a little in advance of the crests of the waves indicating the frequency of earthquakes. In connection with this observation attention may be drawn to the fact that the curves of temperature are those for the air, whilst many of the earthquakes originated beneath the ocean, which gains temperature slowly and loses it slowly.

5. There has been no marked connection between the occurrence of earthquakes and the position of the moon.

6. Earthquakes have been 11·2 per cent. more numerous at low water than at high water. It is frequently assumed that earthquakes are more frequent at one time rather than at another. I have spent much time in the tabulation of the earthquakes of Japan and other countries, comparing together the frequency of earthquakes at certain phases of the moon, at particular seasons, during the day as compared with the night, relatively to the state of the barometer and other meteorological changes, &c., with the general result that there are no strongly marked periods when earthquakes may be expected, the exceptions to rules which may be formulated being almost as numerous as the cases which were the foundation for the rules. The most marked rule about earthquakes is that they chiefly occur during the cold months.

7. With regard to the nature of earthquake motion as deduced from the numerous diagrams which have been obtained, I cannot say that they do more than confirm the results which I have already communicated to the British Association. The greater number of shocks had a duration of from twenty to sixty seconds, but some lasted more than four minutes. The duration recorded depended on the situation of the observer, and on the nature of the instruments. Two observers, with similar instruments, two or three hundred yards apart, might considerably differ as to the length of time assigned for the duration of a disturbance. If one observer was situated on a marsh whilst the other was on hard ground, the former would record the longer time for the duration of sensible motion.

An instrument with a large multiplying index, and sensitive to small but quick movements, will often commence to write a record before an instrument which has only a small multiplying power. Again, an instrument with very little friction, and susceptible to very slow movements, will continue to write a record, after an instrument with considerable friction has ceased to move. Strictly speaking it would appear that the whole of an earthquake has never yet been recorded; many of the preliminary tremors at the commencement of a disturbance and the slow pulsations which bring a disturbance to a close being lost.

The preliminary tremors have an amplitude which is a small fraction of a millimeter, and a period of twenty-five seconds to sixteen seconds. The tremors may be followed by a shock which consists of three or four very rapidly performed back and forth motions, having an amplitude of from one to ten millimeters. The maximum acceleration during such a movement, calculated on the assumption of harmonic motion, sometimes reaches five hundred millimeters per second. Such a shock is on the verge of being dangerous. In ordinary disturbances it is from ten to one hundred millimeters per second. After the shock we get a series of irregular motions, perhaps accompanied by other shocks. These irregular motions are the chief features in ordinary disturbances, and the tremors and shock may be absent. The maximum amplitude recorded is from a fraction of a millimeter to one or two millimeters. The period is from five seconds to three seconds. The direction of motion of these irregular vibrations constantly changes. They do not appear to have any direct connection with that in which the earthquake is being propagated. The direction of a shock, however, seems to coincide with the direction of propagation.

As the disturbance dies out the period of these irregular movements increases, and waves with a period of two or three seconds have been recorded.

For information respecting the velocity of propagation, I will refer to my report of 1881, where some general results were given. I shortly expect to be able to give more definite information on this subject.

Experiments on the Direction of Motion of a Point.

Hitherto the only means that we have had at our disposal for determining the direction of motion of a point, has been either to combine the records of two rectangular components, or to trace a few of the more conspicuous curves in a record given by a seismograph writing on a stationary plate. Both of these methods can only be applied to prominent vibrations in a record, and each of them, unless under special circumstances, is liable to error. The records given by seismographs with single indices writing on moving plates, are for several reasons also open to error, especially perhaps on account of the friction of the moving plate exerting a drag on the recording index. To partially overcome these difficulties, I have constructed a record receiver which works as follows: —Shortly after the commencement of the disturbance, the smoked plate on which the index of a seismograph is writing, is suddenly dropped vertically out of range of the index. It is next pushed along horizontally, and then raised vertically back to its original level, so that it is again in contact with the recording point.

This operation is quickly repeated twelve times, at intervals of every two seconds, so that twelve different diagrams are obtained on a strip of smoked glass, each one being written on a different part of the plate. In this way all effects of drag produced by the moving plate upon the pointer are eliminated. As I have thus far only obtained one set of diagrams, I must reserve a description of the results until a future occasion.

The simultaneous observation of Earthquakes at three stations in Telegraphic connection.

The advantages to be gained by the observation of earthquakes at three or more stations in telegraphic connection were first definitely pointed out by Professor J. A. Ewing, in a communication to the Seismological Society. A very similar method had, however, been previously followed by Mr. T. Gray and myself, in our observations on artificially produced disturbances.

The method which I am now following is briefly as follows:—Near to my house I have established, at the corners of a triangle, the sides of which are each approximately 800 feet, similar instruments. These are fixed on the heads of stakes level with the surface of the ground. The records are written on smoked glass plates which at the time of an earthquake are drawn by means of a falling weight beneath the writing indices. By means of electrical connections, these plates are simultaneously set in motion by the withdrawal of a catch. As they move along, time intervals are marked by levers deflected by electro-magnets every time a small pendulum passes a cup of mercury. The pendulum, which is usually held deflected, is set swinging by an automatic arrangement in my house. Its first swing relieves the catches and sets the plates in motion. By means of the time ticks it is easy to compare the occurrence of any special vibration taken at the various stations within one hundredth part of a second. At the corner of my triangle, at Station Number I., the ground is moderately hard. Station II. is situated on a small promontory leading out into a marsh and near a shallow pond. Station III., where the ground is moderately hard, is behind a heavy brick building which stands very near to the almost perpendicular face of a deep moat. The results which have hitherto been obtained, are briefly as follows :—

1. The diagram extending over the longest period of time and showing the largest waves is always obtained from Station II. in the vicinity of the marshy ground,—the diagrams at the other two stations being much smaller. The smallest record is invariably that at Station III. near the deep moat.

2. At Stations I. and II. waves which may be the same can occasionally be identified, but the identification of a wave at III., which is common to I. and II., is not only rare, but it is accompanied by great uncertainty.

3. In a given earthquake we find that the frequency of waves at the different stations in given intervals of time is different. For example, the number of complete east and west vibrations during the first twenty seconds of time at the different stations during five earthquakes was as follows :—

Frequency of Waves.

Number of Waves in twenty seconds.

1884. Date of Earthquake	Station I.	Station II.	Station III.
March 26	18	14	Not observed
March 31	23	20	21
April 6	25	21	20
May 6	61	50	61
May 11	58	50	64

From the above table it is evident that the average period must be different at different stations. The small number of waves observed at Station III. in March 31 and April 6 is probably due to the smallness in amplitude of many waves, which, because the period of the earthquakes was long, have coalesced in the diagram to form a straight line. Speaking generally we may say that the average period is longest at Station II. near the marsh.

At any given station, however, the period varies considerably during the same disturbance. Thus, in March 31, the period of the north and south motion near the commencement of the disturbance was ·26 second. A few seconds later it was ·4 second.

A similar result is obtained by the analysis of the diagram taken at Station II. Selecting the largest waves from the diagrams of the different earthquakes which are seen to be in the north and south components of motion, their periods in seconds are as follows:—

1884. Date of Earthquake	Periods in Seconds		
	Station I.	Station II.	Station III.
March 26	·66	·66	—
March 31	·26	·28	·33
April 6	·45	·65	·40
May 6	·48	·60	·53
May 11	·26	·45	·28

The maximum amplitudes or half semi-oscillation in millimeters measured in the north and south components, are as follows:—

1884. Date of Earthquake	Amplitudes in Millimeters		
	Station I.	Station II.	Station III.
March 26	·166	·65	—
March 31	·062	·104	·041
April 6	·16	·8	·08
May 6	·3	·1	·08
May 11	·29	·8	·08

On the assumption of harmonic motion the maximum velocities in millimeters per second calculated from the above periods and amplitudes are as follows:—

1884. Date of Earthquake	Maximum Velocities in Millimeters per second		
	Station I.	Station II.	Station III.
March 26	1·5	5·6	—
March 31	1·4	2·2	·75
April 6	2·2	7·4	1·2
May 6	3·7	10	·9
May 11	7	10	1·7

The maximum acceleration in millimeters per second calculated from the maximum velocities and amplitudes, is as follows:—

1884. Date of Earthquake	Maximum Acceleration in Millimeters per second		
	Station I.	Station II.	Station III.
March 26	1·4	48·2	—
March 31	31·2	46·5	13·7
April 6	30·2	68·4	18
May 6	45·6	100	10·1
May 11	20·3	125	36·1

From this last table we see that, although the period of motion at Station II. is slow in consequence of the very large amplitude usually experienced at that station, the maximum velocity, and more markedly the maximum acceleration, which may be taken as a measure of the intensity or destructive power of a disturbance, have been much greater than at Stations I. and III.

One of the most remarkable earthquakes in the series was that of March 26. Although the amplitude of this was sufficiently great to constitute a destructive shock, the period was so long that the disturbance almost escaped attention. Several persons observed lamps and pendulums swinging, and thought there might be an earthquake occurring, but I only found one or two persons who detected any motion of the ground or building.

Speaking generally about these observations, it may be said that had three independent observers been placed at the three stations which are only 800 feet apart, and each had been provided with similar instruments, they could not have failed in giving very different accounts of the same earthquake, both as to its period, its duration, and, I may add, its direction. A result of practical interest that is dependent in the records which I have obtained, is the benefit to be derived by engineers and architects by making a systematic seismic survey of the ground, on which they intend to erect important structures in earthquake-shaken districts.

Observations with the Gray-Milne Seismograph.

As this instrument has been described and illustrated in the 'Quarterly Journal of the Geological Society of London' (vol. xxxix. p. 218), and in other publications, I will not describe the details of its construction. It consists of a pair of conical pendulum seismographs, which record upon the smoked surface of a drum, two mutually rectangular components of the horizontal motion of the earth. The drum is kept continuously in motion by clock-work. The vertical motion is described by a spring lever seismograph. At a certain part of the earthquake, a mark is made on the drum, simultaneously with which time is recorded from a specially arranged time-piece. By this means the time can be calculated at which any particular vibration of an earthquake occurred.

As the instrument is designed more for the systematic observation of earthquakes, rather than for experimental purposes, I entered into correspondence with the Meteorological Department of this country to admit it into their department as an instrument for regular observation. This Mr. Arai Ikunosuke, the director of the Meteorological Department, has kindly done. After repairing slight damage, which it suffered in its transit, it was exhibited to His Imperial Majesty the Emperor of this country. Since then a heavy brick column on a massive concrete foundation has been built for its instalment, and it has been put in charge of a regular observer. During the early part of this year, although several earthquakes were experienced, no results were obtained. This was due to the pointers of the conical or horizontal pendulums, which are extremely sensitive to slight changes in level, slowly wandering to the right and left of their normal position on the revolving drum. The consequence of this was, that instead of simply tracing in the smoked surface a single line, they made a path sometimes an inch in breadth, and when the earthquake came the smoked surface on which the record ought to have been written had been removed.

Although I varied the adjustments of the instrument in a variety of manners, I was unable to destroy this tendency to wander. The only explanation which I can offer of the phenomena, is that it is either due to a settlement taking place in the column, which from the nature of the motion is unlikely, or that it was due to actual changes in the level of the soil.

As a final resort the point of suspension of the conical pendulums was brought sufficiently forwards to give them a definitely stable position, since which all earthquakes which have occurred have been successfully recorded. Although I have in this manner destroyed the sensibility of the instrument, I may remark that it is sufficiently sensitive to give a daily record of the firing of a time gun, situated more than 100 yards distant. The intervening ground is hard and full of excavations.

Hitherto, I have not had time to analyse the various records which have been obtained, and am therefore compelled for the present to reserve any report upon them. Mr. Gray is, I am pleased to say, constructing two new seismographs. These are so arranged that they will record, either slow tips in the soil or earthquakes, the diagrams being made with ink on a strip of paper.

Experiments on a Building to resist Earthquake motion.

I have previously drawn attention to the great difference in the effects which moderately strong earthquakes have produced upon European and on Japanese types of buildings, the former being more or less shattered whilst the latter escape without any apparent damage. In the one case we have a building of brick and mortar firmly attached by its foundations to the shaking earth, whilst in the other we have a light wooden structure resting loosely on boulders. If the former is of a type for which patents have been granted, where iron hoops and tie rods together with all the devices which give strength and solidity have been employed, it certainly resists the effects of disturbances which have shattered buildings of ordinary construction. An important objection to dwellings of this order is their great expense.

With the above considerations before one, and with a knowledge that the chief motion in the majority of earthquakes in this country is the horizontal component, I have erected for experimental purposes a small building resting on four cast-iron balls.

The building, which measures 20 feet by 14 feet, is constructed of timber with a shingle roof, plaster walls and ceiling of laths and paper. The balls rest on cast-iron plates with saucer-like edges fixed on the heads of piles. Above the balls and attached to the building are cast-iron plates, slightly concave but otherwise similar to those below. From the records of instruments placed in the building, it would appear that at the time of the earthquake there is a *slow* back and forth motion, but that all the *sudden motion* or *shock* has been destroyed. Thus far the building or rather its foundations have proved successful in eliminating the destructive element of motion.

I am now experimenting on the foundations by using flat plates, and by giving such frictional resistances to movement that the building may become astatic. If this is successful, as I trust it will be, although devices are yet required to destroy the vertical motion of earthquakes, something of practical value will have been done to mitigate the serious results which accompany destructive earthquakes by the elimination of their horizontal movements.

On the Establishment of an Underground Observatory.

In December last year I visited the Takashima Colliery, near Nagasaki, with the object of making investigations preparatory to the establishment of an underground observatory. The phenomena which I had the intention of observing were :—

1. *Earth-tremors.*—It has been observed that these microscopic movements of the soil accompany barometric falls, and it is therefore probable that they may hold some relationship to the escape of gas which in certain parts of the Takashima mine is a source of considerable danger. At this mine the gas escapes several hours before any marked changes take place in the barometrical column. Should it be found that the occurrence of tremors precedes barometric fluctuations the utility of the observations is obvious.

The instruments to be used for observation are tromometers, like those employed by Bertelli and Rossi in Italy, and microphones in a telephonic circuit. During my short stay at the mine, I found that a microphone placed in an unworked part of the mine was at times very active.

2. The observation of delicate levels for the purpose of recording any variations which may take place in the inclination of the ground. Since I left the mine, Mr. John Stoddart, the chief engineer, who has undertaken these various investigations, writes me that he commenced observations with the levels on the surface of the ground. Owing to a gradual subsidence, due to the underground excavations, which is evidenced by numerous cracks on the surface, the changes in the levels are so great that it will be necessary to establish them underground.

3. The measurement of the sinking of the underground excavations. As the mine, which is very large, extends a long distance beneath the ocean, it is not unlikely that some connection may be found between the movement of the roof and the tides. Mr. Stoddart tells me that the contrivance for indicating these effects yields such marked results that a number of similar apparatus are being made for distribution in different parts of the workings.

4. The observation of earth-currents. Whilst I was at the mine, feeble currents were visible on a line only sixty yards in length.

In consequence of a fire which broke out in the mine shortly after I left, it is only quite recently that Mr. Stoddart has had opportunity to turn his attention to these investigations. At a future period I trust that I may be able to report upon them. For facilities enabling these observations to be made, my thanks are due to the Mitsu Bishi Company, who are the owners of the mine.

Earth-tremors and Earth-pulsations.

For the present, the observations on earth-tremors in Tokio have been discontinued. The observations on changes in inclination of the ground, as shown by the movements in the bubbles of levels and in the position of the stile of a pendulum relatively to a point beneath it, are still going on. At the Imperial Observatory a special column has been constructed for these latter observations, and a large series of records are being collected. To work up the observations already made on earth-tremors and earth-pulsations will require considerable time, and I therefore am compelled for the present to reserve any report on them.

Notes in connection with Observations made in the Underground Observatory at the Takashima Colliery near Nagasaki.

Observations with fixed Spirit Levels, &c.

These levels have been tried both on the surface and below ground, but I find that, owing to the extensive underground workings, the movement in the whole mass of the island is so great as to entirely vitiate any record of the more minute earth-movements.

The excess and irregularity of the movement in the strata of the island is owing to the fact that we are working simultaneously three seams of coal of the aggregate thickness of 30 to 36 feet. The lowest seam (which is the only one in which we can hope to get a stable foundation) measures 18 feet in thickness, with a soft shale floor of great depth, on account of which it takes both 'creep' and 'crush'; giving a constantly varying set of movements from which it is impossible to obtain any reliable statistics.

The same reasons render the observations by the microphone and microseismometer totally unreliable.

The lever microphone—with which we have been experimenting—when delicately balanced, registers an almost continuous rattle of sounds caused by the passage of coal-trucks, the 'falling' of coal, and the 'working' or crushing of the strata.

Even when the delicacy of the balance is reduced, so that it does not render a single vestige of sound away from the colliery, it still continues to register intermittent sounds, which can only be attributed to these above-named causes when brought into the mine or on the island.

The microseismometer also shows constant tremors going on, accompanied by very considerable deflections, but without any periodicity or constancy of direction.

In order to be sure that this irregularity was caused by the underground workings, I made a short series of experiments on the mainland at Nagasaki, nine miles distant, with such results as perfectly convinced me of the unreliableness of the observations at Takasima.

I am, however, strongly of opinion that observations of considerable value in their application to the prediction of the out-flow of carburetted hydrogen in coal mines can be obtained from the microseismometer under the following conditions.

1st. That it would need to be erected at a sufficient distance from the mines to insure its being unaffected by tremors caused by the underground workings.

2nd. That it must be close enough to the mines to insure its being affected by the same earth-tremors as are likely to affect the coal strata.

I am led to form the above opinion from the fact that in the brief experiments which I was able to make on the mainland, any increase in the intensity of vibration and amplitude of deflection seemed as a rule to precede a diminution of the barometrical pressure, and it also seems highly probable that an increase of vibratory motion in the coal strata would tend to facilitate the outflow of gases contained therein in even a greater ratio than would the diminution of atmospheric pressure. My personal experience in mining tends entirely to support this deduction, as I have invariably found that in places where the outflow of gas was fairly constant as a general rule, it always increased to a greater or less extent when what is technically called any 'working' of the strata took place.

For the purpose of obtaining more reliable statistics on this head, I have arranged with Mr. F. Ringer of Nagasaki to erect the microseismometer at his observatory on the mainland, eight miles from this island, and we shall be able, by making simultaneous observations, to connect his notes with those made at the observatory at the mine. Of course it would be preferable to have the mainland observatory situated at a point much closer to the mines than this one is, but there is no place nearer where we can be sure of having a reliable observer.

Observations on Earth-currents, &c.

Owing to my inexperience in magnetic observation and the difficulty in getting suitable apparatus constructed or erected down here, I have only begun to make regular observations during the current month. Previous to this, however, I have been making isolated experiments with such rough-and-ready apparatus as could be constructed on the spot.

The results are briefly as follows:—

With one wire connected with an iron bar fixed in the line of a fault below-ground, and the other end fixed to a similar bar inserted in the strata at a distance of about 100 yards, there was a considerable deflection in a home-made galvanometer.

With both ends connected with the coal strata below ground, but away from the vicinity of any fault, the deflection was hardly perceptible.

With one end fixed to the rod inserted in the fault below ground, and the other connected with the surface strata, the deflection was again considerable. I then erected the apparatus in my own house, connecting one end with a rod inserted in the line of a fault, at a short depth from the surface, and the other with the surface strata with the home-made galvanometer I got slight though perceptible deflections, and with the galvanometer which was received from Tokio I have since obtained deflections quite capable of registration.

Owing to my own inexperience and the meagreness of the statistics which I have been able to collect, it would be altogether absurd to give any opinion, as yet, as to the connection (if any) between the movements of the galvanometer and the outflow of gas in the mine, and I think that it is preferable to collect at least one year's statistics before saying anything further on the subject, than to state that, so far as the experiments have progressed, they tend to render me sanguine that such a connection might be established, and also that I would be most happy to receive any advice or suggestions on the subject from people more experienced in the subject than myself.

Tidal Observations.

With regard to the observations to be made with a view to establish the connection (if any) between the crushing together of the roof and floor of the mine and the rise and fall of the tide, Mr. Stoddart writes:—

"I have hitherto made but little progress with these experiments, owing to the difficulties I have had in constructing a tide-gauge to give a daily and hourly register of the rise and fall of the tide, and also in constructing an apparatus for registering the crush of the mine in a similar manner.

"With the little machine which you designed when you were down here I have been able to demonstrate perfectly the most minute movements of the roof and floor in approaching one another, but it is impossible to be sure as to whether the approach is accelerated or retarded as the tide rises and falls until I have completed the construction of a clock register.

"I think that it will be better, therefore, to refrain from remarking on this subject, further than to say that it is being worked at.

"JOHN STODDART,

Takashima: 26th June, 1884.

"To JOHN MILNE, Esq.,
Kobu Dai Gakko, Tokio."

Report of the Committee, consisting of Professor RAY LANKESTER, Mr. P. L. SCLATER, Professor M. FOSTER, Mr. A. SEDGWICK, Professor A. M. MARSHALL, Professor A. C. HADDON, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples.*

EVERY year since their first appointment, your Committee have had the agreeable duty of recording the annually increasing success of the Zoological Station at Naples. On the present occasion they are able to report that at no previous period of its existence has the Institution been in a more flourishing condition than now. Forty-one naturalists have worked at the station during the past twelve months, which brings the number to nearly three hundred who have occupied its tables since the commencement in 1873. Large though the establishment already is, it has for some time been desirable to make additions to the building in order to furnish the means for still further extending the general scope of the institution. From the very outset it has been the aim of the founder, Professor Dohrn, to develop the physiological as well as the morphological investigation of marine organisms, although the latter has necessarily hitherto been the chief concern of the station. It is now intended to erect a new building for a physiological laboratory, adjacent to the present station. For this purpose the municipality of Naples has voted 300 square mètres of land; and well-founded hopes are entertained that very considerable contributions towards this enlargement of the station may be expected from the Italian Government.

Further assistance for Dr. Dohrn's undertaking is forthcoming from Germany, where a public subscription is now being organised throughout the country, in consequence of a meeting held in Berlin on June 26, for the purpose of presenting the Station with a larger seagoing steamer, which is to be fitted up as a floating laboratory; and it is also proposed to endow the Station with a Pension and Reserve Fund. The meeting in question was attended by a number of eminent statesmen and scientists, the Minister of Public Instruction, together with the President and Vice-

President of the Reichstag, taking a prominent part in the proceedings. A letter was also read from H.R.H. the Crown Prince to Dr. Dohrn, in which His Royal Highness expressed his interest in the station, and announced his pleasure in supporting the movement. Worthy testimony was borne by the above-named members of the German Government to the services rendered to science by Professor Dohrn, and of the appreciation in which his many personal sacrifices in the establishment and maintenance of the station were held. The responsibility of the Government in fostering such an undertaking was also fully acknowledged.

Since the last Report was presented additional tables have been taken by Italy and Prussia, supplementary to those previously engaged. These countries as well as Bavaria, Baden, and Cambridge, have also agreed to increase their subscription to 100*l.* per annum for each table; and similar negotiations are pending with other lessors. With reference to the expected increase above indicated, in the income of the station, the Directorate wish to point out that it is to be entirely devoted to the purpose of increasing the present means of investigation, and of establishing a large physiological laboratory. The fulfilment of such anticipations would enable the station to conduct important and exhaustive investigations on sea-fisheries, to develope their scientific basis, and to prosecute biological researches in the widest aspect on questions touching the habits, localities, etc., of marine animals and plants; in short, to embrace the whole field of organic research in the sea.

The General Collections.—The Zoological Station has this year for the first time received a welcome addition in the form of a valuable series of foreign specimens. These consist of two large collections of well-preserved animals and plants from the Atlantic, and the Eastern and Western coasts of South America, obtained by Captain Chierchia of the 'Vettor Pisani' (Italian navy), an officer who had received instruction at the station during the winter of 1881–2 in the methods of preserving marine organisms. The various groups have been distributed amongst Italian and German naturalists for determination and investigation. Further collections are also expected shortly from other Italian and German ships.

The Publications of the Station.—The following details will indicate the activity of this department of the Zoological Station.

1. Of the 'Fauna und Flora des Golfes von Neapel,' the following monographs have been published since the last Report:—

VII. R. Valiante, *Cystoseiræ*, 30 pp., 15 pl.
IX. A. Andres, *Actiniæ* (parte prima), 459 pp., 13 col. pl.
X. B. Uljanin, *Doliolum*, 139 pp., 12 pl.
XI. A. Lang, *Polycladæ*, (1. Hälfte), 240 pp., 24 pl.
XII. G. Berthold, *Cryptonemiaceæ*, 24 pp., 8 pl.

Of the following list the first mentioned work is already in the press, and the others are in course of preparation.

A. Lang, *Polycladæ* (2. Hälfte), about 400 pp., 16 pl.
J. Fraipont, *Polygordius*.
G. v. Koch, *Gorgoniidæ*.
P. Falkenberg, *Rhodomeleæ*.

2. Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' vol. iv. has been completed, occupying 522 pp., with 40 plates; and vol. v. —parts i. and ii. are already published. Several of the papers in this series of memoirs are written in English.

3. The 'Zoologischer Jahresbericht' for 1882 is published, and occu-

pics 1,259 pp.; it is divided into four sections, each with a separate alphabetical index, in order that single sections may be sold separately. Of the 'Bericht' for 1883, sections 2 (Arthropoda), and 3 (Mollusca), are nearly ready, and will be published in September. The whole 'Bericht' is now edited by the station, under the care of Drs. Paul Mayer and W. Giesbrecht. In future the arrangement of the various records will be more uniform, each group of animals being treated under the following heads:—*a.* Anatomy, Ontogeny, etc.; *b.* Biology, Domestication, etc.; *c.* Classification and Faunal relations; *d.* Palæontology. Special care will be taken to render the section on the classification of a group intelligible to, and easy for consultation by, every zoologist whether he be a specialist or not—the new genera, species, varieties, and synonyms in every family being arranged in alphabetical lists.

Extracts from the General Report of the Zoological Station.—The usual lists of the naturalists who have worked at the station, and of the memoirs published by them, will be found appended, together with other details kindly furnished by the officers of the station.

The British Association Table.—Your Committee have the pleasure to report that important researches have been successfully conducted on the table at their disposal during the past year; and further that the table has been occupied during nearly the whole of the working season. The use of the table was successively granted to Mr. A. G. Bourne and Prof. A. M. Marshall, Mr. Bourne's period of occupation extending over a term of six months by special permission of the Committee. Both of these gentlemen have furnished reports concerning the investigations undertaken by them at the station, together with a summary of the results respectively arrived at; and both are to be congratulated on the successful character of their researches. The reports in question are appended.

With these gratifying assurances of the undeniable utility of the British Association table before them, your Committee confidently recommend the renewal of the grant; and they would further specially recommend that the amount should be increased to 100*l.* (instead of 80*l.* and 90*l.* as in previous years), in conformity with the arrangements made by the Directorate of the station with other countries.

I. *Report on the Occupation of the Table by Mr. A. G. Bourne.*

I occupied the table from November 1, 1883, until April 14, 1884.

I devoted the greater portion of the time to a further investigation of the anatomy of the marine leech *Pontobdella*, and, as far as material would allow, of *Branchellion.* The results I obtained have been already published together with other matter in a paper entitled, 'Contributions to the Anatomy of the Hirudinea,' in the 'Quarterly Journal of Microscopical Science,' July 1884.

The most important of these results consisted in a knowledge of the structure and relations of the nephridium in *Pontobdella.* This organ has been hitherto entirely misunderstood, some of its funnels being, indeed, the only portions of it known, these having been described by the French naturalist Vaillant, and stated by him to open directly to the exterior.

I have found that there are a series of ten pairs of these funnels, and that they do not open directly to the exterior, but are connected with a most elaborate network of tubules lying for the most part within the muscular layers of the body wall. This network is continuous, the portion lying on the one side of the body with the portion lying on the other side in the median ventral region, and is also continuous throughout the length of the body in the region in which it occurs—*i e.*, from the ninth post-oral ganglion to the nineteenth.

The tubules collect at certain spots, and pass down to open to the exterior without the intervention of any vesicle. There are 10 pairs of such apertures placed in somites 10–19 inclusive, upon the first annulus of each somite. The apertures are thus metamerically related to the funnels, a pair of apertures corresponding with each pair of funnels.

The organ in reality consists of a paired series of nephridia, each with a funnel to the interior, and a pore to the exterior, and these nephridia differ from those in *Hirudo*, *Clepsine*, etc., in that they remain continuous, those on the one side with those on the other, and each pair with those in front and behind.

Supposing, as we are probably justified in doing, that the organs have arisen by a hollowing of branching mesoblastic cells, we have here a structure which has only advanced upon this primitive condition in developing metamerically repeated funnels and apertures to the exterior.

I obtained but very few specimens of *Branchellion*. I was, however, able to demonstrate the existence of a very similar nephridium in that genus, but I believe far simpler, in that it has not developed any internal funnels and has only a single pair of pores to the exterior, these corresponding to the most posterior pair in *Pontobdella*.

The commonest *Pontobdella* at Naples belongs to the species *P. muricata*, but I obtained single specimens of perhaps two other species, and a specimen which must probably form a new genus; but I should wish to become much more fully acquainted with all the varieties at present known before entering upon any toxonomic questions in a group which presents considerable difficulties in this respect, the characters of most value in forming a systematic arrangement—the number of annuli in a somite, etc.—being at present very inaccurately described.

Since the discovery of *Haplobranchus*, a new genus of Capitobranchiate Annelids belonging to a small, but in many ways very interesting group, I have endeavoured to obtain as many members of the group as possible, in order to complete a comparative study of the group; this I carried out further at Naples. I obtained species of *Oria*, *Fabricia*, and *Amphiglena*, and obtained new results with regard to the structure of these forms. I may state here that I have confirmed the observations of Claparède, which have lately been doubted, as to the arrangement of the modified pair of nephridia which serve as tubiparous glands, and the median position of their aperture to the exterior, in *Amphiglena*.

At the request of Professor Lankester, I undertook the investigation of certain problems connected with the blood system of Mollusca and the supposed taking in and shedding out of water by these animals. I studied *Solen legumen*, and entirely corroborated the results previously obtained at Naples by F. G. Penrose, to the effect that ordinary blood does not exist in the pericardium of that animal, and so probably of other Lamellibranchs. This I demonstrated by means of serial sections which show the nucleated blood corpuscles lying in the ventricle, but absent from the pericardium.

With regard to the supposed taking in of water, I kept various forms, *Solen*, *Solecurtus*, *Psammobia*, *Venus*, and others, alive in sea-water, coloured by various bodies, both in solution and finely particulate, and afterwards obtained sections of various regions; but in no case was there any evidence of anything having been taken in. With iodine green in the sea-water, I found, however, that the colouring matter penetrated, but not from any particular spot, all through to a certain depth; the tissues, in fact, became stained while living, a condition well known to be possible with some other anilin dyes—Bismarck brown, for instance.

I made some observations upon the 'Töpfchen,' or 'ciliated pots,' which occur in the cœlomic fluid of *Sipunculus*. I find that they present two kinds of cilia—a bundle of central long cilia, and around these a circlet of shorter cilia; and there may be seen groups of amœboid corpuscles apparently breaking down—degenerating, surrounded by these ciliated pots which have their long cilia fixed into the mass and twirl themselves round, first one way and then the other, dragging upon the mass until they drag out that portion into which they have fixed their long cilia, and then swim off with it and, I am inclined to believe, digest it. I was, however, unable to arrive at any further conclusion as to their nature.

I also examined the 'brown tubes,' the uterine pouches of *Sipunculus*, with regard to the position of their internal orifices. This I found to agree with a previous unpublished observation of Professor Lankester. It is a transversely elongated slit with ciliated lips lying close to the external aperture, on or upon that surface of the gland.

I extracted a quantity of the green colouring matter from the annelid *Chætopterus* and brought it home in order to make a microspectroscopic examination.

Lastly, I prepared sections, &c., of the suckers of various cephalopoda, in order to obtain facts for a comparison which I am about to make between these structures and the tentacles of *Nautilus pompilius*.

II. *Report on the Occupation of the Table by Professor A. Milnes Marshall.*

I reached Naples in the first week of April, and stayed there till the end of the month. I had originally intended to occupy myself with (*a*) certain points in the development of the Alcyonaria, and (*b*) with a further study, in continuation of former researches, on the development of the muscles of the head and of the posterior cranial nerves of Elasmobranchs. For the former the weather and the season of year proved unfavourable; and of Elasmobranch embryos I was only able to obtain a limited number. I therefore devoted the greater portion of my time to other subjects, and chiefly to an experimental investigation of the nervous system of Antedon, with the object of deciding, if possible, the points of dispute between the Carpenters on the one hand, and on the other, the German morphologists headed by Ludwig.

It is now nearly twenty years since Dr. Carpenter first suggested that the axial cords were really the nerves supplying the muscles of the arms of Antedon: since that time he has steadily maintained this view, and has supported it by a considerable mass of evidence, both anatomical and physiological. The same view is held by Dr. P. H. Carpenter, who has brought forward independent and very important evidence in its favour, chiefly histological and morphological.

Ludwig, on the other hand, and the majority of the Continental writers who have discussed the question, maintain that the real nervous system of Antedon consists of the 'subepithelial bands,' which run along the ventral surface of the arms and disc, immediately beneath and in very close relation with the ciliated epithelium lining the ambulacral grooves. Ludwig and those agreeing with him rely mainly on the close resemblance, or actual identity, in histological structure and in relation to the overlying epithelium between these subepithelial bands and the ambulacral or radial 'nerves' of the starfish, and hold that if the homology of these two structures be admitted, it is extremely difficult to conceive that Crinoids can have in addition to this normal Echinoderm nervous system an additional one—*i.e.*, the axial cords and the central capsule from which they spring—which is altogether unknown and unrepresented in other Echinoderms.

The Carpenters accept the nervous character of the subepithelial bands, but maintain that they form but a small and comparatively subordinate part of the entire nervous system.

My own investigations consisted of an experimental examination of the functions, (*a*) of the central capsule, (*b*) of the axial cords, and (*c*) of the subepithelial bands. I employed both mechanical and chemical irritation as sources of stimulation, and limited the action of the irritants to the desired point by removal of the surrounding parts either mechanically or by means of strong nitric acid.

Concerning the central capsule, I find that so long as this remains intact and in connection with the axial cords, the animal retains the power of co-ordinated movements of the arms, as shown by the normal swimming movements, and by the tendency to right itself when placed in a tank wrong way up—*i.e.*, with the oral surface downwards. This power of co-ordinated movements is not affected by removal of the entire visceral mass, an operation which involves the complete isolation of the subepithelial bands of the several arms from one another. On the other hand, removal or destruction of the central capsule, if thoroughly performed, causes complete and permanent loss of the power of co-ordinated movements. I therefore conclude that the central capsule is the centre governing these movements.

Concerning the axial cords, I find that irritation of them causes active flexion of the arm affected, and also of the other arms, provided the communications of the central capsule with the axial cords be intact.

Division of the axial cord of an arm causes complete physiological separation between the parts on opposite sides of the injury, even though the subepithelial band be carefully preserved. From my experiments on the axial cords, which were very numerous and varied, I conclude that they are the real nerves, both motor and sensory, of the arms.

Concerning the subepithelial bands, I find that, while certainly nervous in structure and presumably in function as well, they are of very subordinate importance. The effects of irritation or destruction of them are almost confined to the tentacles bordering the ambulacral grooves, with which they are in very intimate relation.

Concerning the morphological difficulty involved in the possession by Crinoids of an antambulacral, in addition to the normal ambulacral nervous system of Echinoderms, I would submit the following considerations. The nervous system of an Asterid is not confined to the radial ambulacral bands and their connecting oral commissure, but can be traced over the tube feet, and also over the dorsal or antambulacral surface of the animal.

It may, in fact, be described as a nerve-sheath extending practically over the whole animal and everywhere directly continuous with the external epidermis, of which, indeed, it forms the deepest and specially modified layer. Such a condition of the nervous system there is independent reason for regarding as a very primitive one; and I regard it as the type from which the more specialized nervous systems of the other Echinoderms have been derived. This specialization consists chiefly in separation, more or less complete, of the nervous system from the epidermis, in exaggeration of the radial nerve bands with reduction of the intervening parts of the nerve sheath, and finally in sinking down of the radial nerve bands into and through the dermis so that they become separated from the external epidermis by a layer of connective tissue which may, as in Echinids and some Ophiurids, be firmly calcified. In Echinids the nerve sheath still persists as the external nervous plexus outside the test first described and figured by Lovén.

I consider that in Crinoids the subepithelial bands most certainly are homologous with the radial or ambulacral nerves of a starfish; and I consider that they represent a part of a continuous nerve sheath which has retained permanently its primitive continuity with the epidermis. The axial cords, some of the branches of which can be traced into extremely close proximity with the subepithelial bands, I regard as portions of the antambulacral nerve sheath which, like the radial cords of Echinids, Ophiurids, and Holothurids, have lost their primitive position and shifted into or through the dermis.

On this view the nervous systems of all recent groups of Echinodermata can be reduced to one plan, and furthermore, an explanation is obtained of the histological similarity or identity between the axial cords and subepithelial bands, as well as of the very close relation, and probably continuity, between the two sets of structures in Antedon.

It must be noted, however, that while this enables us to reconcile the Crinoid with the other Echinoderm types of structure, it leaves the gap between the two groups an exceedingly wide one. Antedon, on this view, is very far indeed from being a primitive Echinoderm: it is, indeed, as regards its nervous system, the most highly differentiated of all recent Echinoderms. On the other hand, the starfish has retained an extremely primitive type of nervous system, which must probably be regarded as ancestral for all Echinoderms.

A further point of interest concerning Antedon, that I observed during my stay at Naples, is that not only may the visceral mass be entirely removed from the living animal without causing death, or indeed, any apparent inconvenience, but that such specimens very speedily regenerate the whole visceral mass. I have obtained a series of specimens illustrating the various stages of this very remarkable and extensive regeneration, but have not yet had time to examine or describe them.

I also devoted some time to an examination of fresh specimens of Amphioxus with the object of ascertaining whether the spinal nerves have single or double roots of origin. By following the methods described by Rohon, I have convinced myself of the accuracy of his description of the existence of anterior spinal roots in addition to the well-known and much more obvious posterior roots. Rohon's attempt, however, to homologize the anterior nerves of Amphioxus with certain of the cranial nerves of the more typical vertebrates seems to me entirely devoid of justification.

III. *A List of Naturalists who have worked at the Station from the end of June* 1883 *to the end of June* 1884.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
246	Prof. Gasco	Italy	July 20, 1883	Oct. 21, 1883
247	Prof. G. Parona	"	" 31, "	" 28, "
248	Sig. E. Cercone	Italian Navy	Aug. 19, "	Nov. 9, "
249	Sig. F. Orsini	"	" 20, "	Jan. 18, 1884
250	Dr. Crety	Italy	" 20, "	Nov. 1, 1883
251	Dr. C. Keller	Switzerland	Sept. 4, "	Oct. 1, "
252	Dr. H. Schaninsland	Prussia	" 14, "	" 28, "
253	Mrs. Dr. Boll	Italy	" 15, "	" 17, "
254	Dr. von Sehlen	Prussia	" 23, "	July 4, 1884
255	Prof. N. Wagner	Russia	Oct. 1, "	April 16, "
256	Dr. J. Walther	Saxony	" 18, "	Feb. 28, "
257	Dr. M. Büsgen	Strassburg	" 19, "	" 17, "
258	Mr. A. G. Bourne	British Association	Nov. 5, "	April 14, "
259	Mr. John Beard	Bavaria	" 5, "	" 17, "
260	Mr. W. B. Ransom	Cambridge	" 5, "	" 8, "
261	Prof. R. Kossmann	Baden	" 5, "	Nov. 18, "
262	Dr. G. Jatta	Italy	" 26, "	—
263	Dr. L. Oerley	Hungary	Dec. 9, "	—
264	Prof. C. Vogt	Switzerland	" 12, "	May 23, 1884
265	Mr. F. S. Harmer	Cambridge	" 22, "	—
266	Prof. H. Giercke	Prussia	" 28, "	April 8, "
267	Sig. A. Colombo	Italian Navy	Jan. 1, 1884	" 12, "
268	Dr. van Bemmelen	Holland	" 1, "	—
269	Sig. E. Stassano	Italy	" 1, "	—
270	Prof. F. Clarke	Williams Coll., U.S.A.	" 8, "	May 1, 1884
271	Dr. Albert	Prussia	" 9, "	June 17, "
272	Prof. Fr. Schmitz	"	Feb. 27, "	April 12, "
273	Prof. C. Eberth	"	" 29, "	" 14, "
274	Dr. W. Uljanin	Russia	March 5, "	June 11, "
275	Dr. G. Berthold	Prussia	" 7, "	April 20, "
276	Prof. C. Chun	"	" 16, "	" 30, "
277	Dr. F. Rückert	Bavaria	" 17, "	—
278	Dr. G. Klebs	Würtemberg	" 17, "	April 20, 1884
279	Dr. M. von Brunn	Prussia	" 17, "	—
280	Prof. A. M. Marshall	British Association	April 5, "	April 26, 1884
281	Dr. P. Fraisse	Baden	" 14, "	—
282	Prof. Swaen	Belgium	" 15, "	—
283	Dr. Korotneff	Russia	" 25, "	June 12, 1884
284	Dr. W. Kükenthal	Prussia	May 17, "	—
285	Mr. W. Weldon	Cambridge	June 21, "	—
286	Dr. M. Menzbier	Russia	" 23, "	

IV. *A List of Papers which have been published in the year* 1883 *by the Naturalists who have occupied Tables at the Zoological Station.*

Mr. B. A. Weldon . . Note on the early development of Lacerta muralis. 'Quart. Journ. Microscop. Science,' 1883.

Dr. Th. Weyl . . . Physiologische und chemische Studien an Torpedo. 'Arch. f. Anatomie und Physiologie,' 1883.

Dr. R. Bergh . . . Beitrag zu einer Monographie der Gattung Marionia. 'Mittheil. Zool. Station,' Bd. IV., 1883.

Dr. C. Brandt . . .	Ueber die morpholog. und physiol. Bedeutung des Chlorophylls bei Thieren, 2. Artikel. 'Mittheil. Zool. Station,' Bd. IV., 1883.
Signor E. Stassano . .	Nouvelles Recherches physiologiques sur la Torpille. 'Comptes Rendus,' No. 20, 1883.
"	Contribuzione alla fisiologia degli spermatozoidi. 'Zoolog. Anzeiger,' 1883.
"	Ricerche sulla Sovraeccitabilità Nervosa-Motrice che si manifesta nei primi momenti dell' azione del Curaro. Estr. dal Giornale 'La Psichiatria,' Napoli, 1883.
Dr. G. Fritsch . .	Bericht über die Fortsetzungen der Untersuchungen an electrischen Fischen. 'Sitz. der Berl. Akademie der Wissenschaften,' Berlin, 1883.
Dr. L. Oerley . . .	A Zoologicai Allomasok és az Allattani Kutatasok Ujabb Módszerei, Budapest, 1883.
Dr. C. de Merejkowsky .	Zoonérythrine et autres Pigments animaux. 'Bulletin Soc. Zoologique de France,' 1883.
"	Développement de la Méduse Obelia. *Ibid.*
Dr. F. Blochmann . .	Beiträge zur Kenntniss der Entwickelung der Gastropoden. 'Zeitschrift f. wiss. Zoologie,' Bd. 38, 1883.
"	Ueber die Drüsen des Mantelrandes bei Aplysia und verwandten Formen. *Ibid.*
Dr. O. Hamann . .	Beiträge zur Kenntniss der Medusen. 'Zeitschrift f. wiss. Zoologie,' Bd. 38, 1883.
Prof. A. Weissmann .	Die Entstehung der Sexualzellen bei den Hydromedusen, Jena, 1883.
Dr. J. Frenzel . .	Ueber die sogenannten Kalkzellen der Gastropodenleber. 'Biologisches Centralblatt,' 1883.
"	Neuer Beitrag zur mikroskop. Technik. 'Zoologischer Anzeiger,' 1883.
"	Ueber die Mitteldarmdrüse (Leber) der Dekapoden. 'Sitzungs-Ber. Berliner Akad. der Wissensch,' Bd. 42, 1883.
Dr. A. Della Valle . .	Sui Copepodi che vivono nelle Ascidie composte del Golfo di Napoli. 'Reale Accademia dei Lincei,' 1882–3.
Prof. C. Emery . .	Contribuzioni all' Ittiologia. 'Reale Accademia dei Lincei,' 1882–3.
Dr. A. Korottneff . .	Zur Kenntniss der Siphonophoren. 'Zoolog. Anzeiger, 1883.
"	Entstehung der Gewebe. *Ibid.*
Dr. J. Brock . . .	Untersuchungen über die interstitiellen Bindesubstanzen der Mollusken. 'Zeitschrift f. wiss. Zoologie,' Bd. 39, 1883.
Mr. A. G. Bourne . .	On certain Points in the Anatomy of the Polynoina &c. 'Transact. Linnean Soc.,' 2nd Ser. Vol. ii. 1883.
Prof. A. C. Haddon .	On Budding in Polyzoa. 'Quart. Journal of Microscop. Science,' Vol. xxiii. N. S. 1883.
Mr. E. Shipley . .	On the Structure and Development of Argiope. 'Mittheil. Zoolog. Station,' Bd. IV. 1883.
Dr. von Sehlen . .	Mikrokokken bei Arca Celsi. 'Fortschritte der Medicin,' No. 23, 1883.
Bar. R. Valiante . .	Die Cystoseiren. Monographie VII. der 'Fauna und Flora des Golfes von Neapel,' herausgegeben von der Zoolog. Station, 1883.
Mag. M. Traustedt . .	Die einfachen Ascidien des Golfes von Neapel. 'Mitth. Zoolog. Station,' Bd. IV. 1883.
Dr. G. Berthold . .	Die Bangiaceen. Monographie VIII. der 'Fauna und Flora des Golfes von Neapel,' herausgegeben von der Zoolog. Station 1883.

V. *A List of Naturalists, etc., to whom Specimens have been sent from the end of June* 1883 *to the end of June* 1884.

					Fr. c.
1883.	July	4	Dr. Pietro de Vescovi, Rome	Heads of Fishes	13·15
	,,	9	Prof. Gezá Entz, Klausenburg, for Zool. Inst.	Various	287·
			Prof. Gezá Entz, Klausenburg, for Museum	,,	287·
			College at Nagy-Enyed	Collection	160·
			,, ,, Maros-Vasarhelz	Various	74·50
			Prof. Gezá Entz, Klausenburg	Specimens for dissection	100·
	,,	14	Cand. A. Appellöf, Kristineberg, Sweden	Mollusca	30·60
	,,	15	Prof. Nussbaum, Bonn	Electrical Organs of Torpedo	6·50
	,,	16	Mr. H. C. Chadwick, Manchester	Various	31·
			Prof. A. M. Marshall, ,,	Specimens for dissection	827·35
	,,	19	Morphol. Depart., Cambridge	,, ,,	421·30
	Sept.	7	Prof. H. N. Moseley, Oxford	Various	252·55
			Prof. W. A. Herdman, Liverpool	,,	131·10
	,,	9	Prof. F. E. Schultze, Graz.	,,	14·85
			Dr. A. v. Heider, ,,	,,	6·45
	,,	23	Prof. P. W. Thomas, Auckland, New Zealand	,,	432·
	,,	28	Prof. P. Ströbell, Parma	,,	294·25
	,,	29	Mr. J. Tempère, Storrington	Spongiæ	12·50
	Oct.	14	Dr. Andreæ, Naples	Mollusca	7·35
	,,	21	Prof. R. Hertwig, Bonn	Various	386·45
	,,	24	Prof. Ehlers, Göttingen	Echinod., Cœlent	184·20
	,,	31	Prof. Rüdinger, Munich	Petromyzon	34·75
	Nov.	3	M. G. Schneider, Bâle	Collection	2,229·50
	,,	6	Prof. Kollmann, ,,	Crustacea	17·
	,,	7	Dr. L. Eger, Vienna	Various	77·25
			Dr. O. Hamann, Göttingen	Synapta	8·65
	,,	13	Prof. McIntosh, St. Andrew's U.	Various	360·50
				Annelida, Nemertina	90·55
			Dr. S. van Oye, Lille	Cœlenterata	108·40
	,,	16	Società Tecnica, Florence	Cœlent., Echinodermata.	55·55
	,,	21	Prof. A. C. Haddon, Dublin	Various	250·55
	,,	23	Prof. C. Emery, Bologna	,,	35·50
			M. E. Marie, Paris	Spirographis	23·
	,,	27	H.M. the Queen of Roumania	Small collection	
	,,	29	Prof. Hubrecht, Utrecht	Balanoglossus	
	,,	30	Prof. Kowalewsky, Odessa	Various	51·85
	Dec.	6	Prof. W. Leche, Stockholm	Annelida, Comatula	94·95
	,,	7	Prof. Yseux, U. Libre, Brussels	Collection	1,080·35
	,,	9	Dr. P. H. Carpenter, Windsor	Comatula	35·
	,,	14	Prof. W. J. Stephens, Sydney, N.S.W.	Collection	300·20
	,,	18	Rev. A. M. Norman, Durham	,,	245·45
	,,	20	Prof. H. N. Moseley, Oxford	Various	54·55
	,,	21	Queen's College, Cork	Larvæ of Crustacea	20·70
	,,	22	Dr. F. Blockmann, Heidelberg	Holothuria, etc.	112·75
	,,	23	Prof. Anderson, Queen's Coll., Galway	Sepia	45·25
	,,	28	M. E. Marie, Paris	Pennatula, Nereis	47·90
			Prof. Grenacher, Halle	Eyes of Pterotrachea	15·50
	,,	29	Prof. Richiardi, Pisa	Collection	702·70
			Dr. Boas, Copenhagen	Pteropoda	
1884.	Jan.	6	Prof. Grassi, Catania	Collection	119·
			Prof. P. Stepanoff, Charkoff	,,	116·60

					Fr. c.
1884.	Jan.	12	Mr. A. S. Pennington, Bolton	Collection	81·55
			Mr. T. J. Moore, Liverpool	,,	171·20
			Dr. Dawson, Toronto, Canada	,,	216·70
	,,	18	Dr. Vigelius, Haag	Cassiopeia	50·
	,,	21	Dr. Aug. Müller, Frankfort-on-Maine	Collection	208·
	,,	25	Mr. Ch. J. Gatty, Liverpool	Various	10·
	,,	29	Musée Zoologique, St. Petersburg	Collection	109·65
	,,	30	M. R. Prendel, Odessa	Various	50·
	,,	31	M. J. C. Puls, Ghent	Echinodermata	195·75
	Feb	4	Mr. E. P. Ramsay, Sydney	Collection	547·15
	,,	8	M. Eug. Simon, Paris	Crustacea	85·
			M. E. Marie, Paris	Various	371·95
	,,	13	Prof. Friant, Nancy	Collection	160·80
			Prof. C. Emery, Bologna	,,	107·
	,,	16	Prof. Gezá Entz, Klausenburg	,,	132·85
			Prof. J. Mahisz, Fiume	,,	145·45
			Dr. Zottau v. Roboz, Kaposvar	Serpula	5·75
	,,	21	Prof. R. Leuckart, Leipzig	Octopus, Eledone	96·
	,,	22	M. Jules Maurice, Douai	Chaetopterus, etc.	6·70
	,,	23	Dr. L. Eger, Vienna	Cecrops	6·
	,,	26	Prof. R. Moinez	Collection	203·70
			Prof. C. Emery, Bologna	Hippocampus	5·25
	,,	28	Dr. J. Kennel, Würzburg	Mollusca	13·75
	March	10	Instituto Froebel, Naples	Small collection	
	,,	17	Prof. Anderson, Queen's College, Galway	Collection	366·65
			M. K. May, Oschatz	Holothuria, Echinod.	44·55
	,,	19	Dr. L. Eger, Vienna	Cecrops	23·45
	,,	20	Cav. S. Brogi, Sienna	Mollusca	19·85
	,,	18	M. E. Pölzam, Kasan	Cestus veneris, etc.	11·
	,,	27	Dr. L. Oerley, Budapest	Collection	518·90
	,,	28	M. E. Marie, Paris	Salpæ	257·
			Società Tecnica, Florence	Collection	90·75
			Dr. H. Nussbaum, Warsaw	,,	149·35
			Dr. L. Eger, Vienna	Emys europea	13·
	April	4	Exhibition, Turin	Collection	2050·25
	,,	7	Prof. H. N. Moseley, Oxford	Amphioxus, Lepas	68·85
			Prof. G. Ciaccio, Bologna	Sygnathus, etc.	6·65
	,,	10	M. Marie, Paris	Salpæ	171·50
			Dr. Rawitz, Berlin	Avicula, Lithodomus	10·45
	,,	13	Mr. Bourne, London	Collection	400·60
	,,	18	Prof. R. Leuckart, Leipzig	,,	
	,,	24	M. Sang de Diego, Madrid	,,	822·95
	May	1	Prof. Stepanoff, Charkow	,,	189·45
	,,	5	M. zur Mühlen, Dorpat	Carcharias glaucus	25·
			Mr. H. W. Holder, Stalybridge, Manchester	Corallium, Salpa	16·
	,,	10	Zool. Kabinet, Kasan	Collection	594·25
			Museum der Acad. der Wissenschaften, St. Petersburg	Collection	531·95
	,,	19	Prof. Rüdinger, Munich	Embryos of sharks	23·
	,,	21	Prof. J. S. Blake, Nottingham	Collection	355·05
			Prof. Chun, Königsberg	,,	1422·95
	,,	23	M. Marie, Paris	Petromyzon	56·10
			Società Tecnica, Florence	Rhizostoma, etc.	33·20
			Prof. Emery, Bologna	Ophiuridea	7·
	,,	28	Prof. C. Eberth, Halle	Various	90·30
			Mr. A. S. Pennington, Bolton	Collection	173·70
	,,	31	Musée d'Histoire Nat., Geneva	,,	343·75
			Prof. C. Vogt, Geneva	,,	118·10
	June	4	Dr. Marshall, Leipzig	Tethya lyncurium	6·10

					Fr. c.
1884.	June	4	Prof. A. M. Marshall, Manchester	Collection	1,020·20
			Mr. H. C. C. Chadwick	,,	150·60
	,,	5	Mr. J. Gatty, Liverpool	Corallium rubrum	10·
	,,	16	Prof. Th. Margo, Budapest	,, ,,	33·25
			Prof. Hubrecht, Utrecht	Ascidia mentula	31·
			Dr. L. Eger, Vienna	Comatula	4·35
			M. L. Dreyfus, Wiesbaden	Corallium rubrum	44·75
	,,	23	Prof. Alb. del Prato, Parma	Mollusca	41·55
			Mr. R. Vallentin, Leytonstone	Ascidia	10·00
	,,	27	Prof. F. E. Schultze, Berlin	Collection	335·
			M. Marie, Paris	Corallium	11·70
			M. P. de Loriol, Chalet des Bois	Echinodermata	23·25
	,,	30	Prof. A. Agassiz, Harvard College, Cambridge, Mass.	Collection	1,469·
				Total	25,450·55

VI. *A List of Naturalists to whom Microscopic Preparations have been sent from the end of June* 1883 *to the end of June* 1884.

					Fr. c.
1883.	Sept.	4	Prof. Haddon, Dublin	69 preparations	100·
			Prof. Herdman, Liverpool	12 ,,	20·
			Prof. Thomas, Auckland, New Zealand	28 ,,	60·
			Prof. Yseux, Université Libre, Brussels	30 ,,	60·
	Dec.	14	Prof. Packard, Brown Univ., Providence, R. I., U.S.A.	25 ,,	50·
	,,	15	Prof. McIntosh, St. Andrews University	52 ,,	95·
			Prof. L. Camerano, Turin	50 ,,	100·
1884.	Jan.	31	Dr. A. Gravis, Brussels	33 ,,	44·
	Feb.	24	Zoological Laboratory, University, Charkow	14 ,,	26·
			Physiological Laboratory, University, Charkow	16 ,,	20·50
			Zootomical Laboratory, University, Charkow	2 ,,	4·50
			Dr. W. I. Vigelius, Haag	3 ,,	4·
	June	20	M. Ch. I. Dupont, Beauvais	8 ,,	16·
			Laboratoire de Zoologie, Nancy	7 ,,	15·
			Zootomical Cabinet, University, Kasan	61 ,,	100·
					715·

Fourth Report of the Committee, consisting of Mr. Sclater, Mr. Howard Saunders, *and* Mr. Thiselton Dyer (*Secretary*), *appointed for the purpose of investigating the Natural History of Timor Laut.*

Since our last report was presented to the Association, Mr. Forbes's botanical collection—which, from the result of an unfortunate fire in the drying-house in which the Herbarium had to be prepared, was very small, as he deplores—has been handed over to the Royal Herbarium at Kew. Of this collection Sir Joseph Hooker, at a meeting of the Royal Geographical Society on January 28, 1884, made the following remarks: 'From that time [of the appearance of Professor Decaisne's Flora Timoriensis] to this, the limits of the Australian flora, so long supposed to have been circumscribed with exactitude, have never been laid down, though it has been enormously enlarged to the north by the inclusion of the great island of Papua, which is to a great extent Australian in its biology, and by that of sundry other islets to the north-east and north-west. It is under this point of view that Mr. Forbes's collections are so important. It is true that for the most part they consist of what are generally known as *coral-island* plants. . . . But besides this there are some peculiar forms, and there are two plants of extraordinary interest which I would simply instance as being typical, one of the New Hebridean and one of the Australian flora. It so happened that these two plants belonged to unispecific genera. . . . The existence of these plants pointed to some old communication between these particular islands.' [1]

An orchid brought home in a living state has flowered at Kew, and proves to be *Dendrobium Phalænopsis*, Fitzg., hitherto only known from Queensland.

No detailed account of the ethnographical collection has yet been published; but as the collection has been deposited in the British Museum, a description of the Timor Laut objects will doubtless appear in the catalogue of the Ethnological Department, while the more interesting will be figured in Mr. Forbes's forthcoming volume. At the last meeting of the Association at Southport, Dr. J. G. Garson (Report, p. 566) read a short account of the crania (now in the British Museum) brought from Larat by Mr. Forbes, which has been published *in extenso* in the Journal of the Anthropological Institute, Vol. XIII., and which concludes with the following remarks on the relation of the inhabitants of Timor Laut to those of adjacent countries: 'That the skulls just described are not those of a pure race is very evident. Two very distinct types can be made out—namely, the brachycephalic and the dolichocephalic, the former greatly predominating in number. Both from the information Mr. Forbes has given us as to their appearance, and from the skulls themselves, there is no difficulty in recognising a strong Malay element in the population. The male skull No. 4, and the female No. 6, are typically Malayan in their characters, especially in possessing large open, rounded orbits, and smooth forehead, the superciliary ridges and glabella being almost entirely absent. The other brachycephalic skulls, though not presenting such a striking affinity, agree more or less with this type, but give evidence of mixed characters. The dolichocephalic skull is, on the other hand, markedly of the Papuan type, and corresponds so closely as to be undistinguishable from two crania obtained twenty miles inland from Port Moresby, New Guinea, in the College of Surgeons' Museum, also from another from the Solomon Islands. Along with this form of skull, Mr. Forbes informs me, is associated frizzly hair and dark skin. The examination of the cranial characters of the inhabitants of Timor Laut, as illustrated by the skulls before us, shows that the peopling of this island is no exception to what is usually found in the various groups of islands in the Polynesian Archipelago. From its close proximity to New Guinea, perhaps more of the Papuan element might have been expected.'

In addition, the *Coleoptera* sent home have been examined and described in a recent paper by Mr. C. O. Waterhouse, published in the Zoological Society's 'Proceedings.' The number of species collected was twenty-nine; of these the following deserve special notice on account of

[1] A detailed account was read at the Linnean Society, Nov. 6, 1884.

their geographical distribution: *Diaphoetes rugosus*, a new genus and species of *Staphylinidæ* known from Java; *Cyphogastra angulicollis*, only previously known from Banda; *C. splendens*, a new species allied to the preceding; *Archetypus rugosus*, belonging to a genus of Longicorns of which there was only one species previously known, which species occurs in Waigiou, Dorey, and Aru; *Nemophas forbesii* a new Longicorn nearly allied to *N. grayi* from Amboina. Further, a new species of ground thrush (*Geocichla machiki*) has been described by Mr. Forbes from additional specimens brought home by himself on his return. So that our knowledge of the avifauna of this region has been increased by the addition of twenty-four new species, entirely collected on the few square acres to which the inter-tribal wars of the natives restricted Mr. Forbes's operations.

At the presentation of our last report, Mr. Forbes, who had just returned to England, gave a short description of the region visited by him; but at the meeting of the Royal Geographical Society, to which we have referred above, he gave a more detailed account, which has been published, illustrated by a map, in their 'Proceedings' for March, embodying the geographical observations made by him.

The collections of Fishes, Crustacea, and Hydrozoa, though containing much that was of interest, added few species that were new to science.

A statement in our last report, on page 227, that 'the total expense of Mr. Forbes's expedition has amounted to 300*l*.' ought perhaps to be corrected, as we understand from Mr. Forbes that the total cost was more than double this sum.

Report of the Committee, consisting of Dr. PYE-SMITH, Professor DE CHAUMONT, Professor M. FOSTER, Professor BURDON SANDERSON (*Secretary*), *and* Mr. W. NORTH, *appointed for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen* (*the experiments to be conducted by* Mr. NORTH). *Drawn up by* Mr. NORTH.

I HAVE to report that, owing to various circumstances, I have been unable to prosecute my researches during the past year. An unforeseen difficulty has arisen with regard to the work machine; this is that it is so large that it is difficult to find laboratory accommodation for it, and the noise and vibration caused by the sudden fall of the weight is so great as to be a cause of very serious annoyance to others. I have not yet been able to find a suitable place in which to set it up, but I hope before long to be able to do so. I enclose a copy of the abstract of a paper read before the Royal Society in October last, which gives the results of my researches up to that date, and for the continuation of which the work machine has been constructed. I desire that the Committee may be reappointed.

Report of the Committee, consisting of Mr. JOHN CORDEAUX (*Secretary*), Professor NEWTON, Mr. J. A. HARVIE-BROWN, Mr. WILLIAM EAGLE CLARKE, Mr. R. M. BARRINGTON, *and* Mr. A. G. MORE, *appointed for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House and the Commissioners of Northern and Irish Lights) observations on the Migration of Birds at Lighthouses and Lightvessels, and of reporting on the same.*

THE General Report[1] of the Committee, of which this is an abstract, comprises observations taken at lighthouses and lightvessels, as well as at several land stations, on the east coast of England, the east and west coasts of Scotland, the coasts of Ireland, also the Channel Islands, Orkney and Shetland Isles, the Hebrides, Faroes, Iceland and Heligoland, and one Baltic station on the coast of Zealand, for which the Committee is again indebted to Professor Lütken, of Copenhagen. Altogether 158 stations have been supplied with schedules and letters of instruction for registering observations, and returns have been received from 102.

The best thanks of the Committee are due to their numerous observers for the generally careful and painstaking manner in which they have filled up the schedules, and the very intelligent interest taken by them in the inquiry. Special thanks must be accorded to Messrs. H. Gätke, Heligoland; H. C. Müller, Faroe; and M. Thorlacius, Skykkesholm, Iceland, for the notes sent in from their respective stations; also to Mr. J. H. Gurney, for having commenced on the south-east coast of England a similar system of inquiry, which, for a first trial, has worked well. In all doubtful cases of identity, where birds are killed against the lanterns, a wing is cut off, and a label with the date attached. These have been forwarded in batches to Mr. Gurney for identification, and with most satisfactory results.

The Committee regret that for the second year in succession they have received no report from the west coast of England. A late member of the Committee, Mr. Philip M. C. Kermode, having failed to make any returns, or to send the collected schedules, although repeatedly requested, to Mr. W. E. Clarke, who had undertaken the work of tabulating and reporting on the same, provision has been made by the Committee for supplying the deficiency in any subsequent years.

The observations taken on the east coast of Great Britain in 1883 have been such as generally to confirm the conclusions arrived at in former reports, having reference to direction of flight and lines of migration.

The winter of 1883–4 has been exceptionally mild, and there has been an almost entire absence of severe frosts and lasting snowstorms; the prevailing winds in the autumn, west and south-west, such as observation shows are most favourable for migrants crossing the North Sea and continuing their journey inland. Winds from opposite quarters to these tire out the birds and cause them to drop directly they reach land. Our land stations report a great scarcity both of land and sea birds;

[1] *Report on the Migration of Birds in the Spring and Autumn of* 1883. West, Newman & Co., 54 Hatton Garden, London, E.C.

this has not, however, been the case at sea stations—that is, lightvessels moored off the coast, at distances varying from five to fifty miles. Here the stream of migration, so far from showing any abatement, has flown steadily on in a full tide; and, if we judge from the well-filled schedules which have been returned, there has been a considerable increase in the visible migration, due perhaps in some measure to increased interest and improved observation. Mr. William Stock, of the Outer Dowsing lightvessel, remarks that he had never before seen so many birds pass that station; the rush, also, across and past Heligoland in the autumn was enormous. Migration is more marked, as well as concentrated there, than at any station on the English coast. There was a great movement of various species passing forward on the 6th and 7th of August, and again on the 14th, and more pronounced still on the 21st and 22nd, and on the 20th of August a similar movement was noticed at the Isle of May, at the mouth of the Firth of Forth. It was not, however, until September 21st and the two following days that the first great rush occurred on the English east coast, and a similar great movement or rush is indicated, at the same date, in Mr. Gätke's notes, as well as from the most distant of the lightships. The prevailing winds over the North Sea on September 21st were moderate north-easterly and easterly off the coasts of Denmark and Holland, blowing strong easterly on to the coast north of the Humber, with southerly and south-westerly off the south-east coast, producing cross-currents over the North Sea. Whatever was the impulse, atmospheric or otherwise, which induced such a vast rush of various species at this time, it was one which acted alike, and with precisely the same impulse, on the sea-eagle and the tiny goldcrest.

The second great rush was on October 12th and 13th, a similar movement being recorded at Heligoland. Then, again, from the 27th to the 31st, and somewhat less through the first week in November, the passage across Heligoland, as well as the rush on our east coast, was enormous. Speaking of the nights from the 27th to the 31st inclusive, Mr. Gätke says: 'This was the first move by the million; for four nights there has been a gigantic feathery tide running.' During this time there were variable winds over the North Sea, but generally easterly and south-easterly on the Continent, strong west winds and squalls prevailing generally on November 5th and 6th.

Again, with the outburst of some severe weather in the first week in December, a considerable local movement is indicated along the coast from north to south, culminating in the enormous rush of snow-buntings into Lincolnshire about the end of the first week in that month. A careful perusal of the report will show how generally the rushes across Heligoland correlate with those on the east coast of England, although not always confined to identical species.

A somewhat remarkable and very anomalous movement of migrants is recorded from lightvessels off the Lincolnshire and Norfolk coasts in the spring of 1883. In February, March, April, and May, birds passing the Leman and Ower, Llyn Wells, Outer Dowsing, Newarp and the Cockle lightvessels, were, as a rule, coming from *easterly* and passing in *westerly* directions. The entries show a great immigration of our ordinary autumn migrants from the east in the spring months, and on exactly the same lines and directions as are travelled by the same species in autumn. Had this movement been observed at one station only, we might perhaps have been induced to doubt the accuracy of the return, but the fact of five lightvessels, having no communication with each other, reporting the same circumstances, proves the correctness of the observations.

On the east coast of Scotland Mr. J. A. Harvie-Brown says that the autumn migration of 1883 was pronounced, culminating in a grand rush from October 28th to November 3rd. The heaviest rush of birds, as compared with other years, was observed at the Isle of May on October 13th and 14th. This was with a south wind, although as a rule it is a south-east wind at that point which brings the greatest flights.

In the autumn of 1882, on the east coast of Scotland, the bulk of immigrants are recorded at the southern stations; in 1883 these conditions were reversed, the bulk being recorded from northern stations. On the east coast of England, in 1883, birds appear to have been very equally distributed over the whole coast-line. It will be gathered from the General Report that the dates of the rushes on the east coast of Scotland were slightly later than those on the east coast of England, and that the migrations past the more northerly stations in Scotland were in proportion later than in the south, and also that the dates of the heaviest rushes on the east coast agree fairly with the dates from the west coast.

From the coasts of Ireland Messrs. A. G. More and R. M. Barrington report a decided improvement in filling up the schedules, in some cases three or four being returned from the same station. Forty-two stations were supplied with schedules in the spring of 1883 and thirty-five in the autumn of the same year, returns coming in from thirty-four, one only failing.

The number of migrants in the autumn seems to have been more than usual. A great rush of thrushes (including, probably, redwings), blackbirds, and starlings, took place at the south-eastern and southern stations between October 25th and November 2nd—dates which agree with the great rush on the east coast of England. The migration was particularly marked at the Tuskar rock off the Wexford coast, which is proving itself the best Irish station, and no doubt marks the line of the chief passage from the British coast. The bulk of the immigrants appear to arrive on the south-eastern coast of Ireland, excepting such birds as the bernicle goose and snow-bunting, which are mainly recorded from north-western stations, and rarely entered in schedules from the east or south coast.

An interesting feature this year is the occurrence of several examples of the Greenland falcon on the west coast, no less than eight having been shot at various points from Donegal to Cork and one Iceland falcon at Westport.

Independent of the ordinary notes on migration, the general remarks of the lightkeepers with reference to the nesting of sea-fowl on the islands or outlying skerries are of great interest, and no matter what results are arrived at from this special inquiry, it is satisfactory to be in correspondence with such a number of observers at isolated spots around the coast, and the information supplied cannot fail to be of much interest to future compilers.

An interesting feature of the autumn migration is the occurrence of a flight of the blue-throated warbler (*Cyanecula suecica*). A single adult with bright-blue breast was observed at the Isle of May on the night of September 2–3rd. On the east coast of England twelve were obtained, all being birds of the year, and of these nine on the coast of Norfolk, besides about twenty others seen by competent observers. Very few goldcrests, compared with the enormous flights of the autumn of 1882, have appeared, and the same scarcity is observable in the Heligoland returns. Curiously enough, the hedge-sparrow (*Accentor modularis*), which migrated in immense numbers in the same autumn, has been almost entirely absent. About half a dozen are recorded at Heligoland, none on the east coast of England.

Of the enormous immigration which crosses our east coast in the autumn, either to winter in these islands or merely on passage across them, a small proportion only appear to return by the same routes. Spring returns from lighthouses and lightvessels show birds then move on the same lines as in the autumn, but in the reverse direction. These return travellers do not, however, represent anything like a tithe of the visible immigrants which, week after week and month by month in the autumn, move in one broad stream on to the east coast.

What is called the 'first flight' of the woodcock arrived on the Yorkshire, Lincolnshire, and Norfolk coasts on the night of October 21st. The 'great flight,' or rush, which covered the whole of the east coast from the Farne islands to Yarmouth was on the nights of the 28th and 29th. These two periods correlate with the principal flights of woodcock across Heligoland.

But few woodcock were recorded from stations on the east coast of Scotland, although at the Bell Rock lighthouse, on the night from October 31st to November 1st, Mr. Jack reports an enormous rush of various species, commencing at 7 P.M. Immense numbers were killed, pitching into the sea. 'What we thought were woodcocks struck with great force; birds continued flying within the influence of the rays of light till the first streak of day, continually striking hard all night; we believe a great number of woodcocks struck and fell into the sea.'

Mr. Harvie-Brown records a very great spring migration of woodcocks which appear to have crossed Scotland between the Clyde and the Forth on March 9th, 10th, 11th, and 12th, 1884. These were observed to be the small red Scandinavian bird, which are quite unmistakable and distinct from British-bred birds.

The occurrence of *Locustella fluviatilis* at the Stevns lighthouse at the entrance of the Oresund in Zealand is interesting, as it is the first recorded Danish example of this species.

Altogether there has been a very marked absence on our British coasts of rare and casual visitants. The roller (*Coracias garrula*) occurred in October in two localities—one in Lincolnshire, the other in Suffolk.

Two examples of the sooty shearwater (*Puffinus griseus*) were obtained in Bridlington Bay about the end of September. The island of Heligoland retains its pre-eminence as the casual resting-place of rare wanderers from other lands; and Mr. Gätke's list for 1883 includes *Turdus varius*, *Pratincola rubicola*, var. *indica*, *Phylloscopus superciliosus*, *Hypolais pallida*, *Motacilla citreola*, *Anthus cervinus*, *A. Richardi*, *Oriolus galbula*, *Lanius major*, *Muscicapa parva*, *Linota exilipes*, *Emberiza melanocephala*, *E. cirlus*, *E. rustica*, *E. pusilla*, *Pastor roseus*, and *Xema Sabinii*.

It is well known that large numbers of European birds, presumably driven out of their course, are seen, during the autumn migration, far out over the Atlantic, alighting on the ocean-going steamers. It is proposed by Mr. Harvie-Brown to supply schedules to the principal lines of ocean steam-vessels for the better recording of these occurrences. It must be borne in mind that the immense and constantly-increasing traffic, which in these days bridges the Atlantic and unites the Old and New Worlds, offers unusual chances for birds to break their flight, and ultimately, perhaps, to reach the American coast. In the comparatively narrow seas between the European continent and Great Britain birds are frequently noted as alighting on the rigging of vessels and lightships, roosting in the rigging during the night, to resume their flight at the first streak of dawn.

It is a matter of congratulation that our American and Canadian fellow-workers have instituted a similar system of observation on the migration of birds. At the first Congress of the American Ornithologists' Union, held at New York City, September 26–28, 1883, a Committee on the Migration of Birds was appointed. It is intended to investigate this in all its bearings, and to the fullest possible extent, not only in the accumulation of records of the times of arrival and departure of the different species, but to embrace the collection of all data that may aid in determining the causes which influence migration from season to season.

Your Committee respectfully request their reappointment, and trust that the Association will enable them to continue the collection of facts.

Report of the Committee, consisting of Professor NEWTON (*Secretary*), Professor LANKESTER, *and* Professor GAMGEE, *appointed for the purpose of preparing a Bibliography of certain Groups of Invertebrata.*

THE Committee beg leave to report that the work, compiled by Mr. D'Arcy W. Thompson, B.A., Scholar of Trinity College, Cambridge, though not yet completed, is in a forward state. The whole of the part relating to *Protozoa*, and nearly the whole of that relating to *Spongida*, have been printed off, while a large portion (Sections A to L inclusive) relating to *Cœlenterata* is in type, and the remainder is reported by him to be ready for press.

The Committee cannot but regret the non-completion of the Bibliography by the time originally expected; but they are satisfied that the delay has been in great measure due to causes which will contribute largely to the value of the work; and the Committee have most thankfully to acknowledge the important services to this end kindly rendered by Mr. H. B. Brady, F.R.S., Professor Häckel, Professor Wyatt, of Boston, and Professor Alleyne Nicholson.

The printing of the work has been liberally undertaken by the Press Syndicate of the University of Cambridge, and it will form a volume of about 300 pages.

The Committee herewith transmit a copy of the portions already in type (five sheets and twenty-six slips), whence will be perceived the laborious nature of the work, as well as the effective way in which it has been done.

Report of the Committee, consisting of Sir JOSEPH HOOKER, Dr. GÜNTHER, Mr. HOWARD SAUNDERS, *and* Mr. P. L. SCLATER (*Secretary*), *appointed for the purpose of exploring Kilima-njaro and the adjoining mountains of Eastern Equatorial Africa.*

1. THE Committee have the satisfaction of announcing that they have made arrangements with Mr. H. H. Johnston (who has recently returned from the Congo) to undertake an exploration of Kilima-njaro, and that he is probably by this time encamped upon that mountain.

2. The Committee have arranged with Mr. Johnston to undertake the whole cost of the expedition for 1,000*l.*, without reference to personal remuneration. It is believed that the necessary expenditure will not be covered by this sum, but Mr. Johnston has agreed to make good any deficiency.

3. Towards this sum of 1,000*l.*, the Committee have appropriated a sum of 500*l.*, granted to them by the Association at their last meeting at Southport. The Committee have also received from the Government Grant Committee of the Royal Society two sums of 250*l.* each, so that the whole amount of 1,000*l.* required for the expedition is already available.

4. But looking forward to the risks of African travel, and to the expenditure likely to be incurred on the transport to this country, and on the working out of the collections obtained by Mr. Johnston, the Committee trust that a further sum of fifty pounds may be placed at their disposal.

5. A copy of part of Mr. Johnston's last letter to the Secretary of the Committee, containing an account of the progress of the expedition, is annexed to this Report.

Extracts from a letter from Mr. Johnston to Mr. Sclater, dated British Residency, Zanzibar, May 13, 1884:—

'At last my expedition, thanks to the help of Sir John Kirk, is organised and ready to start. I have engaged thirty-two men here (at Zanzibar), and have sent them off to Mombasa in a daw to await my coming. I myself leave to-day for Mombasa in the mail. At Mombasa, through the Consul (Captain Gissing), I have engaged sixty more men, for it will need nearly a hundred porters to carry my goods and baggage to Chagga. I hope to leave Mombasa in a fortnight's time. I anticipate three weeks' easy travel to Kilima-njaro, and, as far as it is possible to foretell aught in Africa, no serious difficulties seem to stand in my way. The expedition, however, will prove much more costly than I had anticipated. . . . .

'However, I think I shall be able to make both ends meet for six months on Kilima-njaro, and if I stay longer, or make a dash at Kenia, it will be on my own account. I shall *probably* make Taita or Teita (*vide* map) a half-way house, and go backwards and forwards with collections and goods. I shall try to forward collections addressed to you by *every mail* if feasible. Then, if you judge of the value, and estimate that my share of the collections will realise a good amount, it will induce me to devote more time to the country.

'My health, notwithstanding a much more trying climate than I have yet met with in Africa, has been very good, and I have not known an hour's illness or indisposition. Sir John Kirk has shown me the utmost kindness and hospitality, and his help and his influence have smoothed away many difficulties. The expedition promises most favourably, as the present condition of the countries to be traversed is good and peaceful, food abundant, and provisions cheap. . . . .

'I have obtained the services of three of Dr. Fischer's bird-skinners, and have got one botanical collector, trained under Sir John Kirk, and acquainted with the mysteries of "soldering" and preserving in spirit. I have sent for rectified spirit from Bombay, and in the interval am using trade gin. The Sultan has given me three kegs of gunpowder to give as presents to chiefs, and has also furnished me with letters of introduction.

'I am in excellent condition, and start to-day on my journey in the best spirits and with the strongest hopes of its success.'

Report of the Committee, consisting of the Rev. Canon TRISTRAM, *the* Rev. F. LAWRENCE, *and* Mr. JAMES GLAISHER (*Secretary*), *for promoting the Survey of Eastern Palestine.*

THE Committee proceed to give an abridged account of the scientific results of the expedition conducted by Professor Hull, in the winter of 1883–84. These, in fact, are the results of their labours since the last meeting of this Association. Professor Hull reports as follows:

'The Committee of the Palestine Exploration Fund, in the summer of 1883, resolved upon sending out an expedition to examine the geological structure of the Jordan valley and Western Palestine, together with that of the valley of the Arabah, with a view to determine the mode of their formation and physical history. It was also intended to connect the triangulation of the district of Mount Sinai (Jebel Musa) with that of Western Palestine along the district of the Wâdy el Arabah; and to determine the elevation above the sea of the watershed (or "saddle") of that valley, with reference to the practicability of the projected "Jordan Valley Canal Scheme." Several collateral objects were also kept in view —such as the investigation of the sites of Ezion-geber, Kadesh-barnea, and other localities connected with the Israelitish migration and history; but in this place only the scientific aspects of the expedition will be referred to.

'Besides the author, who was put in command of the expedition, the other members were Major Kitchener, R.E., and Mr. Armstrong (formerly Sergeant-Major, R.E.), who joined us in Egypt; Mr. H. C. Hart, Trin. Coll., Dublin, who had been a member of Captain Nares' Polar Expedition, and now joined as botanist and naturalist; Mr. Reginald Lawrence, Associate of the Royal College of Science, Dublin, who acted as meteorologist; and Dr. E. Gordon Hull, who was appointed assistant and medical officer.[1]

'The arrangements for providing camels, tents, food, and supplies were undertaken gratuitously by the well-known firm of Messrs. T. Cook &

[1] Mr. Hart has considerably added to the recognised flora of the district traversed, and Mr. Lawrence has furnished a daily register of the temperature and aneroid readings. Dr. E. G. Hull brought home a large number of photographs.

Son, to whom it is only due to say that they did everything in their power for the comfort and safety of the members of the expedition. A rendezvous of the whole party, including conductor, dragoman, and Arabs of the Towara tribe, took place at Cairo on the 7th of November, 1883, and on Monday, the 11th of the same month, the party started for their desert journey from Moses' Wells (Ayun Musa), near Suez.

'The route taken lay along the plain bordering the Gulf of Suez to Wâdy Gharandel, and thence by the Wâdies Hamr, Suwig, and Nasb, Bark, Lebwey, Berrah, and Es Sheikh, to the base of Mount Sinai (Jebel Musa). Thence, after a few days, in a north-easterly direction by the Wâdies Zelegah, Biyar, El Ain, Et Tihyah, and Ras en Nakb to Akabah.

'Here the Arabs of the Towara tribe who had conveyed the party thus far were dismissed; and arrangements were entered into with the Sheikhs of the Alowîns for a convoy along the Wâdy el Arabah to Petra, and the shore of the Salt Sea (Bahr Lut). This having been effected, the party left Akabah on the 3rd of December; and after visiting Petra, Mount Hor (Jebel Haroun), and several of the branching valleys on either side, reached Es Safieh on the 17th of the same month, and camped by the village of the Ghawarnehs, where they remained ten days, including Christmas Day. Horses and mules having at length arrived from Jerusalem, accompanied by a small escort of Turkish cavalry, the party crossed to the western shore of the Salt Sea, and after examining Khasham (or Jebel) Usdum (the salt mountain), ascended by the Wâdy Zuweirah towards the table-land of Southern Palestine, camping successively at Wâdy el Abd, Tel el Melh, Bir es Saba (Beersheba), Tel Abu Hareireh, and reaching Gaza on the last day of the year. Here the party would have been obliged to remain in quarantine for fifteen days but for the friendly offices of Lord Dufferin, the British Ambassador at Constantinople, who procured their release on the morning of the fifth day. They then proceeded onwards by Jaffa to Jerusalem, whence excursions were made to the Jordan Valley, and other places around, and by which two complete traverses of Southern and Central Palestine were effected. The whole distance traversed was about 700 miles, of which 500 miles were on camel-back, the remainder on horseback. A final expedition through Northern Palestine was then arranged for, but was brought to an end by a heavy fall of snow, which covered the whole of the table-land of Palestine to a depth of two feet and upwards. The party left Jaffa on their return to England on Friday, January 25, Major Kitchener having previously returned to Egypt.

'*Scientific Results.*—Before proceeding to give an outline of the scientific results of the expedition, the author desires to express his obligations to the writings of previous explorers in the same field, especially to those of Russeger, Fraas, Tristram, and of MM. Lartet and Vignes, of the expedition carried out by the Duc de Luynes.

'1. A complete triangulation of the district lying between the mountains of Sinai and the Wâdy el Arabah, including that of the Wâdy el Arabah itself, bounded on the west by the table-land of the Tîh, and on the east by the mountains of Edom and Moab. An outline survey along the line of route was also made, and has been laid down in MS. on a map prepared by Mr. Armstrong on the same scale as the reduced Map of Palestine, viz. $\frac{3}{8}$ inch to one statute mile, or $\frac{1}{168960}$.

'2. Some important rectifications of the borders of the Salt Sea, and of the Gulf of Akabah, were also made.

'3. A geological reconnaissance along the line of route through the districts of Sinai, Akabah, and the Wâdy el Arabah, including the following particulars:—

'(a) Collections of fossils from the Wâdy Nasb limestone, in addition to those already made by Mr. Bauerman and Colonel Sir C. W. Wilson. These fossils (which are being examined by Professor Sollas) go to show that this limestone is of carboniferous age: the Wâdy Nasb limestone was found to continue over a considerable region north of Mount Sinai, and was again recognised amongst the mountains of Moab on the east side of the Salt Sea in the Wâdy el Hessi. As this limestone rests upon a red sandstone foundation, this latter may also be assumed to be of the same geological age, and therefore cannot be the representative of the "Nubian sandstone" of Russeger, which (as Professor Zittel has shown) is of cretaceous age. I propose to call this formation, therefore, "the Desert Sandstone." It forms with the limestone a strip along the borders of the ancient rocks of palæozoic or archæan age, and is about 400 feet in average thickness: the base is generally a conglomerate.

'(b) Above the Wâdy Nasb limestone is another sandstone formation, of which a large portion of the Debet er Ramleh is formed. It is laid open in the Wâdies Zelegah, Biyar, &c., and along the mountains of Edom and Moab. Out of this rock have been hewn the ancient temples, tombs, and dwellings of Petra and the Wâdy Musa. It stretches along the southern escarpment of the Tîh plateau, and forms the base of the limestone cliffs along the margin of the Wâdy el Arabah as far north as Negeb es Salni. This sandstone formation is soft, red, or beautifully variegated, and is in all probability of cretaceous age, and therefore the true representative of the "Nubian sandstone" of Russeger. It will thus be seen that there are two red sandstone formations, one below, the other above the carboniferous limestone of the Wâdy Nasb.

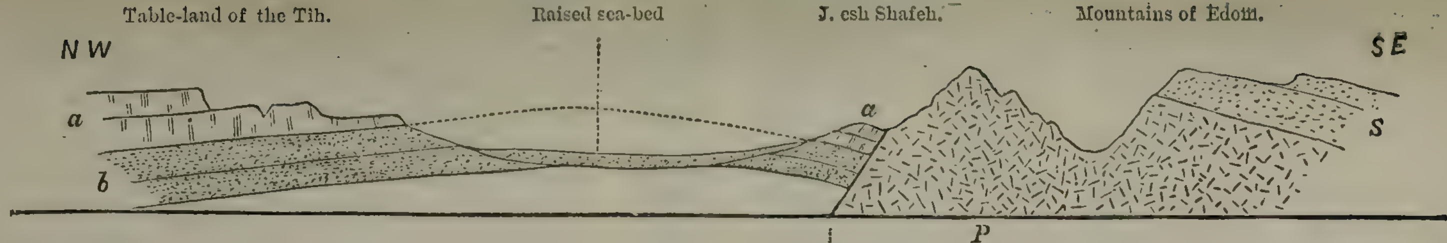
'(c) The geological structure of the Wâdy el Arabah was examined throughout a distance of 120 miles from south to north. That it has been hollowed out along the line of a main fault, ranging from the eastern shore of the Salt Sea to that of the Gulf of Akabah, was clearly determined; and the position of the fault itself was made out and laid down on the map [1] in six or seven places, one being about ten miles north of Akabah, another near the watershed, in which places the limestone of the Tîh (cretaceo-nummulitic) is faulted against the old porphyritic and metamorphic rocks. I give on the next page two sketch sections to illustrate the structure at these points.

'There are numerous parallel and branching faults along the Arabah Valley, but there is one leading fracture running along the base of the Edomite mountains, to which the others are of secondary importance; this may be called "the Great Jordan Valley fault." The relations of the rocks in the Ghor and Jordan Valley have already been shown by Lartet, Tristram, Wilson, and others, to indicate the presence of a large fault corresponding with the line of this remarkable depression, and the author considers the fracture he has observed in the Arabah Valley to be continuous with that of the Jordan.

'(d) The ancient rocks which form the floor either of the Desert or Nubian sandstone formations consist of granite, gneiss, porphyries, and more rarely metamorphic schistose rocks—together with volcanic rocks,

[1] The map used was an enlarged plan from Smith and Grove's Ancient Atlas (J. Murray).

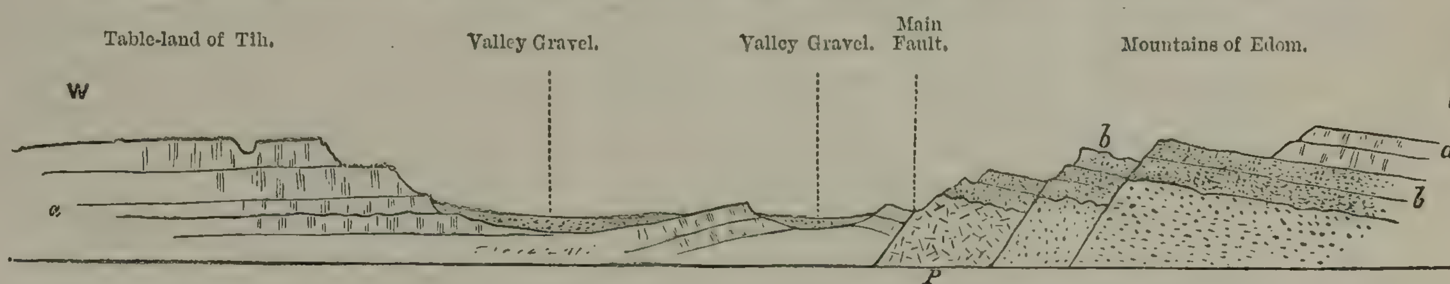
SKETCH SECTION ACROSS THE WÂDY EL ARABAH.



a Cretaceous Limestone resting on
b Nubian Sandstone, forming an arch under the valley.

Desert and Nubian Sandstone, resting on Granite and Porphyry.

SKETCH SECTION ACROSS THE WÂDY EL ARABAH, SHOWING ITS STRUCTURE NEAR THE WATERSHED, OR SADDLE.



a Cretaceous Limestone with Chert.

a Cretaceous Limestone.
b Nubian Sandstone.
P Porphyry and Granite Dykes.

consisting of agglomerates, tuffs, and beds of felspathic trap. The author is disposed to concur with Dr. Lartet in considering the gneissose and granitoid rocks to be of archæan (or Laurentian) age, as they are probably representative of those of Assouan in Upper Egypt, which Principal Dawson has recently identified with those of this age. The granites and porphyries are traversed by innumerable dykes of porphyry and diorite, both throughout the Sinaic mountains and those of Edom and Moab; and the author considers it probable that the volcanic rocks which are largely represented along the base of Mount Hor, and of Jebel Somrah near Es Safieh, are contemporaneous with these dykes. As far as the author was able to observe, none of these dykes penetrate the Desert or Nubian sandstones, and if so, they may be considered of pre-carboniferous age. The upper surface of the ancient rocks was extremely uneven previously to the deposition of the Desert sandstone, having been worn and denuded into ridges and hollows; over this irregular floor the sandstone strata were deposited.

'4. The occurrence of terraces of marl, gravel, and silt, through which the ravines of existing streams have been cut at an elevation (according to aneroid determination) of about 100 feet above the level of the Mediterranean, was taken to show that the level of the Salt Sea (Bahr Lut) at one time stood about 1,400 feet higher than at present. These beds of marl were first observed at the camp at Ain Abu Beweireh; they contain blanched shells of the genera *Melanopsis* and *Melania*. The beds of marl were observed to be enclosed by higher ground of more ancient strata in every direction except towards the north, where they gently slope downwards towards the borders of the Ghor, and become incorporated with strata of the 600-feet terrace.

'The author concurs with Dr. Lartet in thinking that the waters of the Jordan Valley did not flow down into the Gulf of Akabah after the land had emerged from the sea; the disconnection of the inner and outer waters was very ancient, dating back to Miocene times.

'The occurrence of beds of ancient lakes, consisting of coarse gravel, sand, and marl, amongst the mountains of Sinai, and in the Wâdy el Arabah, where now only waterless valleys occur, taken in connection with other phenomena, have impressed the author with the conviction that the former climatic conditions of Arabia Petræa were very different from those of the present day. Such terraces have been observed by Dr. Post in the Wâdy Feirân, and Colonel Sir C. W. Wilson in the Wâdy Solaf, and by the author in the Wâdies Gharandel, Goweisah, Hamr, Solaf, and Es Sheikh or Watiyeh. It would appear that, at a period coming down probably to the prehistoric, a chain of lakes existed amongst the tortuous valleys and hollows of the Sinaitic peninsula. The gypseous deposits of Wâdy Amarah and of 'Ain Hawareh are old lake beds, and Mr. Bauerman has observed remains of fresh-water shells (*Lymnæa truncatula*) and a species of *Pisidium* in "lake or river alluvium" of the Wâdies Feiran and Es Sheikh.[1]

'7. The author considers it probable that these ancient Sinaitic lakes belong to an epoch when the waters of the Mediterranean and the Red Sea rose to a level considerably higher than at present, and when, consequently, there was less fall for the inland waters in an outer direction. The evidence of a submergence, to a depth of at least 200 feet, is abundantly

[1] *Quart. Jour. Geol. Soc.*, vol. xxv. p. 32.

clear in the occurrence of raised beaches or sea beds with shells, corals, and crinoids of species still living in the adjoining waters. The raised beaches of the Mediterranean and Red Sea coasts have been observed by the officers of the Ordnance Survey, and by Fraas, Lartet, Schweinfurth, Post, and others. They were observed by the author at the southern extremity of the Wâdy el Arabah, and shells and corals were found round the camp of December 3 at an elevation of about 130 feet above the Gulf of Akabah.

'These ancient sea beds are represented in the Egyptian area by the old coast-line of 220 feet, discovered by Fraas along the flanks of the Mokattam Hills above Cairo, and recently described by Schweinfurth.[1] The period in which the sea rose to this level may be stated in general terms as the Pliocene, but it continued downwards till more recent times; and the author believes that at the time of the Exodus the Gulf of Suez reached as far as the Great Bitter Lake,[2] a view in which he is supported by Principal Sir W. Dawson. It is scarcely necessary to observe that through the longer portion of this period of submergence Africa was disconnected from Asia.

'8. The Miocene period is not represented by any strata throughout the district traversed by the expedition. The author considers that in this part of the world the Miocene period was one of elevation, disturbance, and denudation of strata, not of accumulation. To this epoch he refers the emergence of the whole of the Palestine, and of the greater part of the Sinaitic area from the sea, in which the cretaceo-nummulitic limestone formations were deposited. To this epoch also he considers the faulting and flexuring of the strata is chiefly referable; and notably the formation of the great Jordanic line of fault, with its branches and accompanying flexures in the strata—which are very remarkable along the western sides of the Ghor. These phenomena were accompanied and followed by extensive denudation, and the production of many of the principal physical features of the region referred to.

'9. The evidences of a Pluvial period throughout this region are to be found (*a*) in the remains of ancient lake beds, (*b*) in the existence of terraces in the river valleys, (*c*) in the great size and depth of many valleys and gorges, now waterless except after severe thunderstorms, and (*d*) in the vastly greater size of the Salt Sea (or Dead Sea), which must have had a length of nearly 200 English miles from north to south at the time when its surface was at a higher level than that of the Mediterranean at the present day. The author considers that this Pluvial period extended from the Pliocene through the post-Pliocene (or Glacial) down to recent times. As it is known, from the observations of Sir J. D. Hooker, Canon Tristram, and others, that perennial snow and glaciers existed in the Lebanon during the Glacial epoch, the author infers that the adjoining districts to the south of the Lebanon must have had a climate approaching that of the British Isles at the present day; and that, in a region of which many parts are over 2,000 feet in elevation, there must have been abundant rainfall. Even when the snows and glaciers of the Lebanon had disappeared, the effects of the colder climate which was passing away must have remained for some time, and the vegetation must have been more luxuriant down to within the epoch of

[1] *Ueber die geol. Schichtengliederung d. Mokattam bei Cairo; Zeitsch. d. Deut. geol. Gesell.* 1883.

[2] *Quarterly Statement*, April 1884.

human habitation. The author's views generally coincide with those of Theobald Fisher, as extended by him to a much wider area.[1]

'10. The author considers that there are reasons for concluding that the outburst of volcanic phenomena in North-eastern Palestine in the region of the Jaulan and Hauran, &c., has an indirect connection with the formation of the great Jordan Lake of the Pluvial period. The presence of water in considerable volume is now recognised as necessary to volcanic activity, and the author submits that this interdependence was brought about when the waters of the lake stretched as far north as the little Lake of Huleh. These waters, under a pressure of several hundred feet, would find their way into the interior of the earth's crust along the lines of the great Jordan Valley fault and of its branches, and thus supply the necessary "steam-power" for volcanic action. The period when the volcanoes of the Jaulan and Hauran were in action appears to have ranged from the Pliocene through the post-Pliocene to the beginning of the recent; when, concurrent with the falling away and partial drying up of the waters of the great lake, the volcanic fires became extinct, and the great sheets of basaltic lava ceased to flow.

'If these views are correct, it would seem that during the Glacial epoch Palestine and Southern Syria presented an aspect very different from the present. The Lebanon throughout the year was snow-clad over its higher elevations, while glaciers descended into some of its valleys. The region of the Hauran, lying at its southern base, was the site of several extensive volcanoes, while the district around, and the Jordan Valley itself, was invaded by floods of lava. A great inland sea, occupying the Jordan Valley, together with the existing comparatively restricted sheets of water, stretched from Lake Huleh on the north to a southern margin near the base of Samrat Fiddân in the Wâdy el Arabah of the present day, while numerous arms and bays stretched into the glens and valleys of Palestine and Moab on either hand. Under such climatic conditions, we may feel assured, a luxuriant vegetation decked with verdure the hills and vales to an extent far beyond that of the present, and amongst the trees, as Sir J. D. Hooker has shown, the cedar may have spread far and wide.

'11. The author has not thought it necessary to go into the question of the origin of the salinity of the Salt Sea, as this question is now fully understood. He is obliged to differ from Dr. Lartet in his view of the origin of the salt mountain, Jebel Usdum,[2] which he (the author) regards as a portion of the bed of the Salt Sea when it stood about 600 feet above its present level. This level exactly corresponds to that of the terraces, both along the south and east of the Ghor, formed of lacustrine materials. The upper surface of Jebel Usdum was examined by Messrs. Hart and Laurence, of our party, but previous explorers have considered the sides inaccessible.

'12. The author concurs with previous writers in considering that the Cretaceous and Tertiary periods succeeded each other over this region (at least as far as the marine deposits are concerned) without any important physical disturbances; in consequence of which the limestone formations of these periods are in physical conformity and are generally incapable of

[1] *Studien über das Klima der Mediterrischen Länder*, Peterman's Mittheilungen, 1879.

[2] Lartet regards the strata of this mountain as belonging to the Nummulitic period.

separation. It seems probable, however, that while the Nummulitic limestones predominate in the Egyptian and Nubian areas, those of the Cretaceous period were more fully developed over the area of Arabia Petræa and Palestine.

'The scientific results of which the above is a summary are intended to be published *in extenso* by the Palestine Exploration Fund, together with a geological map of the whole district, and one on a larger scale of Wâdy el Arabah. The popular narrative of the expedition will appear before the close of the year.'

Report of the Committee, consisting of Mr. BRABROOK (*Secretary*), Mr. FRANCIS GALTON, Sir RAWSON RAWSON, *and* Mr. C. ROBERTS, *appointed for the purpose of defraying the expenses of completing the preparation of the final Report of the Anthropometric Committee.*

THE members of the Committee report:—

1. That they have met and have applied the 10*l.* voted to them in payment to Mr. J. Henry Young for his assistance in the calculation of the tables in the final report.

2. That they have received from Dr. C. K. Ord, R.N., Dr. Power, of Her Majesty's Convict Prison at Portsmouth, and other gentlemen, additional information and suggestions of new branches of inquiry. Dr. Ord's observations have been published in the annual report of the West Kent Natural History, Microscopical, and Photographic Society. Observations on Eyesight, and a Scale of Physical Proportions, by Mr. Charles Roberts, are appended to this report.

3. That they have had brought under their notice from many quarters evidence of the interest which the work of the Anthropometric Committee has excited, and of the desire to follow it up.

4. That they recommend, therefore, that a small committee should be reappointed for the purpose of continuing and promoting the collection of Anthropometric observations.

Observations on Eyesight, contributed by Mr. C. Roberts.

Much unnecessary alarm has been caused in this country by the publication of observations made in Germany on the deteriorating influences of certain occupations, and especially of school and college life, on the eyesight of children and young persons. The statistics collected by the Anthropometric Committee, though not so numerous as could be wished, show that no such deterioration occurs in England, but, on the contrary, that between ages 10 and 40 years a slight improvement takes place, a result which might be expected from the operation of the physiological law that the function of an organ increases with its use. As no English statistics of eyesight bearing on this subject have been published, the following may be acceptable.

Observations were made by means of the Army test-dots on all classes of the population following town and country occupations. The test-dots were devised as a minimum test,[1] but as a maximum test they are visible (theoretically) at a distance of 57 feet, and owing to this great range are not well adapted for testing the sight of persons living in towns, where large well-lighted rooms, suitable for making the examinations, are difficult to find. Instead, therefore, of using the whole of the returns sent in, one thousand observations, which are known to have been taken under the proper conditions of space and illumination, are made use of, with the following results:—

OBSERVATIONS ON THE EYESIGHT MADE WITH THE ARMY TEST-DOTS ON 1,000 MALES OF THE AGES FROM 15 TO 65 YEARS.

	Feet	Feet	Per cent.
Theoretical distance at which the dots are visible . . .	57·0		
Mean or most frequent distance observed	57·5 +	0 5	
Average distance of total number ,, ...	50·2 −	7·3	= 12·7.
,, ,, at ages between 15 and 40 years observed	50·8 −	6·7	= 11·7
,, ,, ,, ,, 40 ,, 65 ,, ,, . .	46·7 −	10·8	= 18·8
,, ,, of total country population observed . .	51·9 −	5·6	= 9·7
,, ,, ,, town ,, ,, . . .	50·0 −	7·5	= 13·0

The agreement between the calculated and the *mean* observed distance shows that the examinations were made under the proper conditions of space and light. The *average* shows a deficiency of eyesight, which, when distributed over the whole number of persons examined, reduces the distance to 50·2 feet, or 7·3 feet (12·7 per cent.) below the normal standard. The deficiency of sight below the age of 40 years is 6·7 feet (11·7 per cent.), and above that age 10·8 feet (18·8 per cent.), showing that it is largely due to the natural degeneracy of the sight from advancing age. The average sight of the country population is a little better than that of towns, but this may be attributable in some measure to the more favourable conditions under which the examinations were made; the difference is about 2 feet in favour of country folks. It is difficult to draw the line between good and imperfect eyesight, but considerable practice with the Army test-dots shows that a person who can distinguish them at a distance of 30 feet (or half their theoretical distance) has good sight; and all below it may be said to have imperfect sight. Up to 30 feet 10·8 per cent. of the persons examined failed to distinguish the test-dots, and at 15 feet, the distance fixed by the Army regulations for the exclusion of recruits for imperfect eyesight, barely 1 per cent. failed to distinguish the test-dots. The failures up to 35 feet were at the rate of 19·3 per cent., and up to 40 feet 26·5 per cen

To ascertain the influence of school-life on the eyesight of boys, about 3,000 observations, made with Snellen's types, No. 1 and No. 10, by the Rev. T. A. Preston, at Marlborough College,[2] have been examined with the following results. The statistics are valuable as

[1] Each test-dot is one-fifth of an inch square, and corresponds at a distance of 15 feet with the bull's-eye of a target two feet square at 600 yards distance. A recruit who cannot clearly distinguish the dots at a distance of 15 feet is deemed unfit for military service.

[2] These observations were made with the book of tests for *The Detection of Colour Blindness and Imperfect Eyesight*, prepared by Mr. C. Roberts for the Committee, and they reflect the greatest credit on the skill and perseverance of Mr. Preston. Not only are the observations of great value to science in the aggregate, but each boy was benefited by being informed of the condition of his eyesight. The first edition of the book of tests having been sold out, a second edition, with some important alterations which practice has shown to be necessary or desirable, has been issued by Messrs. J. and A. Churchill, of New Burlington Street, W.

having been obtained under exactly similar conditions, and made on boys who may be said to have had a hereditary, as well as a personal, experience of educational discipline.

EYESIGHT OF 1,146 BOYS AND MASTERS AT MARLBOROUGH COLLEGE.

	Boys				Masters	
Age last birthday	11-12	13-14	15-16	17-19	20-40	40-60
Number of observations . . .	183	521	315	93	19	5
Average of No. 1 test-type, inches .	17·4	18·3	19·4	20·5	21·8	11·2
„ No. 10 „ feet .	9·4	9·2	9·2	9·4	10·0	6·0

The *mean*, or most frequent, distance at which No. 1 was read, was 19 inches, *i.e.* 7 inches in excess of the theoretical distance of 12 inches; while No. 10 was read at the exact theoretical distance of 10 feet. The *average* distance at which the boys read the smaller type was 18·7 inches, a deficiency of $\frac{3}{10}$ of an inch for the whole school; and the average distance at which the larger type was read was 9·3 feet, or a loss of $\frac{7}{10}$ of a foot. The nineteen masters, between 20 and 40 years of age, read both types at a greater average distance than the boys. The average distance at which No. 1 was read increases at an almost uniform rate of 1 inch for every two years up to 18 years of age. The sight of the five masters, of the age of 40 and upwards, is probably exceptional, and the number of observations are too few to be relied on.

The following table is interesting as showing the relation which the two tests bear to each other when applied to the same individuals. The general disposition of the figures shows that the sight which is proved to be good by one test is good also by the other test; but there are some notable exceptions to this rule, a few of which are probably due to errors

TABLE SHOWING THE RELATION OF THE NEAR AND DISTANT SIGHT OF MARLBOROUGH COLLEGE BOYS, AS TESTED BY NO. 1 (12 INCHES) AND NO. 10 (10 FEET) TEST-TYPES.

Distance in inches at which Test-type No. 1 was read	Distances in feet at which No. 10 Test-type was read. ½	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total, No. 1 Test	
Under 4 in.		1																		1	8·2 per cent. Imperfect near sight.
From 4 to 6	2	3	2																	7	
6— 8	1	7	3			1														12	
8—10		10	2	2		4		3	2	4										27	
10—12		13	1	1	3	3	5	1	7	1	6	1	3							45	
12—14		7	10	2	2	3	6	7	17	13	7	3	4	2	5	1				89	86·5 per cent. Good near sight.
14—16		3	11		5	2	8	18	7	25	18	7	6	4	1	2				117	
16—18			4	7	3	5	13	13	24	30	33	13	6	3	1	3				158	
18—20			2	3	4	4	6	16	31	43	39	26	23	11	2	3				213	
20—22				1	1	3	1	11	18	25	29	28	32	13	12	7	2			183	
22—24			1			5		1	7	15	24	24	19	9	10	8	2	1	1	127	
24—26								2	2	3	12	19	11	13	9	5	1			17	
26—28								1		1	4	8	7	4	3	1	5		1	33	5·3 per cent.
28—30										1	2	2	4	1	4	3		1		18	
30—32													1	1		2	1		1	6	
Total, No. 10 Test	3	44	36	16	18	30	39	73	115	161	174	131	116	61	47	35	11	2	3	1115	
	16·7 per cent. Short sight.							74·5 per cent. Good far sight.							8·8 per cent. Long sight.						

of observation. The table also shows the difficulty, already referred to, of drawing the line between good and imperfect eyesight. Judging from the value of the groups of figures, I have separated the boys whose sight with No. 1 falls short of 12 inches, and with No. 10 of 7 feet, as possessing imperfect eyesight, forming 8·2 and 16·7 per cent. of the total number respectively. Thus 83·3 per cent. of the boys possess $\frac{7}{10}$ and upwards far sight, and 91·8 per cent. possess $\frac{12}{12}$ and upwards of normal near vision. Sight which with both tests falls within the central square of the following table may be deemed good for all the ordinary purposes of life.

Astigmatism.—Tested by letters constructed of horizontal and vertical lines, 60·3 per cent. of the Marlborough College boys were found to be more or less astigmatic; 28·5 per ce nt. of the defect being horizontal, and 31·8 per cent. vertical, while 39·7 per cent. were entirely free from the defect. The following figures show that there is a disposition for astigmatism to increase with age:—

ASTIGMATISM OF 1,124 BOYS AT MARLBOROUGH COLLEGE.

Age last birthday . .	11—12	13—14	15—16	17—19 years.
Number of observations .	182	535	313	94
Normal sight . . .	41·2	41·7	39·9	32·0 per cent.
Vertical astigmatism .	32·0	30·0	31·9	38·3 ,,
Horizontal ,, .	26·8	28·3	29·1	33·0 ,,

Colour-blindness.—This defect was found to exist among the Marlborough boys to the extent of 2·5 per cent.

A SCALE OF PHYSICAL PROPORTIONS FOR LIFE INSURANCE AND RECRUITING, constructed by Mr. C. Roberts from data collected by himself, Dr. Beddoe, and the Anthropometric Committee. The table shows the average breathing capacity, weight, chest-girth, and strength of arm, for each inch of stature of adult males (23–50 years) and adult females (18–45 years) from 58 to 72 inches.

Adult Males					Adult Females			
Strength of arm as in drawing a bow	Chest-girth across nipples, empty	Weight, including indoor clothes	Breathing capacity	Stature without shoes	Breathing capacity	Weight, including indoor dress	Chest-girth below breasts	Strength of arm as in drawing a bow
lbs.	Inches	lbs.	Cubic ins.	Inches	Cubic ins.	lbs.	Inches	lbs.
85·1	38·9	165·6	290	72	238	141·1	32·7	51·1
83·9	38·4	163·3	280	71	230	139·1	32·2	50·4
82·7	37·8	161·0	270	70	221	137·2	31·7	49·7
81·5	37·3	158·7	260	69	213	135·2	31·2	49·0
80·3	36·7	156·4	250	68	204	133·3	30·8	48·3
79·2	36·2	154·1	240	67	196	131·3	30·4	47·6
78·0	35·7	151·8	230	66	187	129·4	30·0	46·8
76·8	35·1	149·5	220	65	179	127·4	29·5	46·1
75·6	34·6	147·2	210	64	170	125·4	29·0	45·4
74·4	34·0	144·9	200	63	162	123·5	28·5	44·7
73·3	33·5	142·6	190	62	153	121·5	28·1	44·0
72·1	33·0	140·3	180	61	145	119·6	27·6	43·3
70·9	32·4	138·0	170	60	136	117·6	27·2	42·6
69·7	31·9	135·7	160	59	128	115·6	26·6	41·9
68·5	31·3	133·4	150	58	119	113·7	26·1	41·2

Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Secretary*), Mr. WILLIAM SHAEN, Mr. STEPHEN BOURNE, Miss LYDIA BECKER, Sir JOHN LUBBOCK, *Bart.*, Dr. H. W. CROSSKEY, Sir HENRY E. ROSCOE, Mr. JAMES HEYWOOD, *and* Professor N. STORY MASKELYNE, *appointed for the purpose of continuing the inquiries relating to the teaching of Science in Elementary Schools.*

SINCE the re-appointment of your Committee at Southport no legislation affecting the teaching of science in elementary schools has taken place, and it is yet too early to estimate the whole influence of the Education Code of 1882 in that respect. Some indications, however, have been gathered from the Blue-book and from some of the large Boards.

The first effect of the change of Code upon the teaching of science is shown in the return of the Education Department for this year; but as the tabulated statements only extend to August 31, 1883, they contain merely the results of those examinations that were made of schools which came under the new Code between April 1 and August 1, 1882, or about 28 per cent. of the whole. The following conclusions may be drawn: 1st. Elementary science was taken up by scarcely any schools examined during these months, the number of departments that took it up as the second class subject being only 15, while 3,988 took up geography, 1,644 (girls) needlework, and 114 history. It must be remembered that geography is more scientific than it was before, but needlework is rapidly displacing it in girls' schools. 2nd. The exclusion of the Fourth Standard from instruction in specific subjects has reduced the number of scholars so taught by 56·6 per cent.; but the remaining 43·4 per cent.—that is to say, the children in Standards V., VI., and VII.—do receive a larger proportion of scientific teaching. The actual number of children examined during these four months in the mathematical and scientific specific subjects is given in Column I. of the following table; Column II. gives the estimated number who would have been examined under the old Code; Column III. the number of those who would have been above Standard IV.

Subject	Col. I.	Col. II.	Col. III.
Algebra	8,256	1,847	799
Euclid and Mensuration	604		
Mechanics, Scheme A.	635	1,393	603
Ditto ditto B.	—		
Animal Physiology	7,078	8,537	3,696
Botany	1,020	642	278
Agriculture (principles of)	422	—	—
Chemistry	368	—	—
Sound, Light, and Heat	196	—	—
Magnetism and Electricity	1,133	—	—
Domestic Economy	6,090	16,890	7,232
Totals	25,802	29,309	12,608

Comparing Columns I. and II., it will be seen that the actual number examined in these subjects is not much less than would have been examined under the old Code, when the Fourth Standard was included; but the number of girls who have taken up domestic economy is 10,800 less. If we compare Column I. with Column III., which embraces the same Standards, it appears that double the number of children have passed in these mathematical and scientific subjects. This is, no doubt, mainly due to the fact that English literature and physical geography are removed to the category of class subjects. The great gain has evidently been to the study of algebra, that subject and Euclid being taken up by about eleven times as many as previously took up mathematics. Animal physiology and botany have also largely increased. Mechanics is about the same, while of the new subjects magnetism and electricity has proved itself the favourite, while agriculture, chemistry, and sound, light, and heat follow in order. The only subject that has actually lost ground is domestic economy, which is no longer obligatory in girls' schools if a specific subject is taken.

The following table gives the number of passes in specific subjects made by the London School Board children in 1881–2, and in 1883–4. The second column gives the estimated number of those that were made in Standards above IV., corresponding to Column III. in the previous table.

Subject	1881–2		1883–4
	Standard IV. and upwards	Over Standard IV.	
Algebra Euclid and Mensuration	213	101	3,113 139
Mechanics	48	23	165
Animal Physiology	8,667	4,094	5,657
Botany	534	252	686
Agriculture (principles of)	—	—	299
Chemistry	—	—	198
Sound, Light, and Heat	—	—	179
Magnetism and Electricity	—	—	825
Domestic Economy	9,597	4,533	3,478
Totals	19,059	9,003	14,739

The following information has been furnished from the Manchester School Board:—

I. Class subjects.

Departments	1882				1883–84		
	Grammar	Geography	Needlework	History	English	Geography	Needlework
Boys	26	24	—	1	31	30	—
Girls	26	11	8	1	28	4	23
Junior	13	10	—	—	21	13	3
Mixed	4	—	1	—	4	—	3
Totals	69	45	9	2	84	47	29

Historical and geographical readers are provided in every department, and even though the subject be not taken for the Government examination, the children are always questioned on the matter of the reading books by the Board's Inspector.

II. Specific subjects (scientific).

Subject	Departments			
	1882		1884	
	Boys	Girls	Boys	Girls
Algebra . . . } Mathematics .	4	—	13	1
Euclid and Mensuration }			1	—
Mechanics	3	—	1	—
Animal Physiology	2	—	2	—
Botany	1	—	—	3
Domestic Economy	—	10	—	2
Totals . .	10	10	17	6

III. Science teaching under the Science and Art Department is given as follows:—

Subject	Departments	
	Boys	Girls
Mathematics	3	2
Physiology	1	1
Chemistry	3	2
Sound, Light, and Heat	2	2
Magnetism	2	2
Totals . .	11	9

The Brighton School Board had the following number of children studying the specific subjects during the quarter ending March 25, 1884:—

	Boys	Girls
Algebra.	285	—
Euclid and Mensuration	13	—
Animal Physiology	292	6
Magnetism and Electricity	149	—
Domestic Economy	—	261

As to class subjects, the ten boys' departments all take up geography as the second, the number of children under instruction being 2,879; while only one girls' department, with 119 children, takes geography for the Government examination, though it is taught in most of the others through reading lessons. The other nine girls' departments, with 2,339 children, take needlework as the second class subject.

At the Southport meeting a recommendation was passed that this Committee 'be requested to consider the desirableness of making representations to the Lords of the Committee of Her Majesty's Privy Council on Education in favour of aid being extended towards the fitting up of workshops in connection with elementary day schools or evening classes, and of making grants on the results of practical instruction in such workshops under suitable direction, and, if necessary, to communicate with the Council.'

As it was believed that the second Report of the Royal Commissioners on Technical Instruction would have an important bearing upon this question, the Committee was not called together till the publication of that Report. It was not issued till May, and it then appeared that, in addition to a very large amount of valuable information, the Royal Commissioners had recommended, among other things:—

'(*b*) That there be only two class subjects instead of three in the lower division of elementary schools, and that the object lessons for teaching elementary science shall include the subject of geography.'

'(*d*) That proficiency in the use of tools for working in wood and iron be paid for as a specific subject, arrangements being made for the work being done, so far as practicable, out of school hours. That special grants be made to schools in aid of collections of natural objects, casts, drawings, &c., suitable for school museums.'

With reference to recommendation (*b*) your Committee, without expressing any opinion as to the desirability of forming one subject out of geography and elementary science, consider that, if this change be effected, the two class subjects which will then represent literature and science should stand upon an equal footing. This would be in accordance with the resolution of the Council passed on December 5, 1881, in considering the recommendations of your Committee in regard to the proposals for the new Code. At present, if only one class subject is taken, the Code requires that it should be 'English' (grammar and literature); but many managers or teachers might prefer taking science.

With respect to recommendation (*d*) your Committee thoroughly approve of the proposals, which, if carried out, would realise the wish expressed in the reference to them from the Southport meeting.

They have not, however, thought it necessary to communicate at once with the Council, as there is no immediate legislation in prospect, and the meeting at Montreal might like to give further instructions on the subject.

The name of Professor N. Story Maskelyne, M.P., has been replaced on the Committee.

Second Report of the Committee, consisting of Sir JOSEPH WHITWORTH, Sir W. THOMSON, Sir F. J. BRAMWELL, Mr. A. STROH, Mr. BECK, Mr. W. H. PREECE, Mr. E. CROMPTON, Mr. E. RIGG (*Secretary*), Mr. A. LE NEVE FOSTER, Mr. LATIMER CLARK, Mr. H. TRUEMAN WOOD, *and* Mr. BUCKNEY, *appointed for the purpose of determining a Gauge for the manufacture of the various small Screws used in Telegraphic and Electrical Apparatus, in Clockwork, and for other analogous purposes.*[1]

1. Since the presentation of its first Report on a gauge for small screws at the meeting of the Association held in 1882 at Southampton, this Committee has further examined into the recommendations there made, with the result that they now have to propose some important modifications, the general effect of which will, it is felt, be to materially facilitate the introduction of the system.

2. The want of unanimity on the part of the Committee referred to in paragraph 7 of that Report arose mainly on the question as to whether the inch or millimetre should be taken as a unit of measurement. It is evident that if either is rigidly adhered to, and in any way employed in the nomenclature of the screws, as, for example, in specifying the diameter, pitch, or threads per inch or per mm., the same dimensions could not be expressed in whole numbers in the other unit, and thus a material obstacle would be at once introduced to its general adoption.

3. It should be pointed out, however, that it has hitherto been the common practice to designate such small screws as the Committee alone is considering, not by any specific dimension, but by a number, which as a rule is arbitrarily chosen and does not of itself form a guide to the size of the screw. Considering, then, that the unit of measurement is only indirectly connected with the subject of a screw gauge, the Committee has felt that the two units might be reconciled so far as relates to such a subject, and that thus one important difficulty would be removed.

4. The manner in which the series of screws adopted lately by Swiss manufacturers is correlated has been sufficiently explained in the previous Report, and very full explanations are given in the two original pamphlets to which reference is there made.[2] The diameter (D) is related to the pitch (P) by the formula $D = 6 \ P^{\frac{6}{5}}$, (1), all measurements being in millimetres, and P having successively the values 1 (or $0{\cdot}9^0$) mm.; $0{\cdot}9^1$ mm.; $0{\cdot}9^2$ mm.; $0{\cdot}9^3$ mm. . . . $0{\cdot}9^n$ mm.

Thus n, the index, becomes a convenient designating number for the screw, and the formula (1) may be expressed $D = 6 \ (0{\cdot}9^n)^{\frac{6}{5}}$, where $P = 0{\cdot}9^n$.

5. The pitch of any screw can be at once ascertained from its designating number by raising 0·9 to the power indicated by that number; and from this pitch the diameter is directly deducible by the formula (1), so that the number (n) given in the first column of the table, by which a screw is known, is intimately related to all its dimensions.

[1] See Report of the Council presented to the General Committee at Montreal.

[2] *Systématique des vis Horlogères*, by Prof. M. Thury, Geneva, 1878. *Notice sur le Système des vis de la Filière Suisse*, Geneva, 1880, by the same author.

Proposed Small Screw Gauge.

Number	Nominal Dimensions in Thousandths of an Inch			Absolute Dimensions in Millimetres	
	Diameter	Pitch	Threads per Inch	Diameter	Pitch
I.	II.	III.	IV.	V.	VI.
25	10	2·8	353	0·25	0·072
24	11	3·1	317	0·29	0·080
23	13	3·5	285	0·33	0·089
22	15	3·9	259	0·37	0·098
21	17	4·3	231	0·42	0·11
20	19	4·7	212	0·48	0·12
19	21	5·5	181	0·54	0·14
18	24	5·9	169	0·62	0·15
17	27	6·7	149	0·70	0·17
16	31	7·5	134	0·79	0·19
15	35	8·3	121	0 90	0·21
14	39	9·1	110	1·0	0·23
13	44	9·8	101	1·2	0·25
12	51	11·0	90·7	1·3	0·28
11	59	12·2	81·9	1·5	0·31
10	67	13·8	72·6	1·7	0·35
9	75	15·4	65·1	1·9	0·39
8	86	16·9	59·1	2·2	0·43
7	98	18·9	52 9	2·5	0·48
6	110	20 9	47·9	2·8	0·53
5	126	23·2	43·0	3·2	0·59
4	142	26·0	38·5	3·6	0·66
3	161	28·7	34·8	4·1	0·73
2	185	31·9	31·4	4·7	0·81
1	209	35·4	28·2	5·3	0·90
0	236	39·4	25·4	6·0	1·00

6. It is evident that by taking the exact successive powers of 0·9 for the pitch, complex numbers would soon be arrived at. Such dimensions would, however, involve a degree of accuracy which is hardly attainable in practice, and it may be shown that, with two significant figures employed throughout to express the pitch, the degree of accuracy likely to be attained in screws of the kind under consideration is reached. Relying on this fact, the series of pitches given in Column VI.[1] is arrived at for screws ranging from ·236-inch to the smallest in use, 0·01-inch in diameter, in place of the mathematically exact series obtained by raising 0·9 to successively higher powers.[2] And this is the series which the Committee recommends for adoption.

7. Viewing the numbers thus obtained in the first place merely as a graduated series of pitches, and ignoring the unit of measurement, it may be admitted that the series of powers of 0·9 from which they are deduced is perhaps as good a one as can be suggested for the purpose, and it is found to very closely correspond with experience. Thus Column VI., which gives the nearest approximation to this series that is practically required, is well adapted for such a system of screws. It is to be observed that in selecting a series of pitches there are three simple alternatives

[1] It may be incidentally pointed out here that this series comprises two screws, with pitches of 1 mm. and 0·25 mm., which would be serviceable for micrometers.

[2] Sir Joseph Whitworth's gauge, in general use, ends at $\frac{1}{4}$-in., where this commences.

to choose from: (1) to have a constant arithmetical difference between successive pitches, in which case either the pitches of small screws would differ by too great an amount, or those of the larger screws by too small an amount; or (2) to divide the entire range into sets, in each of which the differences are constant. The third alternative is to take successive powers of some other simple fraction, for example 0·8, but such a series would not so well correspond with the screws most generally employed.

8. Accepting this series, it may, however, be urged that it should be based on some aliquot part of an inch rather than on the millimetre. But any advantages to be gained by such a modification are inappreciable. For an examination of the numbers at once shows that they are, for the most part, awkward fractions of a millimetre, and the metric system of measurement thus enjoys no advantage in this respect over that based on the inch. From the point of view of interchangeability, however, of screws to be manufactured in this country and on the Continent, it is essential that the same basis of measurement of the pitch be everywhere adopted; because, having agreed upon only two significant figures on one basis, terminable decimals are obtained, but such terminable decimals could not be accurately expressed by two significant figures on the other basis of measurement.

9. Again, it is to be remembered that the use of metric measurement to designate the pitch need not inconvenience English manufacturers who are desirous of cutting the screws in their lathes. For, as has recently been pointed out by Mr. Bosanquet,[1] it is easy to cut a thread whose pitch differs from one millimetre by an amount which may for all ordinary purposes be neglected ($\frac{1}{55{\cdot}300}$th), with a guide-screw based on the inch by the addition of a wheel of 127 teeth, and thus the series here recommended could, on the rare occasions that it became necessary, be originated on any screw-cutting lathe provided with the requisite wheels. But the Committee do not consider it needful to specially contemplate facility in the originating of the threads, as the screws under consideration are made in a plate or by the aid of dies; and manufacturers on a large scale would be provided with a special lathe for the purpose.

10. Whether the inch or millimetre is adopted as a unit of measurement the series of pitches for these small screws becomes an ideal rarely attained in practice, for with screws tapped in a plate, or even with dies, the exact pitch aimed at will often not be attained; neither is it safe to assume that two screws, tapped in corresponding holes in different plates, will have precisely the same number of threads per inch. This is especially the case with the smaller screws, as may be proved by accurately measuring the pitches of several tapped in holes that are nominally alike.

11. The fact here stated affords a reason against extending the practice of designating screws by their number of threads per inch, already sometimes resorted to in the case of large screws, to the screws now under discussion. It is found that screws, nominally alike, frequently differ in this respect by as much as five or even ten threads in the inch, nor need this occasion surprise when it is remembered that the screw-plates employed must expand to varying extents in the hardening, that the hole is often not more than three or four threads deep, and that the pressure, applied by hand, must vary considerably. Such a nomenclature would thus involve the use of inconveniently high numbers to express a minute

[1] *Phil. Mag.* (Fifth Series), vol. xv. pp. 217, 438.

degree of accuracy but seldom attained, while they convey but little real information, since mere examination would not enable anyone to distinguish between, say, a screw of 169 and 181 threads per inch.

12. The series of diameters must next be considered. Before the formula $D = 6 P^{\frac{6}{5}}$ was adopted, it was ascertained by the minute examination of about 140 small screws that the series very closely corresponds with those recognised as good in the trade, and the screws made in the new plates, known as *Filières Suisses*, which the Committee have had an opportunity of examining, appear to them to be well proportioned in this respect. The series of diameters, like the pitches, are expressed by two significant figures in each case, as the values for D deduced from the formula (1) are necessarily indeterminate in most cases. These diameters are given in millimetres in Column V., and their nearest equivalent in thousandths of an inch in Column II. As the Committee considers that these screws are well-proportioned as regards pitch and diameter, and approves the formula (1) being taken as a basis, it is led to recommend this series of diameters being adopted in conjunction with the pitches already discussed. It has been suggested to the Committee that the introduction of such a system into general use in this country might be facilitated by punching against each hole in the screw-plate, side by side with the designating number, as given in Column I., the approximate diameter of the screw made in it, as expressed in thousandths of an inch (Column II.), as these numbers would convey a meaning to English workmen more definite than the numbers in Column I. or V. The Committee sees no serious objection to such a course; but it should be remembered that screws have hitherto always been recognised by a number seldom higher than twenty-five, and it may be questioned whether any substantial advantage is gained by substituting such high figures as are involved in the expression of the diameters.

13. It will be seen that the series here recommended gives twenty-six screws for the range from $\frac{1}{4}$-inch to the smallest in use. Comparing this number with those of two of the best systems commonly met with, —namely, the Latard (Perrelet et Martin) and Bourgeaux plates, we find that—

For a range of 21 sizes of watch screws on the Latard plate, this gives 15
For a range of 23 sizes of watch screws on the Bourgeaux plate, this gives 17
For a range of 36 sizes of clock screws on the Latard plate, this gives 23

The entire series is thus less than that of well-established plates, and cannot, therefore, be considered greater than the requirements of practice demand; while the fact that the watchmakers (who probably require the most extensive assortment of screws) in Switzerland have accepted it confirms the Committee in its opinion that the series is not deficient in this respect.

14. It remains to consider the form of thread. There are so many practical points to be taken into consideration in discussing such a question that it becomes specially useless to rely much on theory for guidance, and the divergence observable among the forms adopted by different manufacturers is thus very great.

The most important points to be borne in mind in its selection are:—

(1) The threads must be easily cut with the class of screw-cutting tackle ordinarily met with in workshops.

(2) The strength of the threads on the male and female screws must be so correlated that the liability of either to strip is a minimum.

(3) The resistance of the core to torsional stress when force is applied in rotating the screw must be a maximum.

(4) The friction should be as small as possible, in order to reduce wear.

15. In regard to the first of the above conditions it is to be observed that very many of the screws considered by the Committee are usually made by means of a plate in which are round, tapped holes. Such a hole forms a thread by causing the metal to 'flow' from a space towards a thread, and its action is obviously of quite a different character from the cutting action of dies or of a chasing tool. In the case of plates with notched holes the cutting and squeezing actions are combined.

16. As bearing on the second condition, it is evident that, as the strength of the threads depends so essentially on the materials of which the screw and nut are made, and these are very varied, no precise and invariable rule is attainable. If strength were the only point to be considered, a purely triangular form without any rounding would be best, contact being assumed to take place over the entire surface. But in practice it is impossible to secure such perfect contact, and it becomes needful to round off the crests from all the threads; and this rounding is the more necessary as the screws are smaller and irregularities in the manufacture become relatively more marked. This modification is also necessary in view of condition (1) already considered.

17. The third point—namely, the resistance of the core to torsional stress—is determined primarily by the depth of thread. If the sectional area of the ring cut away is less than that of the core, the probability of the latter breaking across may be regarded as approximately equal to that of the threads stripping; but it is impossible to maintain a constant ratio, as such a condition would require the thread to be so fine in the case of small screws that there would be no sufficient hold in the nut. Thus in the very smallest screws (those below ·030-inch in diameter) the ratio $\frac{\text{area of core}}{\text{sectional area of thread}}$ is less than 1, and it gradually increases till a proportion of between 2 and 3 is attained.

18. Condition (4) is evidently best satisfied by a square thread. Such a form is, however, impracticable in the case of the small screws under consideration, but it is obviously approximated to according as the angle of a triangular thread is made less and the rounding greater.

19. The angles that have been adopted in practice show, as might be expected, considerable variation. On the one hand an angle of 60° is rarely exceeded, the thread being thus derived from the equilateral triangle, and, on the other hand, 45° may be taken as the lower limit.

20. The depth of a thread is evidently a function both of its angle and of the amount of rounding at the top and bottom. It may conveniently be expressed as a fraction of the pitch (taken as unity). In the case of the small screws in general use the mean value of the depth thus expressed is found to be 0·563, the maximum being 0·771, and the minimum 0·311. It is evident that any increase in the depth beyond what is essential will materially and needlessly increase the difficulty of manu-

facture when a screw-plate is used; at the same time the depth must not be too much reduced on account of the greater tendency of the thread to strip. It is further important that the additional torsion involved in cutting a deep thread, which materially increases the risk of tearing the metal across, should not be lost sight of.

21. The Committee, after comparing together a large number of different forms of thread, some of which are in actual use, while others have only been suggested, were much tempted to recommend the Whitworth thread for adoption by the British Association, because it is so well known in this country, and experience has proved indisputably that it is excellent when employed for engineers' bolts, &c. But, as appears from sections 16 and 18, in the case of small screws the tendency should rather be to increase the rounding on account of the difficulties of manufacture, and the depth of the Whitworth thread is 0·64 of the pitch, which is considerably in excess of 0·563, the average adopted in practice. The Whitworth thread is, moreover, characterised by a greater angle than is usual in small screws.

22. The advisability of modifying the form of thread of small screws as compared with those of greater diameter is fully recognised by the Swiss Committee, their thread for the former having an angle of $47\frac{1}{2}°$, while that for the latter is 53°, nearly the same as that of the Whitworth thread. In the case of small screws made in the *Filière Suisse* the crest of each thread is rounded off with a radius equal to $\frac{1}{6}$th the pitch, and the hollow with $\frac{1}{5}$th the pitch. The actual depth is 0·60 the pitch, somewhat less than in the Whitworth thread.

23. While approving the general form of thread here described, this Committee could not but feel that the difference in the roundings ($\frac{1}{6}$th at the top and $\frac{1}{5}$th at the bottom) was unnecessary. Looking, moreover, to the fact that very many of the screws of the sizes now under consideration are for electrical and telegraphic instruments, and, therefore, may be of brass, and that, with threads of such dimensions, it is impossible for the eye to ascertain whether a given screw satisfies the required conditions in regard to such small differences between the crest and hollow of the thread, the Committee feels that an equal rounding ($\frac{2}{11}$ths of the pitch) at the top and bottom would be preferable. This would maintain the angle of thread and the depth the same—namely, $47\frac{1}{2}°$ and $\frac{3}{5}$ths of the pitch respectively.

24. Having now discussed the three main points that require to be considered in any system of screws—namely, the pitches, diameters, and form of thread, it seems desirable to enumerate briefly the recommendations at which the Committee has arrived. These are:—

(1) That the series of diameters for screws from $\frac{1}{100}$th inch to $\frac{1}{4}$th inch be that given in millimetres in Column V., the nearest thousandths of an inch being given in Column II.; these diameters being the series calculated by making P, in the formula $D = 6\ P^{\frac{6}{5}}$, have in succession the following values:—

1 (or $0{\cdot}9^0$) mm.; $0{\cdot}9^1$ mm.; $0{\cdot}9^2$ mm.; $0{\cdot}9^3$ mm.; . . . . . $0{\cdot}9^n$ mm.

Only two significant figures are taken to represent the diameters.

(2) That the pitches of these screws be the above gradually decreasing series, each pitch being $\frac{9}{10}$ths of its predecessor, but that only two significant figures be used in their expression. The series thus obtained is given in Column VI.

(3) That in view of the desirability of securing a system of small

screws, international in its character, English manufacturers of screws, screw-plates, &c., adopt the exact pitches given in millimetres in Column VI., which, as explained in par. 9, can, if required, be originated on an English lathe. Further, in view of the fact that small screws and screw-plates, while nominally alike, will not unfrequently differ considerably as regards their number of threads per inch, the practice of designating such screws by their number of threads per inch should not be adopted. For reference, however, the approximate number of threads per inch, as calculated from the pitch given in Column VI., are given in Column IV.

(4) That the designating numbers given in Column I., being the indices of the powers to which 0·9 is raised to obtain the pitch, be punched against each hole in the screw-plate, and that, if thought desirable, its diameter in thousandths of an inch (Column II.) might be punched side by side with this number.

25. In his *Systématique des vis Horlogères*, Prof. Thury has done for the small screws used by watch, clock, and scientific instrument makers what was done forty years ago by Sir J. Whitworth for the larger screws used by engineers; and, like the admirable system introduced by the latter, the scheme here advocated is based on the data obtained by measuring the several dimensions of many screws accepted by practical men as being well-proportioned.

26. The Committee has had an opportunity of examining both screws and screw-plates (for the smaller screws) made on this system, which it is convinced will satisfy all the demands of practice. The Committee can, therefore, confidently recommend its adoption by the British Association, subject to the slight modification discussed in par. 23 ; and it feels that an important incidental advantage would be the support it would at once receive on the Continent, and the consequent increased rapidity with which it might be expected to come into general use ; for it cannot be doubted that its recognition by so important a body as the British Association would have considerable influence in establishing the system abroad.

[The recommendation for the appointment of this Committee having failed to reach the Committee of Recommendations at Southport in time to allow of its sanction by the General Committee, the Council at their meeting on November 6, 1883, requested the Committee to continue their labours, and undertook to recommend to the General Committee at Montreal that this Report be printed among the Reports.]

Report of the Committee, consisting of Sir FREDERICK BRAMWELL (*Secretary*), Professor A. W. WILLIAMSON, Professor Sir WILLIAM THOMSON, Mr. ST. JOHN VINCENT DAY, Sir F. ABEL, Captain DOUGLAS GALTON, Mr. E. H. CARBUTT, Mr. MACRORY, Mr. H. TRUEMAN WOOD, Mr. W. H. BARLOW, Mr. A. T. ATCHISON, Mr. R. E. WEBSTER, Mr. A. CARPMAEL, Sir JOHN LUBBOCK, Mr. THEODORE ASTON, *and* Mr. JAMES BRUNLEES, *appointed for the purpose of watching and reporting to the Council on Patent Legislation.*

THE Act for the reform of the Patent Laws, passed in 1884, having only come into operation in January of the present year, sufficient time has not yet elapsed for its working to be tested. The Committee, therefore, have no report to make at present, but they think it well to ask to be reappointed, in order that they may be in a position to watch the working of the Act, and, if necessary, to report upon it. The Committee would be glad if the grant of 5*l.* for expenses could be renewed.

Report of the Committee, consisting of Mr. J. PARK HARRISON, General PITT-RIVERS, Mr. F. GALTON, Professor FLOWER, Professor THANE, Dr. BEDDOE, Mr. BRABROOK, Dr. MUIRHEAD, Mr. F. W. RUDLER, Professor MACALISTER, *and* Dr. GARSON (*Secretary*), *appointed for the purpose of defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining Illustrative Photographs with a view to their publication.*

DURING the past year your Committee have found it necessary to extend their researches into the domain of physical anthropology considerably further than has been done by this Committee in previous years, being convinced that it is only by a knowledge of the physical characters of the earlier inhabitants of the United Kingdom that the intricate question they have in hand can be properly elucidated. Accordingly a sub-committee, consisting of Professors Macalister and Thane and Dr. Garson, was appointed to examine carefully all the osteological remains preserved in different museums and elsewhere of the early inhabitants of the country. To assist in the investigation other members of the Committee have undertaken to act as referees in those portions of the work to which each has specially devoted himself; thus it has been arranged for the examination of any archæological, geological, and historical questions which may arise. Much of the time of the sub-committee has been occupied in determining what measurements of the skull and other parts of the skeleton will be of most use in carrying on the investigation, and in several instances it has been necessary to make experimental researches as to the value of some of the numerous measurements proposed by different anthropologists, in order to ascertain the most suitable for the purpose in view. Such researches, though tedious and involving much labour, will, when completed, your Committee have reason to hope, form a decided advance in physical anthropology. Although considerable progress has been made in the work during the past year, it is not sufficiently advanced for publication, and the Committee consider it advisable to postpone its discussion until more observations shall have been made and more information obtained. They request, however, if it be the pleasure of the Association, that they be reappointed, and that the grant hitherto placed at their disposal, but not drawn upon during the past year, be again renewed and increased to 20*l.*, since they anticipate a considerable amount of clerical assistance will be required to help them in collating the observations already made and which will be made during the ensuing year.

In view of the more extended basis of their researches the Committee consider a slight modification in their designation desirable, and recommend that in future the word ‘Facial’ be omitted. Such an alteration in name will better express the object of the Committee, namely, that of defining the characteristics of the Races and principal Crosses in the British Isles, and obtaining photographs illustrative of their features with a view to their publication.

Report of the Committee, consisting of Professors DEWAR *and* A. W. WILLIAMSON, Dr. MARSHALL WATTS, Captain ABNEY, Dr. STONEY, *and* Professors W. N. HARTLEY, MCLEOD, CAREY FOSTER, A. K. HUNTINGTON, EMERSON REYNOLDS, REINOLD, LIVEING, Lord RAYLEIGH, *and* W. CHANDLER ROBERTS (*Secretary*), *appointed for the purpose of reporting upon the present state of our knowledge of Spectrum Analysis.*

PAPERS CONNECTED WITH SPECTRUM ANALYSIS.

Continuation of List published in Report for 1881.

INSTRUMENTAL.

	1879.	
J. E. Hilgard . .	Optical Densimeter for Ocean Water. (Oct. 1879.)	'United States Coast Survey,' 1877, 108–113; 'Zeitschr. f. Instrumentenkunde,' i. 206–207 (Abs.); 'Beiblätter,' v. 658 (Abs.)
	1880.	
S. P. Langley . .	The Actinic Balance. (Dec. 23.) .	'Am. J.' xxi. 187–198; 'J. de Phys.' [2] i. 148–150 (Abs.)
	1881.	
C. H. Wolff . .	Universalspectralapparat ('Correspondenzbl. des Vereins analyt. Chemiker,' iii. 56.)	'Zeitschr. anal. Chem.' xx. 99–100.
S. P. Langley . .	The Bolometer and Radiant Energy. (Read Jan. 12.)	'Proc. Am. Acad.' xvi. 342–358; 'Zeitschrift f. Instrumentenkunde,' iv. 27–32 (Abs.)
A. Cornu . . .	Études photométriques	'J. de Phys.' x. 189–198; 'Beiblätter,' viii. 501 (Abs.)
C. V. Zenger . .	Ueber ein neues Spectroskop mit gerader Durchsicht.	'Zeitschr. f. Instrumentenkunde,' i. 263–266.
" . .	Le spectroscope à vision directe, appliqué à l'Astronomie physique. (Read Sept. 5.)	'C. R.' xciii. 429–432; 'Beiblätter,' v. 793 (Abs.)
J. Love . . .	On an Overlapping Spectroscope. (Read Sept. 7.)	'Rep. Brit. Assoc.' 1881, 564; 'Beiblätter,' viii. 705 (Abs.)
J. Brunn . . .	Protuberanzspectroskop mit excentrischer, bogenförmiger Spaltvorrichtung.	'Zeitschr. f. Instrumentenkunde,' i. 281–282; 'Beiblätter,' vi. 230 (Abs.)
F. Fuchs . .	Vorschläge zur Construction einiger optischer Vorrichtungen. I. Interferenzspectrometer.	'Zeitschr. f. Instrumentenkunde,' i. 326–329; 'Beiblätter,' vi. 228–229 (Abs.)
C. V. Zenger . .	Le spectroscope à vision directe, à spath calcaire. (Read Nov. 7.)	'C. R.' xciii. 720–722; 'Beiblätter,' vi. 21 (Abs).

INSTRUMENTAL, 1881, 1882.

F. Fuchs	Vorschläge zur Construction einiger optischer Vorrichtungen. II. Spectrophotometer. III. Geradsichtiges Prisma.	'Zeitschr. f. Instrumentenkunde,' i. 349–353; 'Zeitschr. anal. Chem.' xxi. 555 (Abs.); 'Beiblätter,' vi. 228–229 (Abs.)
W. Wernicke	Neues Flüssigkeitsprisma für Spectralapparate.	'Zeitschr. f. Instrumentenkunde,' i. 353–357; 'Beiblätter,' vi. 94–95 (Abs.); 'Zeitschr. anal. Chem.' xxi. 555–556 (Abs.)
E. Ketteler	Der 'Fixator,' ein Ergänzungsapparat des Spectrometers.	'Carl. Repert.' xvii. 645–651; 'J. de Phys.' [2] i. 198–199 (Abs.)
A. Rollett	Ueber ein Polarispectromikroskop, mit Bemerkungen über das Spectrumocular.	'Zeitschr. f. Instrumentenkunde,' i. 366–372; 'Beiblätter,' vi. 229–230 (Abs.); 'Zeitschr. anal. Chem.' xxi. 554–555 (Abs.)
K. W. Zenger	Das Dispersions-Parallelepiped und seine Anwendung in der Astrophysik. (Read Dec. 9.)	'Sitzungsb. d. kgl. böhm. Ges. d. Wiss.' 1881, 416–429; 'Beiblätter,' vi. 286 (Abs.)
	1882.	
F. Miller	Eine Verbesserung an Spectralapparaten.	'Zeitschr. f. Instrumentenkunde,' ii. 29–30; 'Beiblätter,' vi. 231 (Abs.)
T. R. Robinson	Absorption of Light by Prisms. (Jan. 5.)	'Observatory,' 1882, 53–54; 'Beiblätter,' vi. 589 (Abs.)
H. Kruss	Zur quantitativen Spektralanalyse.	'Rep. d. analyt. Chem.' ii. 17–22.
W. L. Stevens	A New Form of Reversible Spectroscope. (Jan. 21.)	'Am. J.' [3] xxiii. 226–229.
C. V. Zenger	Les observations spectroscopiques à la lumière monochromatique. (Read Jan. 23.)	'C. R.' xciv. 155–156; 'Chem. News,' xlv. 86–87 (Abs.); 'J. Chem. Soc.' xlii. 677 (Abs.); 'Am. J.' [3] xxiii. 322–323 (Abs.) 'Beiblätter,' vi. 378–379 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 114 (Abs.)
H. Laspeyres	Ueber Lampen für monochromatisches Licht.	'Zeitschr. f. Instrumentenkunde,' ii. 96–99; 'Beiblätter,' vi. 480 (Abs.)
A. Ricco	Geradsichtige Prismen	'Zeitschr. f. Instrumentenkunde,' ii, 105; 'Zeitschr. anal. Chem.' xxi. 555 (Abs.); 'Beiblätter,' vi. 794 (Abs.)
H. Goltzsch	Spectroskop mit constanter Ablenkung.	'Carl. Repert.' xviii. 188–190; 'Zeitschr. f. anal. Chem.' xxi. 556 (Abs.)

INSTRUMENTAL, 1882.

A. Kurz	Messung des Brechungsexponenten während des Unterrichtes.	'Carl. Repert.' xviii. 190–192.
H. Kruss	Spectralspalt mit symmetrischer Bewegung der Schneiden.	'Carl. Repert.' xviii. 217–228; 'Zeitschr. anal. Chem.' xxi. 182–191; 'Beiblätter,' vi. 286 (Abs.); 'J. Chem. Soc.' xlii. 1229 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 62–63 (Abs.)
A. F. Sundell	Selbstleuchtender Index im Spectroscop. (April 15.)	'Astron. Nachr.' cii. 90; 'Beiblätter,' vi. 876–877 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 422 (Abs.)
De Chardonnet	Sur la transformation actinique des miroirs Foucault et leurs applications en Photographie. (Read April 24.)	'C. R.' xciv. 1171–1173; 'Beiblätter,' vi. 483–484 (Abs.)
A. A. Michelson	Interference phenomena in a new form of Refractometer.	'Am. J.' [3] xxiii. 395–400; 'Phil. Mag.' [5] xiii. 236–242; 'Beiblätter,' vii. 534–535 (Abs.)
C. F. Brackett	Note on the Littrow Form of Spectroscope. (May 12.)	'Am. J.' [3] xxiv. 60–61; 'Beiblätter,' vi. 875–876 (Abs.)
H. A. Rowland	Preliminary Notice of the Results accomplished in the Manufacture and Theory of Gratings for Optical Purposes. (May 25.)	'Johns Hopkins Univ. Circular,' 1882, 248–249; 'Phil. Mag.' [5] xiii. 469–474; 'Nature,' xxvi. 211–213; 'Am. J.' [3] xxiv. 63 (Abs.); 'Observatory,' 1882, 224–228; 'Zeitschr. f. Instrumentenkunde,' ii. 304 (Abs.)
G. D. Liveing and J. Dewar.	On an Arrangement of the Electric Arc for the Study of the Radiation of Vapours, together with Preliminary Results. (Recd. June 8. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 119–122; 'Nature,' xxvi. 213–214 (Abs.); 'Beiblätter,' vi. 934–936 (Abs.) 'J. Chem. Soc.' xliv. 262–263 (Abs.)
A. Cornu	Sur un spectroscope à grande dispersion. (Read June 16.)	'Séances Soc. franç. de Phys.' 1882, 165–170; 'Beiblätter,' vii. 285 (Abs.); viii. 33 (Abs.)
J. Bodynski	Ueber eine einfache Methode zur approximativen Bestimmung der Brechungsexponenten flüssiger Körper.	'Carl. Repert.' xviii. 502–504; 'Beiblätter,' vi. 932 (Abs.)
H. Schulz	Ein neuer Hülfsapparat zur Spectralanalyse.	'Pflüger's Archiv,' xxviii. 197–199; 'Ber.' xv. 2754 (Abs.); 'Beiblätter,' vi. 674 (Abs.)
J. F. D. Donnelly	A Meteorological Spectroscope. (Sept. 14.)	'Nature,' xxvi. 501; 'Beiblätter,' vii. 25 (Abs.); 'J. de Phys.' [2] iii. 44 (Abs.)

INSTRUMENTAL, 1882, 1883.

C. Soret . . .	Sur un réfractomètre destiné à la mesure des indices et de la dispersion des corps solides. (Read Sept. 18.)	'C. R.' xcv. 517–520; 'Beiblätter,' vi. 870–872 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 414–415 (Abs.)
A. Johnson . .	Newton, Wollaston, and Fraunhofer's lines. (Sept. 19.)	'Nature,' xxvi. 572; 'Beiblätter,' vii. 65–66 (Abs.)
C. Soret . . .	Sur un réfractomètre destiné à la mesure des indices de réfraction et de la dispersion des corps solides. (Dec. 1882.)	'Arch. de Genève' [3] ix. 5–32; 'J. de Phys.' [2] ii. 138–139.

1883.

R. T. Glazebrook .	On a Spectrophotometer. (Read Jan. 29.)	'Proc. Phil. Soc. Camb.' iv. 304–308; 'Beiblätter,' viii. 211–212 (Abs.)
N. von Konkoly .	Das Reversions-Spectroscop . .	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 128–133.
" .	Ueber ein neues Spectroscop . .	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 134–135.
A. Cornu . . .	Sur un spectroscope à grande dispersion.	'J. de Phys.' [2] ii. 53–57; 'Zeitschr. f. Instrumentenkunde,' iii. 171–172 (Abs.)
Garbe . . .	Note sur un spectroscope à fente inclinée. (Read March 2.)	'Soc. franç. de Phys. 1883, 59–62; 'J. de Phys.' [2] ii. 318–321.
L. Thollon . .	Sur un nouveau collimateur. (Read March 5.)	'C. R.' xcvi. 642–643; 'Nature,' xxvii. 476 (Abs.); 'Beiblätter,' vii. 285 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 180–181 (Abs.)
P. Garbe . . .	Sur un spectroscope à fente inclinée. (Read March 26.)	'C. R.' xcvi. 836–837; 'Beiblätter,' vii. 456 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 214–215 (Abs.)
N. von Konkoly .	Ein sehr einfacher und wirksamer Spektralapparat.	'C. S. f. Optik und Mech.' iv. 76–77; 'Beiblätter,' vii. 456 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 324–325 (Abs.)
C. V. Zenger . .	Spectroscope à vision directe très puissant. (Read April 9.)	'C. R.' xcvi. 1039–1041; 'Nature,' xxvii. 596 (Abs.); 'Chem. News,' xlvii. 213 (Abs.); 'Beiblätter,' vii. 456–457 (Abs.); 'Am. J.' [3] xxv. 469 (Abs.); 'Zeitschr. anal. Chem.' xxii. 540–541 (Abs.)

INSTRUMENTAL, 1883.

L. Thollon	Sur l'emploi de la lunette horizontale pour les observations de spectroscopie solaire. (Read April 23.)	'C. R.' xcvi. 1200–1202; 'Nature,' xxviii. 24 (Abs.); 'Beiblätter,' vii. 456 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 216 (Abs.)
C. Braun	Ueber ein verbessertes Prisma à vision directe. (April 23.)	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 197–200.
G. D. Liveing and J. Dewar.	On the use of a Collimating Eyepiece in Spectroscopy. (Read April 30.)	'Proc. Camb. Phil. Soc.' iv. 336–342; 'Beiblätter,' vii. 892–893 (Abs.)
"	On Some Modifications of Soret's Fluorescent Eyepiece. (Read April 30.)	'Proc. Camb. Phil. Soc.' iv. 342–343.
G. D. Liveing	On a Spectrometer and Universal Goniometer adapted to the ordinary wants of a Laboratory. (Read April 30.)	'Proc. Camb. Phil. Soc.' iv. 343–344.
Cruls	Sur l'emploi d'un verre biréfringent dans certaines observations d'analyse spectrale. (Read April 30.)	'C. R.' xcvi. 1293–1294; 'Nature,' xxviii. 48 (Abs.); 'Beiblätter,' vii. 529 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iv. 135 (Abs.)
E. v. Gothardt	Ein Spectroskop für Kometen- und Fixstern-Beobachtungen.	'Central-Zeitung f. Optik u. Mech.' iv. 121; 'Beiblätter,' vii. 595 (Abs.)
N. v. Konkoly	Ein neuer Reversionsspektralapparat.	'Central-Zeitung f. Optik u. Mech.' iv. 122–124; 'Beiblätter,' vii. 595 (Abs.)
E. v. Gothardt	Ein einfaches Stativ für Geissler'sche Spektralröhren.	'Central-Zeitung f. Optik u. Mech.' iv. 146–147; 'Zeitschr. f. Instrumentenkunde,' iii. 320–321 (Abs.); 'Beiblätter,' viii. 216 (Abs.)
H. A. Rowland	On Concave Gratings for Optical Purposes.	'Am. J.' [3] xxvi. 87–98; 'Phil. Mag.' [5] xvi. 197–210; 'Beiblätter,' vii. 862–863 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iv. 135 – 136 (Abs.); 'J. de Phys.' [2] iii. 184–185 (Abs.)
A. Crova	Description d'un Spectrophotomètre.	'Ann. Chim. et Phys.' [5] xxix. 556–573.
P. Desains	Note sur les spectres solaires. Appareil réfringent en sel gemme. (Read Sept. 24.)	'C. R.' xcvii. 689–693; 732; 'Beiblätter,' vii. 858–859 (Abs.)
H. Wild	Ueber die Umwandlung meines Photometers in ein Spectrophotometer.	'Ann. Phys. u. Chem. N.F.' xx. 452–468; 'Nature,' xxix. 253 (Abs.); 'J. de Phys.' [2] iii. 142–143 (Abs.)

INSTRUMENTAL, 1883, 1884—EMISSION SPECTRA, 1880, 1881.

E. Lommel	Spectroskop mit phosphorescirendem Ocular; Beobachtungen über Phosphorescenz. (Oct. 1883.)	'Ann. Phys. u. Chem. N.F.' xx. 847–860; 'Am. J.' [3] xxvii. 236–237 (Abs.)
E. von Gothard	Dr. v. Konkoly's Sternspektralapparat in Verbindung mit einem Kolorimeter.	'Central-Zeitung f. Optik u. Mech.' iv. 241–243.
F. Melde	Ueber einige physikalische Versuche und Hilfseinrichtungen.	'Zeitschr. f. Instrumentenkunde,' iii. 388–392; 'Beiblätter,' viii. 220 (Abs.)

1884.

F. Lippich	Vorschlag zur Construction eines neuen Spectralapparates.	'Zeitschr. f. Instrumentenkunde,' iv. 1–8; 'Beiblätter,' viii. 300–302 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 520 (Abs.)
N. von Konkoly	Illumination of Spectroscope Micrometers.	'Monthly Not. Astr. Soc.' xliv. 250.
W. Zenker	Das neue Spectrophotometer von Crova, verglichen mit dem von Glan, nebst einem Vorschlag zur weiteren Verbesserung beider Apparate.	'Zeitschr. f. Instrumentenkunde,' iv. 83–87; 'Beiblätter,' viii. 499–500 (Abs.)
W. N. Hartley	On the Use of Moist Electrodes	'Chem. News,' xlix. 149; 'Beiblätter,' viii. 581 (Abs.)
T. Liebich	Neuere Apparate für die Wollaston'sche Methode zur Bestimmung von Lichtbrechungsverhältnissen.	'Zeitschr. f. Instrumentenkunde,' iv. 185–189.
H. Wild	Spektrophotometer	'Dingler's J.' cclii. 462–465.

EMISSION SPECTRA.

1880.

F. Lippich	Untersuchungen über die Spectra gasförmiger Körper. (Read May 13.)	'Sitzungsb. Wien. Akad.' lxxxii. II. 15–33; 'Ann. Phys. u. Chem.' N.F. xii. 380–398.
O. Lohse	Ueber die Glüherscheinungen an Metallelectroden innerhalb einer Wasserstoffatmosphäre von verschiedenem Drucke. (Aug. 1880.)	'Ann. Phys. u. Chem.' N.F. xii. 109–114.

1881.

W. Crookes	On the Viscosity of Gases at High Exhaustions. (Recd. Dec. 26, 1880. Read Feb. 17, 1881.)	'Phil. Trans.' clxxii. 387–434; 'Proc. Roy. Soc.' xxxi. 446–458 (Abs.); 'Chem. News,' xliii. 85–89 (Abs.); 'Nature,' xxiii. 421–423, 443–446 (Abs.); 'Beiblätter,' v. 836–846 (Abs.)
B. Hasselberg	Beiträge zur Spectroskopie der Metalloide. (Read April 28.)	'Bull. Acad. Imp. S. Petersb.' xxvii. 405–417.

Emission Spectra, 1881, 1882.

R. Thalén . .	Spektralundersökningar rörande Skandium, Ytterbium, Erbium och Thulium. (Read June 8.)	'Öfversigt af Kongl. Vetensk. Akad. Förhandlingar,' xxxviii. No. 6, 13–21; 'J. de Phys.' [2] ii. 35–40; 'Ber.' xvi. 776 (Abs.); 'Chem. News,' xlvii. 217 (Abs.); 'J. Chem. Soc.' xliv. 954 (Abs.)
W. N. Hartley . .	Note on certain Photographs of the Ultra-violet Spectra of Elementary Bodies. (Read June 16, 1881.)	'J. Chem. Soc.' xli. 84–90; 'Chem. News,' xliii. 289 (Abs.); 'Beiblätter,' v. 659–660 (Abs.); vi. 789–720 (Abs.)
O. W. Huntington .	On the Spectrum of Arsenic. (Read June 28.)	'Proc. Am. Acad. Boston [2] ix. 35–38; 'Am. J.' [3] xxii. 214–217; 'Beiblätter,' v. 868 (Abs.)
L. Thollon . .	Longueurs d'onde des bandes spectrales données par les composés du carbone. (Read Aug. 1.)	'C. R.' xciii. 260; 'Ann.' Chim. et Phys.' [5] xxv. 287-288.
A. Wüllner . .	Ueber die Spectra des Wasserstoffs und des Acetylens. (Aug. 10.)	'Ann. Phys. u. Chem.' N.F. xiv. 355–362; 'J. Chem. Soc.' xlii. 129–130 (Abs.)
" . .	Einige Bemerkungen zu den Versuchen des Hrn. Wesendonck über Spectra der Kohlenstoffverbindungen. (Aug. 10.)	'Ann. Phys. u. Chem.' N.F. xiv. 363–366.
E. Goldstein . .	Ueber das Bandenspectrum der Luft. (Read Oct. 13.)	'Sitzungsb. Wien. Akad.' lxxxiv. II. 693–701; 'Ann. Phys. u. Chem. N.F. xv. 280–288; 'J. Chem. Soc.' xlii. 677 (Abs.)
B. Hasselberg . .	Bemerkung zu Hrn. Wüllner's Aufsatz: 'Ueber die Spectra des Wasserstoffs und des Acetylens.' (Nov. 1881.)	'Ann. Phys. u. Chem.' N.F. xv. 45–49.

1882.

G. D. Liveing and J. Dewar.	On the Spectrum of Water. No. II. (Recd. Jan. 14. Read Jan. 26.)	'Proc. Roy. Soc.' xxxiii. 274–276; 'J. Chem. Soc.' xliv. 140 (Abs.); 'Beiblätter,' vi. 481 (Abs.)
W. N. Hartley .	The Analysis of Rhabdophane, a New British Mineral. (Read Jan. 19.)	'J. Chem. Soc.' xli. 210–220; 'Chem. News,' xlv 40 (Abs.)
Piazzi Smyth . .	On the Constitution of the Lines forming the Low-Temperature Spectrum of Oxygen. (Read Jan. 30.)	'Trans. Roy. Soc. Edinb. xxx. 419–425; 'Phil. Mag.' [5] xiii. 330–337; 'Nature,' xxv. 403 (Abs.); 'J. de Phys.' [2] ii. 289 (Abs.)

EMISSION SPECTRA, 1882.

G. D. Liveing and J. Dewar.	On the Spectrum of Carbon. (Recd. Feb. 23. Read March 9.)	'Proc. Roy. Soc.' xxxiii. 403–410; 'Chem. News,' xlv. 155–156 (Abs.); 'Nature,' xxv. 545–546; 'J. Chem. Soc.' xliv. 1–2 (Abs.); 'Beiblätter,' vi. 675 (Abs.)
"	On the Disappearance of some Spectral Lines and the Variations of Metallic Spectra due to Mixed Vapours. (Recd. March 11. Read March 16.)	'Proc. Roy. Soc.' xxxiii. 428–434; 'J. Chem. Soc.' xliv. 2–3 (Abs.); 'Beiblätter,' vi. 676 (Abs.)
B. Hasselberg . .	Untersuchungen über das zweite Spectrum des Wasserstoffs. (Read April 13.)	'Mém. Acad. S. Pétersb.' [7] xxx. No. 7, 1–24; 'Phil. Mag.' [5] xvii. 329–353 (Abs.); 'Beiblätter,' vii. 691–694 (Abs.)
H. E. Roscoe and A. Schuster.	The Spectrum of Terbium.	'J. Chem. Soc.' xli. 283–287; 'Ber.' xv. 1280–1284; 'Beiblätter,' vi. 790–792 (Abs.)
P. T. Clève . .	Note préliminaire sur le didyme. (Read June 5.)	'C. R.' xciv. 1528–1530; 'Chem. News,' xlv. 273; 'J. Chem. Soc.' xliv. 18 (Abs.); 'Ber.' xv. 1750 (Abs.); 'Beiblätter,' vii. 771–772 (Abs.)
W. N. Hartley .	On the Reversal of the Metallic Lines as seen in Over-exposed Photographs of Spectra. (Recd. May 19. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 84–86; 'J. Chem. Soc.' xliv. 263 (Abs.); 'Am. J.' [3] xxiv. 471–472 (Abs.); 'Beiblätter,' vii. 27 (Abs.)
G. D. Liveing and J. Dewar.	On an Arrangement of the Electric Arc for the Study of the Radiation of Vapours, together with Preliminary Results. (Recd. June 8. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 119–122; 'Nature,' xxvi. 213–214 (Abs.); 'Beiblätter,' vi. 934–936 (Abs.); 'J. Chem. Soc.' xliv. 262–263 (Abs.)
"	On the Ultra-violet Spectra of the Elements. Part I. (Recd. June 8. Read June 15.)	'Phil. Trans.' clxxiv. 187–222; 'Proc. Roy. Soc.' xxxiv. 122–123 (Abs.); 'Beiblätter,' vi. 934 (Abs.); vii. 849–856 (Abs.); 'J. Chem. Soc.' xliv. 262 (Abs.)
	Part II. (Recd. June 8. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 123 (Abs.)
"	General Observations on the Spectra of Carbon and its Compounds. (Recd. June 12. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 123–130; 'J. Chem. Soc.' xliv. 261–262 (Abs.)
B. Brauner . .	Sur le didyme. (Read June 26.)	'C. R.' xciv. 1718–1719; 'Chem. News,' xlvi. 16–17; 'J. Chem. Soc.' xliv. 18 (Abs.); 'Ber.' xv. 2231 (Abs.)

EMISSION SPECTRA, 1882, 1883.

Jamin and G. Maneuvrier.	Sur les apparences de l'arc électrique dans la vapeur du sulphure de carbone. (Read July 3.)	'C. R.' xcv. 6–7; 'Phil. Mag.' [5] xiv. 324–325.
P. T. Clève . .	Quelques remarques sur le didyme. (Read July 3.)	'C. R.' xcv. 33; 'J. Chem. Soc.' xlii. 1165 (Abs.); 'Beiblätter,' vi. 772 (Abs.)
Sir J. Conroy . .	The Spectrum of the Light emitted by the Glow-worm. (July 29.)	'Nature,' xxvi. 319; 'Beiblätter,' vi. 880 (Abs.)
J. Spiller . .	Spectrum of the Light of the Glow-worm. (Aug. 5.)	'Nature,' xxvi. 343; 'Beiblätter,' vi. 880 (Abs.)
D. van Monckhoven	De l'élargissement des raies spectrales de l'hydrogène. (Read Aug. 21.)	'C. R.' xcv. 378–381; 'Chem. News,' xlvi. 149 (Abs.); 'J. Chem. Soc.' xliv. 139 (Abs.)
K. Wesendonck .	Untersuchungen über die Spectra der Kohlenverbindungen.	'Ann. Phys. u. Chem.' N.F. xvii. 427–467; 'J. Chem. Soc.' xliv. 761 (Abs.)
A. Wüllner . .	Einige Bemerkungen zu den Mittheilungen der Herren Hasselberg und Goldstein. (Sept. 4.)	'Ann. Phys. u. Chem.' N.F. xvii. 587–592.
D. van Monckhoven	De l'influence de la température sur les spectres des métalloïdes. (Read Sept. 18.)	'C.R.' xcv. 520–522; 'Phil. Mag.' [5] xiv. 406–407; 'Chem. News,' xlvi. 171–172 (Abs.); 'J. Chem. Soc.' xliv. 140 (Abs.); 'Beiblätter,' vi. 877 (Abs.).
J. Herschel . .	Soda Flames in Coal Fires.	'Nature,' xxvii. 78.
Sm.	Flame in Coal Fire. (Nov. 24.)	'Nature,' xxvii. 103.
J. R. Capron . .	Swan Lamp Spectrum and the Aurora. (Nov. 30.)	'Nature,' xxvii. 149; 'Beiblätter,' vii. 108–109 (Abs.)
J. Munro . .	Swan Lamp Spectrum and the Aurora. (Dec. 18.)	'Nature,' xxvii. 173; 'Beiblätter,' vii. 193 (Abs.)
G. D. Liveing and J. Dewar.	On the Origin of the Hydrocarbon Flame Spectrum. (Recd. Dec. 14. Read Dec. 21.)	'Proc. Roy. Soc.' xxxiv. 418–429; 'Nature,' xxvii. 257–259; 'Chem. News,' xlvi. 293–297; 'Beiblätter,' vii. 288–289 (Abs.); 'J. Chem. Soc.' xliv. 641–642 (Abs.)

1883.

W. Hittorf . .	Bemerkungen zu dem Aufsatze von W. Siemens: Ueber das Leuchten der Flamme. (Feb. 5.)	'Ann. Phys. u. Chem.' N.F. xix. 73–77; 'J. Chem. Soc.' xliv. 697 (Abs.)
G. D. Liveing and J. Dewar.	Note on the Reversal of Hydrogen Lines; and on the Outburst of Hydrogen Lines when Water is dropped into the Arc. (Recd. March 1. Read March 8.)	'Proc. Roy. Soc.' xxxv. 74–76; 'Chem. News,' xlvii. 122; 'Nature,' xxviii. 21–22 (Abs.); 'Beiblätter,' vii. 371–372 (Abs.); 'J. Chem. Soc.' xliv. 837–838 (Abs.)

EMISSION SPECTRA, 1883.

G. D. Liveing . .	The Ultra-Violet Spectra of the Elements. (March 9.)	'Proc. Roy. Inst.' x. 245–252; 'Beiblätter,' vii. 598–599 (Abs.)
W. N. Hartley . .	On Homologous Spectra. (Read March 15.)	'J. Chem. Soc.' xliii. 390–400; 'Nature,' xxvii. 522 (Abs.); 'Chem. News,' xlvii. 138 (Abs.); 'Am. J.' [3] xxvi. 401–402 (Abs.); 'Ber.' xvi. 2659–2660 (Abs.); 'Beiblätter,' viii. 217–218 (Abs.).
W. N. Hartley and W. E. Adeney .	Measurements of the Wave-lengths of Lines of High Refrangibility in the Spectra of Elementary Substances. (Recd. March 20. Read April 19.)	'Phil. Trans.' clxxv. 63–137; 'Proc. Roy. Soc.' xxxv. 148–149 (Abs.); 'Chem. News,' xlvii. 193–194 (Abs.); 'Beiblätter,' vii. 599–600 (Abs.)
W. N. Hartley . .	On the Spectrum of Beryllium, with Observations relative to the Position of that Metal among the Elements. (Read April 19.)	'J. Chem. Soc.' xliii. 316–319; 'Ber.' xvi. 1859–1860 (Abs.); 'Am. J.' [3] xxvi. 316–317 (Abs.); 'Beiblätter,' vii. 895 (Abs.)
B. Hasselberg . .	Untersuchungen über das zweite Spectrum des Wasserstoffs. Zweite Abhandlung. (Read May 10.)	'Mém. Acad. Imp. S. Pétersb.' xxxi. No. 14, 30 pp.; 'Beiblätter,' viii. 381–384 (Abs.); 'Mem. Spettr. ital.' xiii. 97–105 (Abs.)
W. Crookes . .	On Radiant Matter Spectroscopy. The Detection and Wide Distribution of Yttrium. (Bakerian Lecture. Recd. May 24. Read May 31.)	'Phil. Trans.' clxxiv. 891–918; 'Proc. Roy. Soc.' xxxv. 262–271 (Abs.); 'Chem. News,' xlvii. 261–264 (Abs.); 'Ber.' xvi. 1689 (Abs.); 'J. Franklin Inst.' lxxxvi. 118–128; 'Beiblätter,' vii. 599 (Abs.); 'J. Chem. Soc.' xlvi. 241–242 (Abs.); 'Chem. News,' xlix. 159–160, 169–171, 181–182, 194–196, 205–208; 'Ann. Chim. et Phys.' [6] iii. 145–187.
W. N. Hartley . .	On Line Spectra of Boron and Silicon. (Recd. May 28. Read June 21.)	'Proc. Roy. Soc.' xxxv. 301–304; 'Chem. News,' xlviii. 1–2; 'J. Chem. Soc.' xlvi. 242 (Abs.); 'Beiblätter,' viii. 120 (Abs.)
" . .	Researches on Spectrum Photography in relation to New Methods of Quantitative Chemical Analysis. Part I. (Recd. June 20. Read June 21.)	'Phil. Trans.' clxxv. 49–62.

EMISSION SPECTRA, 1883, 1884.

H. Becquerel	Spectres d'émission infra-rouges des vapeurs métalliques. (Read July 9.)	'C. R.' xcvii. 71–74; 'Chem. News,' xlviii. 46 (Abs.); 'Nature,' xxviii. 287 (Abs.); 'Beiblätter,' vii. 701–702 (Abs.); 'Am. J.' [3] xxvi. 321 (Abs.); 'Ber.' xvi. 2487 (Abs.); 'J. Chem. Soc. xlvi. 1 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 49 (Abs.)
C. Piazzi Smyth	Cyanogen in Small Induction Sparks in Free Air. (July 25.)	'Nature,' xxviii. 340-341.
R. Thalén	Om de lysande spektra hos Didym och Samarium. (Read Sept. 12.) (Sur les spectres brillants du didym et du samarium.)	'Öfversigt k. Vetensk. Akad. Förhandl.' xl. No. 7, 3-16; 'J. de Phys.' [2] ii. 446-449; 'Ber.' xvi. 2760 (Abs.); 'Beiblätter,' vii. 893–895 (Abs.)
P. T. Clève	On Samarium and its Compounds.	'J. Chem. Soc.' xliii. 362–370; 'Chem. News,' xlviii. 74–76; 'Ber.' xvi. 2493 (Abs.)
"	Om Samarium. (Read Sept. 12.)	'Öfversigt. k. Vetensk. Akad. Förhandl.' xl. No. 7, 17–26; 'Beiblätter,' viii. 264 (Abs.)
W. N. Hartley	The Investigation by means of Photography of the Ultra-violet Spark Spectra emitted by Metallic Elements and their Combinations under varying Conditions. (Brit. Assoc.)	'Chem. News,' xlviii. 195–196; 'Nature,' xxix. 89–90; 'J. Chem. Soc.' xlvi. 137–138 (Abs.); 'Beiblätter,' viii. 302 (Abs.)
	1884.	
E. Wiedemann	Note on an Observation by Professor Hartley. (Feb. 1884.)	'Chem. News,' xlix. 117; 'J. Chem. Soc.' xlvi. 801 (Abs.); 'Beiblätter,' viii. 581 (Abs.)
K. Wesendonck	Ueber die Spectra des Fluorsiliciums und des Siliciumwasserstoffs.	'Ann. Phys. u. Chem.' N.F. xxi. 427–437; 'J. Chem. Soc.' xlvi. 649 (Abs.)
C. Fiévez	Sur des changements de réfrangibilité observés dans les spectres électriques de l'hydrogène et du magnésium. (Read March 1.)	'Bull. Acad. Roy. Belgique' [3], vii. 245–247; 'Beiblätter,' viii. 506 (Abs.)
W. N. Hartley	Researches in Spectrum Photography in Relation to New Methods of Quantitative Chemical Analysis. Part II. (Recd. Feb. 28. Read March 13.)	'Proc. Roy. Soc.' xxxvi. 421–422 (Abs.); 'Chem. News,' xlix. 128 (Abs.); 'Beiblätter,' viii. 705–706 (Abs.)
G. D. Liveing and J. Dewar.	Spectroscopic Studies on Gaseous Explosions. No. I. (Recd. March 28. Read April 3.)	'Proc. Roy. Soc.' xxxvi. 471–478; 'Chem. News,' xlix. 227–229; 'Nature,' xxix. 614–615; 'Beiblätter,' viii. 644–645 (Abs.)

Emission Spectra, 1884.—Absorption Spectra, 1881, 1882.

C. Fiévez . . .	De l'influence de la température sur les caractères des raies spectrales. (Read April 5.)	'Bull. Ac. Belg.' [3] vii. 348–355; 'Beiblätter,' viii. 645–646 (Abs.); 'Les Mondes' [3] viii. 481–483; 'Chem. News,' l. 128 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectral Lines of the Metals developed by Exploding Gases.	'Phil. Mag.' [5] xviii. 161–173.

ABSORPTION SPECTRA.

1881.

A. Cornu . . .	Sur l'absorption atmosphérique des radiations ultra-violettes.	'J. de Phys.' x. 5–16.
E. Jessen . .	Photometrie des Absorptionsspectrums der Blutkörperchen.	'Zeitschr. f. Biol.' xvii. 251–272; 'Ber.' xv. 952 (Abs.)
C. Pulfrich . .	Photometrische Untersuchungen über Absorption des Lichtes in isotropen und anisotropen Medien. (July 1881.)	'Ann. Phys. u. Chem.' N. F. xiv. 177–218; 'Am. J.' [3] xxiii. 50 (Abs.); 'J. de Phys.' [2] i. 285–286 (Abs.)
M. de Chardonnet .	Sur l'absorption des rayons ultra-violets par quelques milieux. (Read Aug. 29.)	'C. R.' xciii. 406–408; 'Chem. News,' xliv. 191 (Abs.); 'Beiblätter,' v. 745 (Abs.); 'Les Mondes,' lvi. 59–61; 'Chem. News,' xliv. 306 (Abs.)
K. Hock . . .	Alkaloïdreactionen im Spectralapparate.	'Arch. Pharm.' xix. 358–359; 'Ber.' xiv. 2844 (Abs.)
J. R. Capron . .	A Plea for the Rain Band. (Nov. 1881.)	'Observatory,' 1882, 42–47, 71-77; 'Beiblätter,' vi. 485 (Abs.)
K. Hock . . .	Sur quelques réactions spectrales d'alcaloïdes et de glycosides. (Read Nov. 21.)	'C. R.' xciii. 849–851; 'J. Chem. Soc.' xlii. 349 (Abs.); 'Beiblätter,' vi. 232 (Abs.); 'Ber.' xiv. 2844 (Abs.)
H. Moissan . .	Sur le chromocyanure de potassium. (Read Dec. 19.)	'C.R.' xciii. 1079-1081; 'Chem. News,' xlv. 22 (Abs.); 'Ber.' xv. 243 (Abs.)

1882.

W. N. Hartley . .	Contributions to the Chemistry of Cerium Compounds. (Read Jan. 19.)	'J. Chem. Soc.' xli. 202–209; 'Chem. News,' xlv. 40 (Abs.)
" . .	Researches on the Relation of the Molecular Structure of Carbon Compounds to their Absorption Spectra. Part VI. On the Constitution of Pyridine, Picoline, Quinoline, and Cyanuric Acid.	'J. Chem. Soc.' xli. 45–49; 'Beiblätter,' vi. 375–376 (Abs.)
J. Aitken . . .	Colour of the Mediterranean and other Waters. (Read Feb. 6.)	'Proc. Roy. Soc. Edinb.' xi. 472–483; 'J. Chem. Soc.' xlii. 1017–1018 (Abs.); 'Beiblätter,' vi. 379-380 (Abs.)

ABSORPTION SPECTRA, 1882.

C. H. Wolff . .	Einige neuen Absorptionsspektren.	'Repert. anal. Chem.' ii. 55–56: 'Zeitschr. anal. Chem.' xxii. 96–97 (Abs.); 'Chem. News, xlvii. 178 (Abs.)
E. Lecher . .	Ueber Ausstrahlung und Absorption. (Read March 2.)	'Sitzungsb. Wien. Akad. lxxxv. II. 441–490; 'Ann. Phys. u. Chem.' N.F. xvii. 477–518 (Abs.)
J. Chappuis . .	Sur le spectre d'absorption de l'ozone. (Read March 27.)	'C. R.' xciv. 858–860; 'Chem. News,' xlv. 163 (Abs.); 'J. Chem. Soc.' xlii. 1017 (Abs.); 'Beiblätter,' vi. 482–483; (Abs.); 'Am. J.' [3] xxiv. 56–57 (Abs.)
" . .	Sur le spectre d'absorption de l'acide pernitrique. (Read April 3.)	'C. R.' xciv. 946–948; 'J. Chem. Soc.' xlii. 1017 (Abs.); 'Beiblätter,' vi. 483 (Abs.); 'Am. J.' [3] xxiv. 58–59 (Abs.)
J. Aitken . .	Note on the Absorption of Sea Water. (Read May 1. Extract from a letter to Professor Tait.)	'Proc. Roy. Soc. Edinb.' xi. 637; 'Beiblätter,' vii. 372 (Abs.)
J. Chappuis . .	Étude spectroscopique sur l'ozone.	'Ann. de l'école norm.' [2] xi. 137–186; 'Beiblätter,' vii. 458 (Abs.)
De Chardonnet .	Sur la transparence actinique des verres d'optique. (Read May 29.)	'C. R.' xciv. 1468–1470.
W. J. Russell and W. Lapraik.	A Spectroscopic Study of Chlorophyll. (Read June 1.)	'J. Chem. Soc.' xli. 334–341; 'Nature,' xxvi. 636–639; 'Ber.' xv. 2746 (Abs.)
W. N. Hartley. .	Researches on Spectrum Photography in relation to New Methods of Quantitative Chemical Analysis. Preliminary Note. (Recd. May 19. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 81–84; 'Ber.' xv. 2924–2925 (Abs.); 'J. Chem. Soc.' xliv. 263–264 (Abs.); 'Beiblätter,' vii. 109–110 (Abs.); 'Zeitschr. anal. Chem.' xxii. 539–540 (Abs.)
" . .	On the Reversal of the Metallic Lines as seen in Over-exposed Photographs of Spectra. (Recd. May 19. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 84–86; 'J. Chem. Soc.' xliv. 263 (Abs.); 'Am. J.' [3] xxiv. 471–472 (Abs.) 'Beiblätter,' vii. 27 (Abs.)
C. Zimmermann .	Untersuchungen über das Uran.	'Ann. der Chem.' ccxiii. 285–329; 'Chem. News,' xlvi. 172 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 220–222 (Abs.)
S. P. Langley . .	The Mount Whitney Expedition. (July 13.)	'Nature,' xxvi. 314–317.
O. Tumlirz . .	Ueber eine Methode zur Untersuchung der Absorption des Lichtes durch gefärbte Lösungen. (Read July 13.)	'Wien. Anz.' 1882, 165–166 (Abs.); 'Beiblätter,' vii. 895–896 (Abs.); 'Chem. News,' xlix. 201 (Abs.)

ABSORPTION SPECTRA, 1882, 1883.

G. D. Liveing and J. Dewar	On the Reversal of the Spectral Lines of Metals. (Brit. Assoc.)	'Nature,' xxvi. 466; 'J. de Phys.' [2] ii. 434–435.
W. de W. Abney .	Sunlight and Skylight at High Altitudes. (Brit. Assoc.)	'Nature,' xxvi. 586; 'Beiblätter,' vii. 28 (Abs.); 'J. de Phys.' [2] iii. 47–48 (Abs.)
S. P. Langley . .	Sunlight and Skylight at High Altitudes. (Brit. Assoc.)	'Nature,' xxvi. 586–589; 'Am. J.' [3] xxiv. 393–398; 'Beiblätter,' vii. 28 (Abs.); 'J. de Phys.' [2] iii. 47–48 (Abs.)
C. Binz . . .	Ueber das Verhalten von Blut und Ozon zu einander. ('Med. C.-Bl.' xx. 721–725. Oct. 14.)	'Chem. Centr.' 1882, 810–811; 'J. Chem. Soc.' xliv. 486–487 (Abs.)
M. Nencki and N. Sieber.	Ueber das Urorosein, einen neuen Harnfarbstoff. (Oct. 1882.)	'J. pr. Chem.' xxvi. 333–336; 'Chem. News.' xlvii. 12 (Abs.); 'J. Chem. Soc.' xliv. 101 (Abs.); 'Ber.' xv. 3087 (Abs.)
G. D. Liveing and J. Dewar.	On the Circumstances producing the Reversal of Spectral Lines of Metals. (Read Oct. 30.)	'Proc. Camb. Phil. Soc.' iv. 256–265; 'Beiblätter,' vii. 530–532 (Abs.)
W. de W. Abney .	Work in the Infra-red of the Spectrum.	'Nature,' xxvii. 15–18; 'Beiblätter,' vii. 695–697 (Abs.); 'J. de Phys.' [2] iii. 48 (Abs.)
T. L. Phipson . .	On the Colouring Matter (Ruberine) and the Alkaloid (Agarythrine) contained in *Agaricus Ruber*.	'Chem. News,' xlvi. 199–200; 'J. Chem. Soc.' xliv. 100 (Abs.); 'Ber.' xvi. 244 (Abs.)
J. L. Soret . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances. (Cinquième mémoire.)	'Arch. de Genève' [3] x. 429–494; 'Beiblätter,' viii. 385–386 (Abs.)
J. Chappuis . .	Sur les spectres d'absorption de l'ozone et de l'acide pernitrique.	'J. de Phys.' [2] i. 494–504.
S. P. Langley . .	The Selective Absorption of Solar Energy. (Dec. 30.)	'Am. J.' [3] xxv. 169–196; 'Ann. Phys. u. Chem.' N.F. xix. 226–244, 384–400; 'Phil. Mag.' [5] xv. 153–183; 'Ann. Chim. et Phys.' [5] xxix. 497–542; 'J. de Phys.' [2] ii. 371–374 (Abs.); 'J. Franklin Inst.' lxxxviii. 157–158 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iv. 27–32 (Abs.)

1883.

W. de W. Abney and R. Festing.	Note on the Absorption Spectrum of Iodine in Solution in Carbon Disulphide. (Recd. Jan. 18. Read Jan. 25.)	'Proc. Roy. Soc.' xxxiv. 480–482; 'Chem. News,' xlvii. 63; 'Beiblätter,' vii. 291 (Abs.); 'J. de Phys.' [2] iii. 145–146 (Abs.)

ABSORPTION SPECTRA, 1883.

G. D. Liveing and J. Dewar.	Notes on the Absorption of Ultra-violet Rays by Various Substances. (Recd. March 1. Read March 8.)	'Proc. Roy. Soc.' xxxv. 71–74; 'Chem. News,' xlvii. 121; 'Nature,' xxvii. 521–522 (Abs.); 'Beiblätter,' vii. 373–374 (Abs.); 'Ber.' xvi. 1671 (Abs.); 'J. Chem. Soc.' xliv. 837–838 (Abs.); 'J. de Phys.' [2] iii. 218–219 (Abs.)
" . .	Note on the Reversal of Hydrogen Lines; and on the Outburst of Hydrogen Lines when Water is dropped into the Arc. (Recd. March 1. Read March 8.)	'Proc. Roy. Soc.' xxxv. 74–76; 'Chem. News,' xlvii. 122; 'Nature,' xxviii. 21–22 (Abs.); 'Beiblätter,' vii. 371–372 (Abs.); 'J. Chem. Soc.' xliv. 837–838 (Abs.)
" . .	Note on the Order of Reversibility of the Lithium Lines. (Recd. March 1. Read March 8.)	'Proc. Roy. Soc.' xxxv. 76; 'Chem. News,' xlvii. 133; 'Nature,' xxvii. 499 (Abs.); 'Beiblätter,' vii. 457 (Abs.); 'J. Chem. Soc.' xliv. 839 (Abs.)
W. de W. Abney and R. Festing.	Atmospheric Absorption in the Infra-Red of the Solar Spectrum. (Recd. March 5. Read March 15.)	'Proc. Roy. Soc.' xxxv. 80–83; 'Nature,' xxviii. 45–46; 'J. Chem. Soc.' xliv. 837 (Abs.); 'J. de Phys.' [2] iii. 219 (Abs.)
C. A. MacMunn .	Observations on the Colouring-Matters of the so-called Bile of Invertebrates, and on some unusual Urine Pigments, &c. (Recd. March 8. Read April 5.)	'Proc. Roy. Soc.' xxxv. 370–403; 'J. Chem. Soc.' xlvi. 194–198 (Abs.)
B. Brauner . .	Contribution to the Chemistry of the Cerite Metals. (Read April 5.)	'J. Chem. Soc.' xliii. 278–289; 'Chem. News,' xlvii. 175 (Abs.)
C. H. Koyl . .	On Professor Langley's 'Selective Absorption.' (Univer. Scient. Assoc. Read May 2.)	'Johns Hopkins Univ. Cir.' ii. 145–146; 'Phil. Mag.' [5] xvi. 317–318; 'Beiblätter,' vii. 899 (Abs.)
W. N. Hartley . .	On Real and Pseudo-Reversals of Metallic Lines. (May 18.)	'Nature,' xxviii. 123–124.
J. L. Soret . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances. (Quatrième mémoire.)	'Arch. de Genève,' [3] ix. 513–554; 'Beiblätter,' vii. 600 (Abs.)
J. G. Otto . .	Beiträge zur Kenntniss der Blutfarbstoffe.	'Pflüger's Archiv f. Physiol.' xxxi. 240–244; 'Ber.' xvi. 2688–2689 (Abs.)
" . .	Studien über das Methämoglobin.	'Pflüger's Archiv f Physiol.' xxxi. 245–267 'Ber.' xvi. 2689 (Abs.)
A. Poehl . . .	Zur Lehre von den Fäulnissalkaloïden. (June 6.)	'Ber.' xvi. 1975–1988.

ABSORPTION SPECTRA, 1883.

W. de W. Abney and R. Festing.	The Influence of Water in the Atmosphere on the Solar Spectrum and Solar Temperature. (Recd. June 14. Read June 21.)	'Proc. Roy. Soc.' xxxv. 328–341; 'J. Chem. Soc.' xlvi. 241 (Abs.); 'Beiblätter,' viii. 507 (Abs.)
H. W. Vogel . .	Ueber die Absorption des Seewassers.	'Beiblätter,' vii. 532.
O. Jacobsen and F. Wierss.	Ueber einige Derivate der Orthotoluylsäure. (Read July 23.)	'Ber.' xvi. 1956–1962; 'J. Chem. Soc.' xliv. 1121 (Abs.)
G. Krüss and S. Oeconomides.	Beziehungen zwischen der Zusammensetzung und der Absorptionsspektren organischer Verbindungen. (Recd. Aug. 10.)	'Ber.' xvi. 2051–2056; 'J. Chem. Soc.' xliv. 1041–1042 (Abs.); 'Beiblätter,' vii. 897–899 (Abs.)
C. V. Zenger . .	Études astrophotographiques. (Read Aug. 27.)	'C. R.' xcvii. 552–555; 'Beiblätter,' vii. 860–862 (Abs.)
Egoroff . . .	Sur la production des groupes telluriques fondamentaux A et B du spectre solaire par une couche absorbante d'oxygène. (Read Aug. 27.)	'C. R.' xcvii. 555–557; 'Beiblätter,' vii. 859–860 (Abs.); 'Am. J.' [3] xxvi. 477 (Abs.)
J. L. Soret . .	Sur l'absorption des rayons ultraviolets par les milieux de l'œil et par quelques autres substances (Read Aug. 27.)	'C. R.' xcvii. 572–575; 'Beiblätter,' vii. 856–858 (Abs.)
P. T. Clève . .	On Samarium and its Compounds.	'J. Chem. Soc.' xliii. 362–370; 'Chem. News,' xlviii. 74–76; 'Ber.' xvi. 2493 (Abs.)
P. Plósz . . .	Ueber einige Chromogene des Harns und deren Derivate. (Recd. Sept. 6.)	'Zeitschr. physiol. Chem.' viii. 85–94; 'Ber.' xvi. 2933–2934 (Abs.)
J. L. Soret . .	Sur l'absorption des rayons ultraviolets par les substances albuminoïdes. (Read Sept. 10.)	'C. R.' xcvii. 642–644; 'Chem. News,' xlviii. 169 (Abs.); 'Nature,' xxviii. 536 (Abs.); 'J. Chem. Soc.' xlvi. 242–243 (Abs.); 'Beiblätter,' viii. 385–386 (Abs.)
,, . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances. (Cinquième mémoire.)	'Arch. de Genève,' [3] x. 429–494.
A. Tschirch . .	Die Reindarstellung des Chlorophyllfarbstoffes. (Read Nov. 12.)	'Ber.' xvi. 2731–2736; 'J. Chem. Soc.' xlv. 57–62.
,, . .	Untersuchungen über das Chlorophyll und einige seiner Derivate. (Dec. 1883.)	'Ann. Phys. u. Chem.' N.F. xxi. 370–383.
J. L. Soret . .	Sur le spectre d'absorption du sang dans la partie violette et ultraviolette. (Read Dec. 3.)	'C. R.' xcvii. 1269–1270; 'Chem. News,' xlix. 10 (Abs.); 'J. de Pharm.' [5] ix. 141–143; 'J. Chem. Soc.' xlvi. 381 (Abs.); 'Ber.' xvii. 'Referate,' 111–112 (Abs.); 'Beiblätter,' viii. 385–386 (Abs.)

ABSORPTION SPECTRA, 1884.—PHYSICAL RELATIONS, 1880, 1881.

1884.

J. L. Soret and E. Sarasin.	Sur le spectre d'absorption de l'eau. (Read March 10.)	'C. R.' xcviii. 624–626; 'Chem. News,' xlix. 182 (Abs.); 'J. Chem. Soc.' xlvi. 701 (Abs.); 'Beiblätter,' viii. 508 (Abs.); 'Am. J.' [3] xxvii. 485–486 (Abs.)
J. L. Soret . .	Sur la couleur de l'eau . . .	'Arch. de Genève' [3] xi. 276–296; 'Beiblätter,' viii. 508 (Abs.)
J. H. Stebbins .	On the Spectra of the Azo-Colours. (Read April 1.)	'J. Am. Chem. Soc.' vi. 117–120.
A. Morghen . .	Lo spettro di assorbimento del vapore di jodio. (Read June 15.)	'Atti R. Accad. Lincei. Transunti' [3] viii. 327–330; 'Beiblätter,' viii. 822–823 (Abs.)
" . .	Lo spettro di assorbimento del vapore di jodio. (June 1884.)	'Mem. Spettr. ital.' xiii. 127–131; 'Beiblätter,' 822–823 (Abs.)

PHYSICAL RELATIONS.

1880.

W. Dietrich . .	Ueber das Verhältniss der Intensitäten der beiden Natriumlinien. (Dec. 1880.)	'Ann. Phys. u. Chem.' N.F. xii. 519–526; 'J. de Phys.' x. 506 (Abs.)

1881.

Hurion . . .	Application des franges de Talbot à la détermination des indices de réfraction des liquides.	'J. de Phys.' x. 154–158.
A. Cornu . . .	Études photométriques . . .	'J. de Phys.' x. 189–198; 'Beiblätter,' viii. 501 (Abs.)
N. Chamantoff .	Sur la photographie de la partie moins réfrangible du spectre. (In Russian.)	'J. soc. phys.-chim. russe,' xiii. 320–328; 'J. de Phys.' [2] i. 577 (Abs.)
B. C. Damien . .	Indices de réfraction de l'eau en surfusion.	'J. de Phys.' x. 198–202.
W. E. Ayrton and J. Perry.	Note on the Index of Refraction of Ebonite. (Read June 25.)	'Proc. Phys. Soc.' iv. 345–348; 'Phil. Mag.' [5] xii. 196–199; 'Beiblätter,' v. 741 (Abs.); 'J. de Phys.' x. 507 (Abs.)
M. v. Frey and J. v. Kries.	Ueber die Mischung von Spectralfarben.	'Archiv f. Physiol.' 1881, 336–353; 'Beiblätter,' vi. 109–110 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 110–111 (Abs.); 'J. de Phys.' [2] i. 513–514 (Abs.)
H. Dufet . . .	Influence de la température sur les indices principaux du gypse. (Read July 7.)	'Bull. Soc. Min. de France,' iv. 191–196; 'Beiblätter,' vi. 287 (Abs.)

PHYSICAL RELATIONS, 1881.

C. Pulfrich	Photometrische Untersuchungen über Absorption des Lichtes in isotropen und anisotropen Medien. (July 1881.)	'Ann. Phys. u. Chem.' N.F. xiv. 177–218; 'Am. J.' [3] xxiii. 50 (Abs.); 'J. de Phys.' [2] i. 285–286 (Abs.)
B. C. Damien	Recherches sur le pouvoir réfringent des liquides.	'Ann. de l'école norm.' [2] x. 233–304; 'Beiblätter,' v. 579–584 (Abs.); 'J. de Phys.' x. 394–401, 431–434 (Abs.)
S. P. Langley	Distribution de l'énergie dans le spectre normal. (Read July 18.)	'C. R.' xciii. 140–143; 'Beiblätter,' v. 660–661 (Abs.)
E. Lecher	Ueber die spectrale Vertheilung der strahlenden Wärme. (Read July 21.)	'Wien. Anz.' 1881, 193–194.
K. H. Schellbach	Das Minimum der Ablenkung eines Lichtstrahls im Prisma.	'Ann. Phys. u. Chem.' N.F. xiv. 367.
L. Thollon	Longueurs d'onde des bandes spectrales données par les composés du carbone. (Read Aug. 1.)	'C. R.' xciii. 260; 'Ann. Chim. et Phys.' [5] xxv. 287–288.
J. H. Gladstone	Observations on the Specific Refraction and Dispersion of Light by Liquids. (Brit. Assoc.)	'Nature,' xxiv. 468 (Abs.); 'Beiblätter,' vi. 21 (Abs.)
Lord Rayleigh	Experiments on Colour. (Brit. Assoc. Sept. 2.)	'Nature,' xxv. 64–66.
A. Crova	Comparaison photométrique des sources lumineuses de teintes différentes. (Read Sept. 26.)	'C. R.' xciii. 512–513; 'Phil. Mag.' [5] xii. 445–447; 'Chem. News,' xliv. 214 (Abs.); 'Beiblätter,' v. 867–868 (Abs.)
A. Cornu	Détermination des longueurs d'onde des radiations très-réfrangibles du magnésium, du cadmium, du zinc et de l'aluminium.	'J. de Phys.' x. 425–431.
J. Macé de Lépinay and W. Nicati.	Recherches sur la comparaison photométrique des diverses parties d'un même spectre.	'Ann. Chim. et Phys.' [5] xxiv. 289–337.
J. W. Brühl	Ueber den Zusammenhang zwischen den optischen und den thermischen Eigenschaften flüssiger organischer Körper. (Read Nov. 3.)	'Sitzungsb. Wien. Akad.' lxxxiv. II. 817–875; 'Monatsh. f. Chem.' ii. 716–774; 'Ann. der Chem.' ccxi. 121–178; 'J. Chem. Soc.' xlii. 263 (Abs.); 'Beiblätter,' vi. 377–378 (Abs.)
,,	Berichtigung	'Ann. der Chem.' ccxi. 371–372; 'Beiblätter,' vi. 377–378 (Abs.)
H. Schröder	Untersuchungen über die Abhängigkeit der Molecularrefraction flüssiger Verbindungen von ihrer chemischen Zusammensetzung. (Read Nov. 5.)	'Sitzungsb. Akad. München,' 1882, 57–104; 'Ann. Phys. u. Chem.' N.F. xv. 636–675; 'J. Chem. Soc.' xlii. 1153–1154 (Abs.)

PHYSICAL RELATIONS, 1881, 1882.

H. Schröder . .	Untersuchungen über die Abhängigkeit der Molekularrefraktion von der chemischen Constitution der Verbindungen. (Nov. 7. Read Nov. 14.)	'Ber.' xiv. 2513–2516; 'J. Chem. Soc.' xlii. 351–352 (Abs.)
J. W. Brühl . .	Die Beziehung zwischen den physikalischen Eigenschaften organischer Körper und ihrer chemischen Constitution. (Read Nov. 14.)	'Ber.' xiv. 2533–2539; 'Am. J.' [3] xxiii. 234–235 (Abs.)
P. P. Bedson and W. C. Williams.	Ueber die Bestimmung des specifischen Brechungs-vermögen fester Körper in ihren Lösungen. (Recd. Oct. 18. Read Nov. 14.)	'Ber.' xiv. 2549–2556; 'J. Chem. Soc.' xlii. 351 (Abs.); 'Beiblätter,' vi. 91–93 (Abs.); 'J. de Phys.' [2] i. 377–378 (Abs.)
E. Ketteler and C. Pulfrich.	Photometrische Untersuchungen. (Nov. 1881.)	'Ann. Phys. u. Chem.' N.F. xv. 337–378; 'Am. J.' [3] xxiii. 486–487 (Abs.)
Piltchikoff . .	Mesure des indices de réfraction des liquides à l'aide des lentilles formées des mêmes liquides. (In Russian.)	'J. soc. phys.-chim. russe,' xiii. 393–410; 'Beiblätter,' vii. 189–190 (Abs.); 'J. de Phys.' [2] i. 578–579 (Abs.)
A. W. Soward . .	Notes on the Recombination of the Spectral Colours by a Second Prism reversed.	'Chem. News,' xliv. 267–268; 'Beiblätter,' vi. 90–91 (Abs.)
H. Dufet . .	Variation des indices de réfraction du gypse avec la température.	'J. de Phys.' x. 513–519.
A. Crova and Lagarde.	Détermination du pouvoir éclairant des radiations simples. (Read Dec. 5.)	'C. R.' xciii. 959–961; 'Phil. Mag.' [5] xiii. 72–73; 'Chem. News,' xliv. 315 (Abs.); 'Beiblätter,' vi. 96 (Abs.)
J. W. Brühl . .	Ueber die Molekularrefraktion der Citracon- und Mesaconsäureäther. (Dec. 8. Read Dec. 12.)	'Ber.' xiv. 2736–2744; 'J. Chem. Soc.' xlii. 829–830 (Abs.); 'Beiblätter,' vi. 376 (Abs.)
,, . .	Ueber die Molekularrefraktion der Methacryl- und der Crotonsäure. (Recd. Dec. 22.)	'Ber.' xiv. 2797–2801; 'J. Chem. Soc.' xlii. 827 (Abs.); 'Beiblätter,' vi. 477–478 (Abs.)
F. Flawitzky . .	Das molekulare Brechungsvermögen der Terpene. (Dec. 18, 1881. Read Jan. 9, 1882.)	'Ber.' xv. 15–16.

1882.

J. Fröhlich . .	Experimentaluntersuchungen über die Intensität des gebeugten Lichts; II. (Jan. 1.)	'Ann. Phys. u. Chem.' N.F. xv. 576–613; 'J. de Phys.' [2] i. 559–560 (Abs.)
J. Thomsen . .	Brechungsvermögen und Verbrennungswärme. (Jan. 1882.)	'Ber.' xv. 66–69; 'J. Chem. Soc.' xlii. 567 (Abs.); 'Beiblätter,' vi. 377–378 (Abs.)

PHYSICAL RELATIONS, 1882.

H. Landolt . .	Ueber die Molecularrefraction flüssiger organischer Verbindungen. (Read Jan 19.)	'Sitzungsb. Berl. Akad.' 1882, 64–91; 'Ann. der Chem.' ccxiii. 75–112; 'Beiblätter,' vii. 843–848 (Abs.)
C. V. Zenger . .	Les observations spectroscopiques à la lumière monochromatique. (Read Jan. 23.)	'C. R.' xciv. 155–156; 'Chem. News,' xlv. 86–87 (Abs.); 'J. Chem. Soc.' xlii. 677 (Abs.); 'Am. J.' [3] xxiii. 322–323 (Abs.); 'Beiblätter,' vi. 378–379 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 114 (Abs.)
A. Crova . . .	Projection du foyer du prisme .	'J. de Phys.' [2] i. 84–86.
S. P. Langley . .	La distribution de l'énergie dans le spectre normal.	'Ann. Chim. et Phys.' [5] xxv. 211–219; 'J. de Phys.' [2] ii. 233–234 (Abs.)
W. N. Hartley .	Researches on the Relation of the Molecular Structure of Carbon Compounds to their Absorption Spectra. Part VI. On the Constitution of Pyridine, Picoline, Quinoline, and Cyanuric Acid.	'J. Chem. Soc.' xli. 45–49; 'Beiblätter,' vi. 375–376 (Abs.)
J. Hopkinson . .	On the Refractive Index and Specific Inductive Capacity of Transparent Insulating Media. (Read Feb. 25.)	'Proc. Phys. Soc.' v. 38–40.
Wiedemann . .	Ueber einige von der Herren J. W. Brühl und V. Zenger aufgestellte Beziehungen zwischen physikalischen Constanten chemischer Verbindungen. (Feb. 24. Recd. Feb. 28.)	'Ber.' xv. 467–470; 'Beiblätter,' vi. 370–371 (Abs.), 377–378 (Abs.)
E. Albert . .	Ueber die Aenderung des Farbentones von Spectralfarben und Pigmenten bei abnehmender Lichtstärke.	'Ann. Phys. u. Chem.' N.F. xvi. 129–160; 'J. Chem. Soc.' xlii. 1153 (Abs.)
C. Pulfrich . .	Entgegung auf die Abhandlung des Hrn. V. v. Lang: 'Bestimmung der Brechungsquotienten einer concentrirten Cyaninlösung.' (March, 1882.)	'Ann. Phys. u. Chem.' N.F. xvi. 335–348.
A. Kurz . . .	Messung des Brechungexponenten während des Unterrichtes.	'Carl. Repert.' xviii. 190–192.
A. Crova and Lagarde.	Détermination du pouvoir éclairant des radiations simples.	'J. de Phys.' [2] i. 162–169.
H. Schröder . .	Fernere Untersuchungen über die Abhängigkeit der Molekularrefraction flüssiger Verbindungen von ihrer chemischen Constitution. (April 22.)	'Ber.' xv. 994–998; 'J. Chem. Soc.' xlii. 910–911 (Abs.)
H. Landolt . .	Ueber die Molekularrefraktion flüssiger organischer Verbindungen. (Read April 24.)	'Ber.' xv. 1031–1040; 'J. Chem. Soc.' xlii. 909–910 (Abs.)

PHYSICAL RELATIONS, 1882.

P. Desains . .	Recherches sur la distribution de la chaleur dans la région obscure des spectres solaires. (Read April 24.)	'C. R.' xciv. 1144–1147; 'Beiblätter,' vi. 479–480 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 214 (Abs.)
De Chardonnet .	Sur la transformation actinique des miroirs Foucault et leurs applications en photographie. (Read April 24.)	'C. R.' xciv. 1171–1173; 'Beiblätter,' vi. 483–484 (Abs.)
S. Merz . . .	Ueber Dispersions-Verhältnisse optischer Gläser.	'Zeitschr. f. Instrumentenkunde,' ii. 176–180; 'Beiblätter,' vi. 673–674 (Abs.)
A. A. Michelson .	Interference Phenomena in a New Form of Refractometer.	'Am. J.' [3] xxiii. 395–400; 'Phil. Mag.' [5] xiii. 236–242; 'Beiblätter,' vii. 534–535 (Abs.)
R. Schelske . .	Versuche über Farbenmischung .	'Ann. Phys. u. Chem.' N.F. xvi. 349–358.
A. Hurion . .	Sur les conditions d'achromatisme dans les phénomènes d'interférence. (Read May 15.)	'C. R.' xciv. 1345–1347.
De Chardonnet .	Sur la transparence actinique des verres d'optique. (Read May 29.)	'C. R.' xciv. 1468–1470; 'Beiblätter,' vii. 459–460 (Abs.)
W. C. L. van Schaik	Recherches concernant la dispersion électromagnétique sur un spectre de grande étendue.	'Archives Néerlandaises,' xvii. 373–390; 'Beiblätter,' vii. 919–920 (Abs.)
C. E. de Klercker .	Recherches sur la dispersion prismatique de la lumière. (June 7.)	'Bihang till k. Svenska Vet. Akad. Handl.' vii. No. 1, 1–55.
Des Cloiseaux . .	Sur l'indice de réfraction du chlorure d'argent naturel. (Read June 8.)	'Bull. Soc. Min. de France,' v. 143; 'Beiblätter,' vii. 25 (Abs.)
G. Wyrouboff . .	Sur la dispersion du chromate de soude à $4H_2O$. (Read June 8.)	'Bull. Soc. Min. de France, v. 160–161.
H. Hammerl . .	Ueber Regenbogen, gebildet durch Flüssigkeiten von verschiedenen Brechungsexponenten. (Read July 6.)	'Sitzungsb. Wien. Akad.' lxxxvi. II. 206–215; 'Wien. Anz.' 1882, 149 (Abs.); 'Beiblätter,' vii. 383–385 (Abs.)
A. Hurion . .	Sur les conditions d'achromatisme dans les phénomènes d'interférence. (Read July 10.)	'C. R.' xcv. 75–77.
J. L. Soret and E. Sarasin.	Sur la polarisation rotatoire du quartz.	'Arch. de Genève' [3] viii. 5–59, 97–132, 201–228; 'J. de Phys.' [2] ii. 381–386 (Abs.)
De Chardonnet .	Sur la transparence actinique de quelques milieux et en particulier sur la transparence actinique des miroirs de Foucault et leur application en photographie.	'J. de Phys.' [2] i. 305–312.

PHYSICAL RELATIONS, 1882.

H. Schröder . .	Fernere Untersuchungen über die Abhängigkeit der Molecularrefraction flüssiger Verbindungen von ihrer chemischen Constitution. (Aug. 24.)	'Ann. Phys. u. Chem.' N.F. xviii. 148–175; 'J. Chem. Soc.' xliv. 538–539 (Abs.)
J. Bodynski . .	Ueber eine einfache Methode zur approximativen Bestimmung der Brechungsexponenten flüssiger Körper.	'Carl. Repert.' xviii. 502–504; 'Beiblätter,' vi. 932 (Abs.)
A. Johnson . .	Newton, Wollaston, and Fraunhofer's Lines. (Sept. 19.)	'Nature,' xxvi. 572; 'Beiblätter,' vii. 65–66 (Abs.)
P. Desains . .	Sur la distribution de la chaleur dans les régions obscures de spectres solaires. (Read Sept. 4.)	'C. R.' xcv. 433–436; 'J. Chem. Soc.' xliv. 143 (Abs.); 'Beiblätter,' vii. 26–27 (Abs.)
De Chardonnet .	Étude expérimentale de la réflexion des rayons actiniques: influence du poli spéculaire. (Read Sept. 4.)	'C. R.' xcv. 449–451; 'J. Chem. Soc.' xliv. 138–139 (Abs.); 'Beiblätter,' vii. 461–462 (Abs.)
E. Sarasin . .	Indices de réfraction du spath d'Islande. (Read Sept. 11. Société helvétique.)	'Arch. de Genève' [3] viii. 392–394; 'J. de Phys.' [2] ii. 369–371.
E. Wiedemann .	Ueber die Molecularrefraction der geschwefelten Kohlensäureäther, nebst einigen Bemerkungen über Molecularrefractionen im Allgemeinen.	'Ann. Phys. u. Chem.' N.F. xvii. 577–580; 'J. Chem. Soc.' xliv. 762 (Abs.); 'J. de Phys.' [2] ii. 139–140 (Abs.)
J. L. Soret and E. Sarasin.	Sur la polarisation rotatoire du quartz. (Read Oct. 9.)	'C. R.' xcv. 635–638; 'J. Chem. Soc.' xliv. 140–141 (Abs.); 'Beiblätter,' vi. 942–943 (Abs.)
E. Sarasin . .	Indices de réfraction ordinaire et extraordinaire du spath d'Islande, pour les rayons de diverses longueurs d'onde jusqu'à l'extrême ultraviolet. (Read Oct. 16.)	'C. R.' xcv. 680–682; 'Beiblätter,' vi. 944–945 (Abs.)
C. Christiansen .	Methoder til at maale Brydningsforholdet for farvede Vædsker. [Ueber die Messung des Brechungsverhältnisses gefärbter Flüssigkeiten.]	'Oversigt kgl. Danske Vidensk. Selsk. Forh.' 1882, 217–250; 'Ann. Phys. u. Chem.' N.F. xix. 257–267; 'Nature,' xxviii. 308 (Abs.)
J. Moutier . .	Sur le mélange des couleurs. (Read Nov. 25.)	'Bull. Soc. Philom.' [7] vii. 19–21; 'Carl. Repert.' xix. 672–674.
T. W. Engelmann .	Over de zamenstelling van zonlicht, gaslicht en het van Edison's lamp, vergelijkend onderzocht met behulp der bacteriënmethode. (Read Nov. 25.)	'Proc. verb. k. Akad. v. Wetensch. te Amsterdam,' Nov. 25, 1882, No. 5, 4–5; 'Beiblätter,' vii. 380 (Abs.)
R. Nasini . .	Ueber die Atomrefraktion des Schwefels. (Read Nov. 27.)	'Ber.' xv. 2878–2892; 'J. Chem. Soc.' xliv. 264–266 (Abs.); 'Beiblätter,' vii. 281–284 (Abs.)

PHYSICAL RELATIONS, 1882, 1883.

E. Pringsheim . .	Eine Wellenlängenmessung im ultrarothen Sonnenspectrum.	'Ann. Phys. u. Chem.' N.F. xviii. 32-45; 'Am. J.' [3] xxv. 230 (Abs.); 'Phil. Mag.' [5] xv. 235-245; 'J. de Phys.' [2] ii. 424 (Abs.)
De Chardonnet .	Étude expérimentale de la réflexion des rayons actiniques: influence du poli spéculaire.	'J. de Phys.' [2] i. 549-552.
A. Crova . . .	Sur la photométrie solaire. (Read Dec. 18.)	'C. R.' xcv. 1271-1273, xcvi. 124; 'Beiblätter,' vii. 113 (Abs.)
H. Lagarde . .	Mesure de l'intensité photométrique des raies spectrales de l'hydrogène. (Read Dec. 26.)	'C. R.' xcv. 1350-1352; 'J. Chem. Soc.' xliv. 537 (Abs.); 'Beiblätter,' vii. 316-317 (Abs.); 'Phil. Mag.' [5] xv. 226-228.
	1883.	
J. Macé de Lépinay and W. Nicati.	Recherches sur la comparaison photométrique des sources diversement colorées, et en particulier sur la comparaison des diverses parties d'un même spectre. (Read Jan. 5.)	'Soc. Franc. de Phys.' 1883, 11-23; 'J. de Phys.' [2] ii. 64-76.
H. Becquerel . .	Phosphorographie de la région infrarouge du spectre solaire. Longueur d'onde des principales raies. (Read Jan. 8.)	'C. R.' xcvi. 121-124; 'Chem. News,' xlvii. 93 (Abs.); 'Am. J.' [3] xxv. 230 (Abs.); 'Beiblätter,' vii. 294-295 (Abs.); 'Phil. Mag.' [5] xv. 223-226.
E. Wiedemann .	Ueber die Dissociationswärme des Wasserstoffmolecüls und das electrische Leuchten der Gase.	'Ann. Phys. u. Chem.' N.F. xviii. 509-510.
C. Timiriazeff . .	La distribution de l'énergie dans le spectre solaire et la chlorophyll. (Read Feb. 5.)	'C. R.' xcvi. 375-376; 'Nature,' xxvii. 380 (Abs.); 'Beiblätter,' vii. 289 (Abs.); 'J. Chem. Soc.' xliv. 697 (Abs.)
De Chardonnet .	Pénétration des radiations actiniques dans l'œil de l'homme et des animaux vertébrés. (Read Feb. 12.)	'C. R.' xcvi. 441-444; 'Beiblätter,' vii. 460-461 (Abs.)
" . .	Vision des radiations ultra-violettes. (Read Feb. 19.)	'C. R.' xcvi. 509-511; 'Nature,' xxvii. 428 (Abs.); 'Chem. News,' xlvii. 129 (Abs.); 'Beiblätter,' vii. 460-461 (Abs.)
C. V. Zenger . .	Imitation des spectres de diffraction par la dispersion. (Read Feb. 19.)	'C. R.' xcvi. 521-522; 'Beiblätter,' vii. 285-286 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 108 (Abs.)
Mascart . . .	Remarques sur une Communication de M. de Chardonnet relative à la vision des radiations ultra-violettes. (Read Feb. 26.)	'C. R.' xcvi. 571; 'Beiblätter,' vii. 460-461 (Abs.)

PHYSICAL RELATIONS, 1883.

V. v. Lang	Der infrarothe Theil des Sonnenspectrums.	'Carl. Repert.' xix. 107–109; 'Beiblätter,' vii. 374–375 (Abs.)
J. Macé de Lépinay and W. Nicati.	Recherches sur la comparaison photométrique des sources diversement colorées, et en particulier sur la comparaison des diverses parties d'un même spectre.	'J. de Phys.' [2] ii. 64–76; 'Beiblätter,' vii. 596–598 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iii. 290–291 (Abs.)
G. Quincke	Uber die Aenderung des Volumens und des Brechungsexponenten von Flüssigkeiten durch hydrostatischen Druck. (March 1883.)	'Ann. Phys. u. Chem.' N.F. xix. 401–435; 'Sitzungsb. Berl. Akad.' 1883, 409–412 (Abs.): 'Nature,' xxviii. 308–309 (Abs.); 'Ber.' xvi. 1668 (Abs.); 'Phil. Mag.' [5] xvii. 65–68 (Abs.); 'J. de Phys.' [2] ii. 279–280 (Abs.)
J. Kanonnikoff	Sur le pouvoir réfringent des substances organiques dans les dissolutions. (In Russian.)	'J. soc. phys.-chim. russe,' xv. 112–113; 'Ber.' xvi. 950 (Abs.); 'J. pr. Chem.' xxvii. 362–364.
A. König	Ueber den neutralen Punkt im Spektrum der Farbenblinden. (Read March 2.)	'Verhandl. d. phys. Ges. Berlin,' 1883, 20–23.
M. Weinberg	Messung der Wellenlängen des Lichtes mittels Interferenzstreifen im Beugungsspectrum.	Carl. Repert.' xix. 148–154; 'Beiblätter,' vii. 299 (Abs.)
J. Chappuis and C. Rivière.	Sur les indices de réfraction des gaz à des pressions élevées. (Read March 12.)	'C. R.' xcvi. 699–701; 'Phil. Mag.' [5] xv. 299–300; 'Beiblätter,' vii. 370–371 (Abs.)
W. N. Hartley	On Homologous Spectra. (Read March 15.)	'J. Chem. Soc.' xliii. 390–400; 'Nature,' xxvii. 522 (Abs.); 'Chem. News,' xlvii. 138 (Abs.); 'Am. J.' [3] xxvi. 401–402 (Abs.); 'Ber.' xvi. 2659–2660 (Abs.); 'Beiblätter,' viii. 217–218 (Abs.)
A. Abt	Beobachtungen dunkler Interferenzstreifen im Spectrum des weissen Lichtes. (April 7.)	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 352–354.
J. Violle	Sur la radiation de l'argent au moment de sa solidification. (Read April 9.)	'C. R.' xcvi. 1033–1035; 'Chem. News,' xlvii. 213 (Abs.); 'Beiblätter,' vii. 457–458 (Abs.)
P. Barbier	Sur les chlorhydrates liquides de térébenthène. (Read April 9.)	'C. R.' xcvi. 1066–1069; 'J. Chem. Soc.' xliv. 809 (Abs.)
Lord Rayleigh	Distribution of Energy in the Spectrum.	'Nature,' xxvii. 559–560; 'Beiblätter,' vii. 459 (Abs.)

PHYSICAL RELATIONS, 1883.

W. N. Hartley and W. E. Adeney.	Measurements of the Wave-Lengths of Lines of High Refrangibility in the Spectra of Elementary Substances. (Recd. March 20. Read April 19.)	'Phil. Trans.' clxxv. 63–137; 'Proc. Roy. Soc.' xxxv. 148–149 (Abs.); 'Chem. News,' xlvii. 193–194 (Abs.); 'Beiblätter,' vii. 599–600 (Abs.)
Pringsheim . .	Eine Wellenlängenmessung im ultrarothen Sonnenspektrum. (Read April 20.)	'Verhandl. d. phys. Ges. Berlin,' 1883, 36–38; 'Nature,' xxviii. 72 (Abs.)
H. Becquerel . .	Étude des radiations infra-rouges au moyen des phénomènes de phosphorescence. (Read April 23.)	'C. R.' xcvi. 1215–1218; 'Chem. News,' xlvii. 225 (Abs.); 'J. Chem. Soc.' xliv. 761–762 (Abs.); 'Beiblätter,' vii. 699–701 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 49 (Abs.)
H. Dufet . . .	Sur la variation des indices de réfraction de l'eau et du quartz sous l'influence de la température. (Read April 23.)	'C. R.' xcvi. 1221–1224; 'J. Chem. Soc.' xliii. 762–763 (Abs.); 'Beiblätter,' vii. 606–607 (Abs.)
Donders . . .	Over spectroscopische vergelijkingen, betrekking hebbende tot de samenstelling van verschillende lichtbronnen en hoofdzakelijk tot den licht- en kleurenzin. (Read April 27.)	'Proc. Verb. Ak. Wetensch. Amsterdam,' 1882–83, No. 10, 4–6.
H. Dufet . . .	Sur la variation des indices de réfraction de l'eau et du quartz sous l'influence de la température. (Read May 10.)	'Bull. Soc. Min. de France,' vi. 76–80.
W. König . .	Ueber die optischen Eigenschaften der Platincyanüre.	'Ann. Phys. u. Chem.' N.F. xix. 491–512.
De Chardonnet .	Sur la pénétration des radiations actiniques dans l'œil de l'homme et des animaux vertébrés, et sur la vision des radiations ultra-violettes.	'J. de Phys.' [2] ii. 219–225; 'Beiblätter,' vii. 460–461 (Abs.)
J. Kanonnikoff .	Ueber das Brechungsvermögen organischer Verbindungen in Lösungen.	'J. pr. Chem.' N.F. xxvii. 362–364; 'Beiblätter,' vii. 593–594 (Abs.); 'J. Chem. Soc.' xliv. 1041 (Abs.)
S. Reformatsky .	Untersuchungen über einen aus Allyldipropylcarbinol erhaltenen Kohlenwasserstoff: $C_{10}H_{18}$.	'J. pr. Chem.' N.F. xxvii. 389–407; 'Beiblätter,' vii. 689 (Abs.) (Error in Title.)
R. Nasini . . .	Sulla refrazione atomica dello zolfo.	'Gazz. chim. ital.' xiii. 296–311; 'J. Chem. Soc.' xlvi. 149–151 (Abs.)
Bernheimer and Nasini.	Sulle relazioni esistenti tra il potere rifrangente e la constituzione chimica delle combinazioni organiche. (Read May 6.)	'Atti della R. Acc. dei Lincei, Transunti' [3] vii. 227–230; 'Gazz. chim. ital.' xiii. 317–320; 'Beiblätter,' vii. 528–529 (Abs.)

Physical Relations, 1883.

H. Becquerel . .	Maxima et minima d'extinction de la phosphorescence sous l'influence des radiations infra-rouges. (Read June 25.)	'C. R.' xcvi. 1853–1856; 'Chem. News,' xlviii. 22 (Abs.); 'Beiblätter,' vii. 702–703 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 49 (Abs.)
W. Johst . . .	Die Brechungscoëfficienten einiger Gemische von Anilin und Alkohol.	'Ann. Phys. u. Chem.' N.F. xx. 47–62.
C. Rohrbach . .	Ueber eine neue Flüssigkeit von hohem specifischen Gewicht, hohem Brechungsexponenten und grosser Dispersion. (July 11.)	'Ann. Phys. u. Chem.' N.F. xx. 169–174; 'Am. J.' [3] xxvi. 406 (Abs.); 'J. Chem. Soc.' xlvi. 145 (Abs.)
J. L. Soret . .	Sur la visibilité des rayons ultra-violets. (Read July 30.)	'C. R.' xcvii. 314–316; 'Beiblätter,' vii. 856–858 (Abs.)
C. Soret . . .	Sur la réfraction et la dispersion des aluns cristallisés. (Soc. helvétique. Read Aug. 7.)	'Arch. de Genève' [3] x. 300–302; 'Beiblätter,' viii. 374–375 (Abs.)
E. Sarasin . .	Indices de réfraction du spath fluor. (Soc. helvétique. Read Aug. 7.)	'Arch. de Genève' [3] x. 303–304.
B. O. Peirce, Jun. .	On the Sensitiveness of the Eye to Slight Differences of Colour. (Aug. 1883.)	'Am. J.' [3] xxvi. 299–302; 'Zeitschr. f. Instrumentenkunde,' iv. 67–68 (Abs.); 'Beiblatter,' viii. 120 (Abs.)
A. Albitsky . .	Sur le pouvoir réfringent de l'hydrocarbure $C_{12}H_{20}$. (In Russian. Read Aug. 20–Sept. 1.)	'J. soc. phys.-chim. russe,' xv. 524–526.
H. Becquerel . .	Mémoire sur l'étude des radiations infra-rouges au moyen de phénomènes de phosphorescence.	'Ann. Chim. et Phys.' [5] xxx. 5–68; 'Beiblätter,' viii. 647–649 (Abs.)
J. Kanonnikoff .	Sur la relation du pouvoir réfringent et la composition des composées organiques. (In Russian. Read Sept. 15–27.)	'J. soc. phys.-chim. russe,' xv. 434–479; 'Ber.' xvi. 3047–3051 (Abs.); 'Bull. Soc. Chim.' xli. 318–319 (Abs.); 'Beiblätter,' viii. 375–377 (Abs.)
P. Desains . .	Note sur les spectres solaires. Appareils réfringents en sel gemme. (Read Sept. 24.)	'C. R.' xcvii. 689–693, 732; 'Beiblätter,' vii. 858–859 (Abs.)
S. P. Langley . .	Experimental Determination of Wave Lengths in the Invisible Prismatic Spectrum. (Oct. 1883.)	'Am. J.' [3] xxvii. 169–188; 'Phil. Mag.' [5] xvii. 194–214; 'Ann. Chim. et Phys.' [6] ii. 145–176; 'Zeitschr. f. Instrumentenkunde,' iv. 320–322 (Abs.)
Macé de Lépinay and Nicati.	Recherches sur la comparaison photométrique des diverses parties d'un même spectre.	'Ann. Chim. et Phys.' [5] xxx. 145–214.
W. von Bezold .	Ein einfacher Versuch zur Versinnlichung des Zusammenhanges zwischen der Temperatur eines glühenden Drahtes und der Zusammensetzung des von ihm ausgehenden Lichtes. (Oct. 1883.)	'Ann. Phys. u. Chem.' N.F. xxi. 175–178.

PHYSICAL RELATIONS, 1883, 1884.

F. van Assche .	Sur un moyen d'isoler les radiations calorifiques des radiations lumineuses et chimiques. (Read Oct. 15.)	'C. R.' xcvii. 838–840; 'Beiblätter,' vii. 895 (Abs.); 'Am. J.' [3] xxvi. 476–477; 'J. Chem. Soc.' xlvi. 241 (Abs.)
E. Sarasin . .	Indices de réfraction du spath-fluor pour les rayons de différentes longueurs d'onde, jusqu'à l'extrême ultra-violet. (Read Oct. 15.)	'C. R.' xcvii. 850–852; 'Beiblätter,' vii. 891–892 (Abs.)
W. de W. Abney .	Longueurs d'onde des raies A et *a* (Read Nov. 26.)	'C. R.' xcvii. 1206–1207.
,, . .	The Wave Lengths of A, *a* and of Prominent Lines in the Infra-Red of the Solar Spectrum. (Recd. Nov. 20. Read Dec. 6.)	'Proc. Roy. Soc.' xxxvi. 137–138; 'Nature,' xxix. 190; 'Chem. News,' xlviii. 283; 'Beiblätter,' viii. 219 (Abs.)
	1884.	
J. Kanonnikoff .	Sur les relations entre la composition et le pouvoir réfringent des composés chimiques (second mémoire.) (Read Jan. 5–17.) (In Russian.)	'J. soc. phys.-chim. russe, xvi. 119–131; 'Ber.' xvii. Referate, 157–159 (Abs.); 'Nature,' xxx. 84 (Abs.); 'Beiblätter,' viii. 493–496 (Abs.); 'Bull. Soc. Chim.' xli. 549 (Abs.); 'J. Chem. Soc.' xlviii. 1–2 (Abs.)
A. König and C. Dietrici.	Ueber die Empfindlichkeit des normalen Auges für Wellenlangenunterschiede das Lichtes. (Feb. 1884.)	'Ann. Phys. u. Chem.' N.F. xxii. 579–589.
R. Nasini . .	Sulla questione dei doppi legami tra carbonio e carbonio dal punto di vista della chimica ottica. (Read March 2.)	'Atti R. Accad. dei Lincei,' viii. 169–173; 'Beiblätter,' viii. 577–578 (Abs.)
F. Flavitsky . .	Note concernant le mémoire de M. J. Kanonnikoff sur le pouvoir réfringent des substances organiques. (In Russian.)	'J. soc. phys.-chim. russe, xvi. 260–267.
Stas . . .	Rapport sur un travail de M. Fiévez concernant l'influence de la température sur les caractères des raies spectrales. (Read April 5.)	'Bull. Acad. Roy. Belg.' [3] vii. 290–294.
C. Fiévez . .	De l'influence de la température sur les caractères des raies spectrales. (Read April 5.)	'Bull. Acad. Belg.' [3] vii. 348–355; 'Beiblätter,' viii. 645–646 (Abs.); 'Les Mondes' [3] viii. 481–483; 'Chem. News,' l. 128 (Abs.)
A. Schrauf . .	Ueber das Dispersionsäquivalent von Diamant. (April 1884.)	'Ann. Phys. u. Chem.' N.F. xxii. 424–429; 'J. Chem. Soc.' xlviii. 14 (Abs.)
J. E. Keeler . .	On the Absorption of Radiant Heat by Carbon Dioxide. (April 1884.)	'Am. J.' [3] xxviii. 190–198; 'Nature,' xxxi. 46 (Abs.)
R. Nasini . .	Sulla questione dei doppi legami tra carbonio e carbonio dal punto di vista della chimica ottica. (May 1884.)	'Gazz. chim. ital.' xiv. 150–156; 'Ber.' xvii. Referate, 559–561 (Abs.)

PHYSICAL RELATIONS, 1884.—FLUORESCENCE, 1881-1883.

J. H. Gladstone .	Refraction-equivalents of Organic Compounds. (Read May 15.)	'J. Chem. Soc.' xlv. 241-259; 'Chem. News,' xlix. 233 (Abs.); 'Nature,' xxx. 119 (Abs.); 'Ber.' xvii. Referate, 556 (Abs.)
H. Dufet . .	Variation des indices de réfraction du quartz sous l'influence de la température. (Read May 19.)	'C. R.' xcviii. 1265-1268; 'Beiblätter,' viii. 592 (Abs.)
J. Kanonnikoff .	Réponse à la note de M. Flavitsky. (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 448-450.
S. P. Langley . .	Experimentelle Bestimmung der Wellenlängen im unsichtbaren prismatischen Spectrum.	'Ann. Phys. u. Chem.' N.F. xxii. 598-612.
W. de W. Abney and R. Festing.	The Relation between Electric Energy and Radiation in the Spectrum of Incandescence Lamps. (Recd. June 6. Read June 19.)	'Proc. Roy. Soc.' xxxvii. 157-173.
E. L. Nichols .	On the Duration of Colour Impressions upon the Retina. (June 1884.)	'Am. J.' [3] xxviii. 243-252.

FLUORESCENCE.

1881.

O. Lubarsch . .	Bemerkungen zu den Arbeiten des Herrn Lamansky über Fluorescenz. (Sept. 1881.)	'Ann. Phys. u. Chem.' N.F. xiv. 575-580.

1882.

W. de W. Abney .	On the Violet Phosphorescence in Calcium Sulphide. (Read Jan. 28.)	'Proc. Phys. Soc.' v. 35-38; 'Nature,' xxv. 355 (Abs.); 'Phil. Mag.' [5] xiii. 212-214; 'J. Chem. Soc.' xlii. 677-678 (Abs.); 'Beiblätter,' vi. 383 (Abs.); 'Am. J.' [3] xxiii. 322 (Abs.); 'J. de Phys.' [2] ii. 287-288 (Abs.)
G. G. Stokes . .	On the Causes of a Light Border frequently noticed in Photographs just outside the Outline of a Dark Body seen against the Sky; with some Introductory Remarks on Phosphorescence. (Recd. May 20. Read May 25.)	'Proc. Roy. Soc.' xxxiv. 63-68; 'Nature,' xxvi. 142-143; 'Beiblätter,' vi. 682-685 (Abs.)
E. Hagenbach . .	Fluorescenz nach Stokes' Gesetz. (Oct. 1882.)	'Ann. Phys. u. Chem.' N.F. xviii. 45-56; 'J. Chem. Soc.' xliv. 537-538 (Abs.)

1883.

H. Becquerel . .	Résultats de ses recherches sur les effets de phosphorescence. (Read Jan. 19.)	'Soc. Franc. de Phys.' 1883, 24-25.
E. Lommel . .	Die Fluorescenz des Ioddampfes. (March 1883.)	'Ann. Phys. u. Chem.' N.F. xix. 356-358; 'Phil. Mag.' [5] xvi. 463.
H. Becquerel . .	Maxima et minima d'extinction de la phosphorescence sous l'influence des radiations infra-rouges. (Read June 25.)	'C. R.' xcvi. 1853-1856; 'Chem. News,' xlviii. 22 (Abs.); 'Beiblätter,' vii. 702-703 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 49 (Abs.)

FLUORESCENCE, 1883.—ASTRONOMICAL APPLICATIONS, 1881.

H. Becquerel . .	Mémoire sur l'étude des radiations infra-rouges au moyen des phénomènes de phosphorescence.	'Ann. Chim. et Phys.' [5] xxx. 5–68; 'Beiblätter,' viii. 647–649 (Abs.)
E. Lommel . .	Spectroskop mit phosphorescirendem Ocular: Beobachtungen über Phosphorescenz. (Oct. 1883.)	'Ann. Phys. u. Chem.' N.F. xx. 847–860; 'Am. J.' [3] xxvii. 236–237 (Abs.)
,, . .	Die Fluorescenz des Kalkspaths. (Dec. 1883.)	'Ann. Phys. u. Chem.' N.F. xxi. 422–427; 'J. Chem. Soc.' xlvi. 649–650 (Abs.)

ASTRONOMICAL APPLICATIONS.

1881.

P. Tacchini . .	Sulla distribuzione delle macchie, facole e protuberanze solari sulla superficie del sole, durante l' anno 1880.	'Mem. Spettr. ital.' x. 122–123.
G. G. Stokes . .	Lecture on Solar Physics. (April 6.)	'Nature,' xxiv. 595–598, 613–618.
W. de W. Abney .	Lecture on Solar Physics. (May 25.)	Nature,' xxv. 162–166, 187–191, 252–257.
Fiévez . . .	Recherches sur le spectre du magnésium en rapport avec la constitution du Soleil.	'Ann. Chim. et Phys.' [5] xxiii. 366–372.
H. C. Russell . .	The Spectrum and Appearance of the recent Comet. (Read July 6.)	'Journ. and Proc. Roy. Soc. New South Wales,' xv. 81–86.
W. H. M. Christie .	The Comet. (July 12) . . .	'Nature,' xxiv. 236; 'Beiblätter,' v. 663–664 (Abs.); 'Am. J.' [3] xxii. 164.
H. Draper . .	Note on Photographs of the Spectrum of the Comet of June, 1881.	'Am. J.' [3] xxii. 134–135; 'Chem. News,' xliv. 75–76; 'Mem. Spettr. ital.' x. 150–151; 'J. de Phys.' [2] i. 153–154 (Abs.)
W. Huggins . .	Sur la photographie du spectre de la comète *b*, 1881. (Read July 11.)	'C. R.' xciii. 26; 'Beiblätter,' v. 663–664 (Abs.)
Berthelot . .	Remarques à l'occasion de la Communication de M. W. Huggins.	'C. R.' xciii. 26–27; 'Beiblätter,' v. 663–664 (Abs.)
C. Wolf . . .	Observations de la comète *b*, 1881. (Read July 11.)	'C. R.' xciii. 36–37; 'Beiblätter,' v. 663–664 (Abs.)
L. Thollon . .	Observations spectroscopiques sur la comète *b*, 1881. (Read July 11.)	'C. R.' xciii. 37–39; 'Beiblätter,' v. 663–664 (Abs.)
W. Harkness . .	Note on the Observations of Comet *b*, 1881, made at the United States Naval Observatory. (July 13.)	'Am. J.' [3] xxii. 137–139.
C. A. Young . .	Spectroscopic Observations upon the Comet *b*, 1881. (July 14.)	'Am. J.' [3] xxii. 135–137; 'Beiblätter,' v. 663–664 (Abs.)

Astronomical Applications, 1881.

Flammarion	Sur les queues des comètes. (Read July 18.)	'C. R.' xciii. 135–137.
A. Riccò	Sulle osservazioni solari fatte in Palermo nel Luglio 1881. (July 31.)	'Mem. Spettr. ital.' x. 146–147.
"	Osservazioni delle inversioni della coronale 1474 *k*, e delle *b* del magnesio fatte nell' Osservatorio di Palermo.	'Mem. Spettr. ital.' x. 148–151.
L. Thollon	Observations spectroscopiques sur les comètes *c* et *b*, 1881. (Read Aug. 1.)	'C. R.' xciii. 259; 'Beiblätter,' v. 663–664 (Abs.)
P. Tacchini	Sur les spectres des comètes Cruls et Schaeberle. (Read Aug. 1.)	'C. R.' xciii. 261–262; 'Ann. Chim. et Phys.' [5] xxv. 285–287; 'Beiblätter,' v. 663–664 (Abs.)
H. Draper	The Comet	'Nature,' xxiv. 308–309.
v. Konkoly	Spectroskopische Beobachtungen der Cometen 1881 *b* und *c* angestellt am astrophysikalischen Observatorium in O'Gyalla (Ungarn). (Aug. 12.)	'Naturforscher,' xiv. 321–323, 331.
Faye	Sur l'analyse spectrale appliquée aux comètes. (Read Aug. 22.)	'C. R.' xciii. 361–362.
P. Tacchini	Observations solaires faites à l'Observatoire royal du Collège romain pendant le premier trimestre de 1881. (Read Aug. 22.)	" xciii. 380–381.
"	Observations des taches et des facules solaires du mois d'avril au mois de juillet 1881. (Read Aug. 22.)	" xciii. 382.
L. Thollon	Études spectroscopiques sur les comètes *b* et *c*, 1881. (Read Aug. 22.)	'C. R.' xciii. 383–384; 'Beiblätter,' v. 663–664 (Abs.)
B. Hasselberg	Spectroskopische Beobachtungen der Cometen 1881 *b* und *c*. (Read Aug. 25.)	'Bull. de l'Acad. S. Pétersb.' xxvii. 417–425.
Piazzi Smyth	Tebbutt's Comet—Origination of its Proper Light. (Aug. 29.)	'Nature,' xxiv. 430.
G. M. Seabroke	Comet *b*, 1881. (Aug. 29)	" xxiv. 431.
J. R. Capron	Schaeberle's Comet. (Aug. 31)	" xxiv. 430–431
"	Comet, *b* 1881. (Sept. 3)	" xxiv. 431.
H. C. Vogel	Ueber die Spectra der Cometen *b* und *c*, 1881. (Sept. 5.)	'Astron. Nachr.' c. 301–304; 'Beiblätter,' v. 867 (Abs.)
C. V. Zenger	Le spectroscope à vision directe, appliqué à l'Astronomie physique. (Read Sept. 5.)	'C. R.' xciii. 429–432; 'Beiblätter,' v. 793 (Abs.)
Respighi	Sur la lumière des cometes. (Read Sept 5.)	'C. R.' xciii. 439–440; 'Phil. Mag.' [5] xii. 306–307; 'Beiblätter,' v. 745 (Abs.)

ASTRONOMICAL APPLICATIONS, 1881, 1882.

W. Huggins . .	On the Photographic Spectrum of Comet *b*, 1881. (Brit. Assoc.)	'Chem. News,' xliv. 183.
T. W. Backhouse .	Notes on the Spectrum of Comet *c*, 1881, as seen with a Browning's Miniature Spectroscope on the 4¼-inch Telescope. (Oct. 8.)	'Monthly Not. Astr. Soc.' xlii. 43.
E. C. Pickering .	Stars with Peculiar Spectra, discovered at the Astronomical Observatory of Harvard College. (Oct. 11.)	'Astron. Nachr.' ci. 73–74; 'Beiblätter,' vi. 106 (Abs.)
G. H.	Solar Chemistry	'Nature,' xxiv. 581–582.
	On the Spectra of the Comets *b* and *c*, 1881, observed at the Royal Observatory, Greenwich. (Nov. 10, 1881.)	'Monthly Not. Astr. Soc.' xlii. 14–19.
W. Noble . .	Physical Observations of Comet *b*, 1881, made at Forest Lodge, Maresfield. (Read Nov. 11, 1881.)	'Monthly Not. Astr. Soc.' xlii. 47–49.
K. Exner . .	Ueber das Funkeln der Sterne und die Scintillation überhaupt. (Read Nov. 17.)	'Sitzungsb. Wien. Akad.' lxxxiv. II. 1038–1081; 'Ann. Phys. u. Chem.' N.F. xvii. 305–322; 'Wien. Anz.' 1881, 248–249 (Abs.); 'Beiblätter,' vi. 384 (Abs.); 'Zeitschr. f. Instrumentenkunde,' ii. 185–186 (Abs.); 'J. de Phys.' [2] i. 373–377 (Abs.)
T. S. Hunt . .	Celestial Chemistry from the Time of Newton. (Read Nov. 28.)	'Proc. Camb. Phil. Soc.' iv. 129–139; 'Am. J.' [3] xxiii. 123–133; 'Ann. Chim. et Phys.' [5] xxviii. 105–122; 'Beiblätter,' vi. 381 (Abs.)
Tacchini . . .	Sur le spectre de la comète Encke. (Read Dec. 5.)	'C. R.' xciii. 949; 'Beiblätter,' vi. 106 (Abs.)
J. N. Lockyer . .	Preliminary Report to the Solar Physics Committee on the Sun-Spot Observations made at Kensington. (Recd. Nov. 29. Read Dec. 15.)	'Proc. Roy. Soc.' xxxiii. 154–158; 'Chem. News,' xliv. 297–298; 'Beiblätter,' vi. 381–382 (Abs.)
	1882.	
W. Huggins . .	On Comets. (Jan. 20) . . .	'Proc. Roy. Inst.' x. 1–11; 'Ann. Chim. et Phys.' [5] xxvii. 408–425; 'J. de Phys.' [2] ii. 478 (Abs.)
E. Becquerel . .	Sur les phosphorographies du spectre solaire.	'J. de Phys.' [2] i. 139–140.
W. Huggins . .	Note on the Photographic Spectrum of the Great Nebula in Orion. (Recd. March 9. Read March 16.)	'Proc. Roy. Soc.' xxxiii. 425–428; 'Nature,' xxv. 489; 'Ann. Chim. et Phys.' [5] xxviii. 282–285; 'J. de Phys.' [2] ii. 98 (Abs.)

ASTRONOMICAL APPLICATIONS, 1882.

W. Huggins . .	Sur la photographie du spectre de la grande nébuleuse d'Orion. (Read March 13.)	'C. R.' xciv. 685–686; 'Beiblätter,' vi. 382–383 (Abs.)
	Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1881. No. V.	'Monthly Not. Astr. Soc.' xlii. 230–240.
N. C. Dunér . .	Auffindung neuer Spectra von der Classe III. (March 20.)	'Astron. Nachr.' cii. 195–198; 'Beiblätter,' vii. 196 (Abs.)
W. Huggins . .	Photograph of the Spectrum of the Great Nebula in Orion.	'Am. J.' [3] xxiii. 335–336.
P. Tacchini . .	Sulle eruzioni solari metalliche osservate a Roma nel 1881.	'Mem. Spettr. ital.' xi. 53–58.
„ . .	Observations des éruptions solaires en 1881. Spectre de la comète Well. (Read April 17.)	'C. R.' xciv. 1031–1033; 'Beiblätter,' vi. 486 (Abs.)
J. N. Lockyer . .	Eclipse Notes	'Nature,' xxv. 573–578; xxvi. 100–101.
A. Riccò . . .	Les minima des taches du Soleil en 1881. (Read April 24.)	'C. R.' xciv. 1169–1171.
H. Draper . .	Sur les photographies du spectre de la nébuleuse d'Orion. (Read May 1.)	„ xciv. 1243.
A. Riccò . . .	Spettro della Cometa Wells osservato a Palermo.	'Mem. Spettr. ital.' xi. 76.
T. Zona . . .	Su di una particolaritá luminosa rimarcata a Palermo nella coda della cometa Wells.	'Mem. Spettr. ital.' xi. 76–77; 'Beiblätter,' vi. 679 (Abs.)
P. Tacchini . .	Cometa Wells. Spettro osservato all' Equatore Merz del R. Osservatorio del Collegio romano.	'Mem. Spettr. ital.' xi. 77–78.
Maunder . . .	On the Spectrum of Comet *a*, 1882 (Wells), observed at the Royal Observatory of Greenwich. (May 12.)	'Monthly Not. Astr. Soc.' xlii. 251; 'Mem. Spettr. ital.' xi. 79.
T. W. Backhouse .	Spectrum of Wells' Comet. (May 16.)	'Nature,' xxvi. 56; 'Beiblätter,' vi. 678 (Abs.)
H. Draper . .	On Photographs of the Nebula in Orion, and of its Spectrum. (May 1882.)	'Monthly Not. Astr. Soc.' xlii. 367–368.
	The Total Eclipse	'Nature,' xxvi. 75.
	Scientific Results of the Eclipse .	„ xxvi. 181–182.
H. C. Vogel . .	Ueber das Spectrum des Cometen Wells. (June 2.)	'Astron. Nachr.' cii. 159; 'Beiblätter,' vi. 678 (Abs.)
N. C. Dunér . .	Ueber das Spectrum des Cometen Wells. (June 4.)	'Astron. Nachr.' cii. 159; 'Monthly Not. Astr. Soc.' xlii. 412–413; 'Beiblätter,' vi. 678 (Abs.)
T. W. Backhouse .	Observations of Comet *b*, 1881. (June 5.)	'Monthly Not. Astr. Soc.' xlii. 413–421.

ASTRONOMICAL APPLICATIONS, 1882.

N. C. Dunér	Fernere Nachricht über das Spectrum des Cometen Wells. (June 6.)	'Astron. Nachr.' cii. 169.
T. Bredichin	Les vapeurs du sodium dans la comète de Wells. (June 7.)	'Astron. Nachr.' cii. 207; 'Beiblätter,' vi. 678 (Abs.)
N. von Konkoly	Spectroskopische Beobachtungen des Cometen Wells, angestellt am astrophysikalischen Observatorium in O'Gyalla (Ungarn). (June 8.)	'Naturforscher,' xv. 245; 'Beiblätter,' vi. 678–679 (Abs.)
	Further Spectroscopic Observations of Comet *a*, 1882 (Wells), made at the Royal Observatory, Greenwich. (June 9.)	'Monthly Not. Astr. Soc.' xlii. 410–412.
H. C. Vogel	Fernere Beobachtungen über das Spectrum des Cometen Wells. (June 11.)	'Astron. Nachr.' cii. 199–202; 'Beiblätter,' vi. 678 (Abs.)
W. Huggins	On the Photographic Spectrum of Comet (Wells) I, 1882. (Recd. June 15. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 148–150; 'Nature,' xxvi. 179–180 (Abs.); 'Beiblätter, vi. 679 (Abs.); 'Am. J. [3] xxiv. 402–403.
Thollon	Éclipse totale de Soleil observée à Souhag (haute Égypte) le 17 mai (temps civil) 1882. (Read June 19.)	'C. R.' xciv. 1630–1635; 'Beiblätter,' vi. 878–880 (Abs.)
Trépied	Éclipse totale du 17 mai. (Read June 19.)	'C. R.' xciv. 1636–1642; 'Beiblätter,' vi. 878–880 (Abs.)
A. Puiseux	Sur l'éclipse du 17 mai 1882. (Read June 19.)	'C. R.' xciv. 1643–1644; 'Beiblätter,' vi. 878–880 (Abs.)
B. Hasselberg	Ueber das Spectrum des Cometen Wells. (June 22.)	'Astron. Nachr.' cii. 259–264; 'Beiblätter,' vi. 744–745 (Abs.)
W. Huggins	Sur le spectre photographique de la comète I, 1882 (Wells). (Read June 26.)	'C. R.' xciv. 1689–1691.
L. Boss	Comets: their Composition, Purpose, and Effect upon the Earth.	'Observatory,' 1882, 215–221.
P. Tacchini	Observations des protubérances, des facules et des taches solaires faites à l'Observatoire royal du Collège romain pendant le premier semestre 1882. (Read Aug. 7.)	'C. R.' xcv. 276–278.
B. Hasselberg	The Spectrum of Wells' Comet	'Nature,' xxvi. 344 (Abs.)
P. Tacchini	Sur les éruptions métalliques solaires observées à Rome pendant le premier semestre 1882. (Read Aug. 21.)	'C. R.' xcv. 373–378.
J. Janssen	Les méthodes en astronomie physique. (Lecture. Aug. 24, 1882.)	'Ann. du Bureau des Longitudes,' 1883, 779–812; 'Beiblätter,' vii. 323–324 (Abs.)
Begouen	La matière radiante et les comètes.	'Revue scientif.' xxx. 297.

ASTRONOMICAL APPLICATIONS, 1882.

Langley . . .	Observations du spectre solaire. (Read Sept. 11.)	'C. R.' xcv. 482–487; 'J. Chem. Soc.' xliv. 137 (Abs.)
A. Riccò . . .	Sulla diversa attività dei due emisferi solari nel 1881.	'Astron. Nachr.' ciii. 155–156.
Thollon and Gouy .	Sur une comète observée à Nice. (Read Sept. 25.)	'C. R.' xcv. 555–557; 'Beiblätter,' vii. 116 (Abs.)
P. Tacchini . .	Sull' eclisse totale di sole del 17 maggio 1882 osservato a Sohage in Egitto.	'Mem. Spettr. ital.' xi. Sept. 1–14.
A. Riccò . . .	Osservazioni spettroscopiche della cometa Cruls fatte collo spettroscopio di Clean applicato al refrattore di 0^m 25 nell' Osservatorio di Palermo.	'Mem. Spettr. ital.' xi. Sept. 15–17.
Berthelot . .	Remarques sur la lumière propre des comètes.	'Ann. Chim. et Phys.' [5] xxvii. 232–233; 'J. Chem. Soc.' xliv. 261 (Abs.)
J. Janssen . .	Note sur la photographie de la comète *b*, 1881, obtenu à l'observatoire de Meudon.	'J. de Phys.' [2] i. 441–449.
H. C. Russell . .	Observations of the Great Comet (*b*), 1882, made at the Sydney Observatory. (Oct. 5.)	'Monthly Not. Astr. Soc.' xliii. 31.
A. Riccò . . .	The Comet. (Oct. 11) . . .	'Nature,' xxvi. 609–611.
H. C. Vogel . .	Beobachtungen des grossen September-Cometen, 1882. (Oct. 12.)	'Astron. Nachr.' ciii. 279–282; 'Beiblätter,' vii. 28 (Abs.)
A. Riccò . . .	Osservazioni astrofisiche della grande cometa di settembre 1882.	'Astron. Nachr.' ciii. 281–284; 'Beiblätter,' vii. 28 (Abs.)
Thollon and Gouy .	Observations spectroscopiques sur la grande comète (Cruls). (Read Oct. 23.)	'C. R.' xcv. 712–714; 'Nature,' xxvii. 24 (Abs.); 'Beiblätter,' vii. 28–29 (Abs.)
B. Hasselberg . .	Zur Spectroskopie des grossen September-Cometen, 1882. (Oct. 30.)	'Astron. Nachr.' civ. 13–16; 'Beiblätter,' vii. 293–294 (Abs.)
W. Meyer . .	Observations sur la réfraction cométaire. (Read Nov. 2.)	'Arch. de Genève,' [3] viii. 526–535; 'Beiblätter,' vii. 141–142 (Abs.); 'J. de Phys.' [2] ii. 387–388 (Abs.)
Cruls . . .	Sur la grande comète australe, observée à l'Observatoire impérial de Rio-de-Janeiro. (Read Nov. 6.)	'C. R.' xcv. 825–828; 'Beiblätter,' vii. 116 (Abs.)
E. v. Gothard . .	Beobachtungen des grossen September-Cometen 1882 am astrophysicalischen Observatorium zu Herény, Ungarn. (Nov. 6.)	'Astron. Nachr.' ciii. 377–380; 'Beiblätter,' vii. 116 (Abs.)
Gouy and Thollon .	Mesures spectrophotométriques en divers points du disque solaire. (Read Nov. 6.)	'C. R.' xcv. 834–836; 'Beiblätter,' vii. 113–114 (Abs.)
W. T. Sampson .	The Comet. (Nov. 11.) . . .	'Nature,' xxvii. 108–110.

ASTRONOMICAL APPLICATIONS, 1882.

von Konkoly . .	Beobachtung des grossen September-Cometen auf der Sternwarte in O'Gyalla. (Nov. 12.)	'Astron. Nachr.' civ. 45–48; 'Monthly Not. Astr. Soc.' xliii. 56–57; 'Beiblätter,' vii. 293 (Abs.)
Fizeau, Cloué, Loewy, and Janssen.	Rapport au Bureau des Longitudes sur la prochaine éclipse du 6 mai 1883. (Read Nov. 13.)	'C. R.' xcv. 881–885; 'Ann. du Bureau des Longitudes,' 1883, 813–820; 'Nature,' xxvii. 110–112.
P. Tacchini . .	Observations faites pendant l'éclipse totale de Soleil du 17 mai 1882. (Read Nov. 13.)	'C. R.' xcv. 896–898; 'Beiblätter,' vii. 114–116 (Abs.)
W. H. M. Christie .	Magnetic Storm, Aurora, and Sun-Spot. (Nov. 20.)	'Nature,' xxvii. 83.
J. N. Lockyer . .	Note on the Recent and Coming Total Solar Eclipses. (Recd. Nov. 17. Read Nov. 23.)	'Proc. Roy. Soc.' xxxiv. 291–300; 'Nature,' xxvii. 185–189; 'Beiblätter,' vii. 193 (Abs.)
B. Hasselberg . .	Sullo spettro della cometa Finlay. Settembre 1883. (Nov. 30.)	'Mem. Spettr. ital.' xi. No. 11, 1–3; 'Beiblätter,' vii. 293–294 (Abs.)
	The Transit of Venus . . .	'Nature,' xxvii. 156–157.
S. P. Langley . .	Observation of the Transit of Venus, 1882, December 6, made at the Allegheny Observatory. (Dec. 7.)	'Monthly Not. Astr. Soc.' xliii. 71–73.
P. Tacchini . .	Observations du passage de Vénus à l'Observatoire royal du Collège romain. (Dec. 7. Read Dec. 11.)	'C. R.' xcv. 1209–1211.
" . .	Sur la grande tache solaire de novembre 1882, et sur les perturbations magnétiques qui en ont accompagné l'apparition. (Read Dec. 11.)	" xcv. 1212–1214.
Cacciatore . .	The Transit of Venus. (Dec. 13) .	'Nature,' xxvii. 180.
W. Huggins . .	On a Method of Photographing the Solar Corona without an Eclipse. (Recd. Dec. 13. Read Dec. 21.)	'Proc. Roy. Soc.' xxxiv. 409–414; 'Nature,' xxvii. 199–201; 'Am. J.' [3] xxv. 126–130; 'Ann. Chim. et Phys.' [6] iii. 540–550; 'Beiblätter,' vii. 194–195 (Abs.); 'J. de Phys.' [2] iii. 103 (Abs.); 'Astron. Nachr.' civ. 113–118; 'J. de Phys.' [2] ii. 173–175 (Abs.)
A. Crova . . .	Sur la photométrie solaire. (Read Dec. 18.)	'C. R.' xcv. 1271–1273; xcvi. 124; 'Beiblätter.' vii. 113 (Abs.)
	Osservazioni del passagio di Venere sul disco solare fatte in Italia nel 6 dicembre 1882.	'Mem. Spettr. ital.' xi. Dec. 1–23; 'Beiblätter,' vii. 375 (Abs.)
Piazzi Smyth . .	'Madeira Spectroscopic,' 1881–1882 (published by W. and A. K. Johnston, Edinburgh).	'Phil. Mag.' [5] xv. 144–149 (Notice); 'Beiblätter,' vii. 292–293 (Notice).

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L. Thollon	Observation du passage de Vénus, à Avila (Espagne). (Read Dec. 26.)	'C. R.' xcv. 1340–1342.

1883.

W. Huggins	Sur une méthode pour photographier la couronne sans une éclipse de Soleil. (Read Jan. 2.)	'C. R.' xcvi. 51–53.
	The Spectrum of the Great Sun-spot of 1882, Nov. 12–25, observed at the Royal Observatory, Greenwich. (Jan. 12.)	'Monthly Not. Astr. Soc.' xliii. 77–80.
	Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the Year 1883. No. VI. (Jan. 12.)	'Monthly Not. Astr. Soc.' xliii. 80–84.
O. Lohse	Photographie der Corona der Sonne.	'Astron. Nachr.' civ. 209–212; 'Beiblätter,' vii. 291–292 (Abs.)
J. Janssen	Note sur l'observation du passage de la planète Vénus sur le Soleil. (Read Jan. 29.)	'C. R.' xcvi. 288–292; 'Beiblätter,' vii. 375–376 (Abs.)
N. von Konkoly	Astrophysische Beobachtungen.	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 126–127.
"	Ueber die chemische Constitution der Kometen, verglichen mit der der Meteore.	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 135–339.
Thollon and Gouy	Sur le déplacement des raies du sodium observé dans le spectre de la grande comète de 1882. (Read Feb. 5.)	'C. R.' xcvi. 371–372; 'Nature,' xxvii. 380 (Abs.); 'Am. J.' [3] xxv. 309 (Abs.): 'Beiblätter,' vii. 293 (Abs.)
J. Janssen	Note sur divers points de Physique céleste. (Read Feb. 26.)	'C. R.' xcvi. 527–529; 'Nature,' xxvii. 475 (Abs.)
V. v. Lang	Der infrarothe Theil des Sonnenspectrums.	'Carl. Repert.' xix. 107–109; 'Beiblätter,' vii. 374–375 (Abs.)
Maures Horner	Observations of the Transit of Venus, 1882, Dec. 6, made at Mells, Ten Miles South of Bath.	'Monthly Not. Astr. Soc.' xliii. 276–278.
N. von Konkoly	Spectroscopic Observations of Comet *a*, 1883 (Brooks-Swift). (March 12.)	'Monthly Not. Astr. Soc.' xliii. 328–329.
C. A. Young	Observations of the Transit of Venus, Dec. 6, 1882, at Princeton, N.J., and South Hadley, Mass. (March 1883.)	'Am. J.' [3] xxv. 321–329.
E. von Gothard	Beobachtung des Cometen 1883 Brooks-Swift. (March 23.)	'Astron. Nachr.' cv. 135–136.
A. Schuster and W. de W. Abney	On the Total Solar Eclipse of May 17, 1882. (Recd. April 9. Read April 19.)	'Phil. Trans.' clxxv. 253–271; 'Proc. Roy. Soc.' xxxv. 151–155 (Abs.); 'Beiblätter,' vii. 896–897 (Abs.)

ASTRONOMICAL APPLICATIONS, 1883.

H. Draper	Researches upon the Photography of Planetary and Stellar Spectra. (Presented April 11.)	'Proc. Am. Acad. Arts and Sc.' N.S. xi. 231–261.
E. von Gothard	Spectroscopische Beobachtungen von Fixsternen. (Read April 23.)	'Math. u. naturwissenschaftl. Berichte aus Ungarn,' i. 207–209.
Tacchini	Observations des protubérances, facules et taches solaires faites à l'Observatoire royal du Collège romain pendant le troisième et le quatrième trimestre de 1882. (Read April 30.)	'C. R.' xcvi. 1290–1291; 'Nature,' xxviii. 48 (Abs.)
E. von Gothard	Spectroscopische Beobachtungen des grossen September-Cometen 1882 II. (May 6.)	'Astron. Nachr.' cv. 311–314.
W. H. M. Christie	Report by the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich.	'Nature,' xxviii. 136–139.
	The Eclipse Observations	„ xxviii. 145–146.
E. von Gothard	Astrophysical Observations made during the Year 1882 at the Herény Observatory, Hungary.	'Monthly Not. Astr. Soc.' xliii. 420–424.
S. J. Perry	Note on the Chromosphere. (June 5.)	'Monthly Not. Astr. Soc.' xliii. 426–427.
Janssen	Sur l'éclipse solaire. (Read June 18.)	'C. R.' xcvi. 1745; 'Nature,' xxviii. 216 (Abs.)
C. Piazzi Smyth	Note on the Little *b* Group of Lines in the Solar Spectrum and the New College Spectroscope. (Read June 1883.)	'Trans. Roy. Soc. Edinb.' xxxii. 37–44; 'Nature,' xxviii. 287 (Abs.)
	The Eclipse Party	'Nature,' xxviii. 247–248.
P. Tacchini	Sugli spettri di comete osservati nel 1881, e sulla forma dei relativi nuclei.	'Mem. Spettr. ital.' xii. 179–184.
C. V. Zenger	Études astrophotographiques. (Read Aug. 27.)	'C. R.' xcvii. 552–555; 'Beiblätter,' vii. 860–862 (Abs.)
E. v. Gothard	Beobachtung der hellen Linien in dem Spectrum von γ Cassiopeiæ. (Aug. 27.)	'Astron. Nachr.' cvi. 293–294; 'Beiblätter,' vii. 862 (Abs.)
J. Janssen	Rapport à l'Académie sur la mission en Océanie pour l'observation de l'éclipse totale de Soleil du 6 mai 1883. (Read Sept. 3.)	'C. R.' xcvii. 586–602; 'Mem. Spettr. ital.' xii. 201–216.
C. A. Young	Spectroscopic Notes. (Sept. 10)	'Am. J.' [3] xxvi. 333–336; 'Beiblätter,' viii. 221 (Abs.); 'Phil. Mag.' [5] xvi. 460–463.
R. Copeland	Notes on some Recent Astronomical Experiments at High Elevations on the Andes. (Brit. Assoc. 1883.)	'Nature,' xxviii. 606; 'Beiblätter,' viii. 220–221 (Abs.)
von Konkoly	Vorläufige spectroscopische Beobachtung des Cometen Pons-Brooks. (Sept. 30.)	'Astron. Nachr.' cvii. 41–42; 'Observatory,' vi. 333–334; 'Am. J.' [3] xxvii. 76–77; 'Beiblätter,' viii. 33 (Abs.)

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von Konkoly . .	Spectroscopische Beobachtung von γ Cassiopejæ. (Sept. 30.)	'Astron. Nachr.' cvii. 61–62; 'Beiblätter,' viii. 221–222 (Abs.)
L. Thollon . .	Sur l'interprétation de quelques phénomènes de spectroscopie solaire. (Read Oct. 1.)	'C. R.' xcvii. 747–749.
Faye . . .	Réponse à une Note de M. Thollon sur l'interprétation d'un phénomène de spectroscopie solaire. (Read Oct. 8.)	'C. R.' xcvii. 779–782.
H. C. Vogel . .	Einige spectralanalytische Untersuchungen au Sternen, ausgeführt mit dem grossen Refractor der Wiener Sternwarte. (Read Oct. 11.)	'Sitzungsb. Wien. Akad.' lxxxviii. II. 791–815; 'Wien. Anz.' 1883, 174–175 (Abs.); 'Beiblätter,' viii. 508–511 (Abs.)
L. Thollon . .	Observations sur une Réponse de M. Faye concernant divers phénomènes de spectroscopie solaire. (Read Oct. 22.)	'C. R.' xcvii. 900–902.
G. D. Liveing and J. Dewar.	On Sun Spots and Terrestrial Elements in the Sun.	'Phil. Mag.' [5] xvi. 401–408; 'Beiblätter,' viii. 304–305 (Abs.)
C. Montigny . .	De la scintillation des étoiles dans ses rapports avec la constitution de leur lumière, d'après l'analyse spectrale. (Read Dec. 1.)	'Bull. Acad. Roy. Belgique' [3] vi. 644–664.
G. Rayet . . .	Observation du spectre de la comète Pons 1812-Brooks à l'équatorial de 14 pouces (0m·378) de l'Observatoire de Bordeaux. (Read Dec. 10.)	'C. R.' xcvii. 1352–1353; 'Beiblätter,' viii. 221 (Abs.)
	On the Spectrum of Comet *b*, 1883 (Pons-Brooks), observed at the Royal Observatory, Greenwich. (Dec. 13.)	'Monthly Not. Astr. Soc.' xliv. 62–63.
C. Trépied . .	Étude spectroscopique de la comète Pons-Brooks faite au réflecteur de 0m·50 de l'Observatoire d'Alger. (Read Dec. 31.)	'C. R.' xcvii. 1540–1541; 'Nature,' xix. 255 (Abs.)
	1884.	
Thollon . . .	Spectroscopie solaire. Monographie du groupe D.	'J. de Phys.' [2] iii. 5–11; 'Beiblätter,' viii. 647 (Abs.)
C. Trépied . .	Sur le spectre de la comète Pons-Brooks. (Read Jan. 7.)	'C. R.' xcviii. 32–33.
L. Thollon . .	Observations spectroscopiques faites à Nice sur la comète Pons. (Read Jan. 7.)	'C. R.' xcviii. 33; 'Beiblätter,' viii. 221 (Abs.)
W. Huggins . .	On Photographing the Solar Corona without an Eclipse.	'Am. J.' [3] xxvii. 27–32.
	Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1883. No. VII.	'Monthly Not. Astr. Soc.' xliv. 89–96.

ASTRONOMICAL APPLICATIONS, 1884.—METEOROLOGICAL, 1881.

H. C. Vogel . .	Einige Beobachtungen über den Cometen Pons-Brooks, insbesondere über das Spectrum desselben. (Jan. 18.)	'Astron. Nachr.' cviii. 21–26.
B. Hasselberg . .	Spectroskopische Beobachtungen des Cometen Pons-Brooks. (Jan. 20.)	'Astron. Nachr.' cviii. 55–56.
P. Tacchini . .	Sugli spettri di comete osservati nel 1882 e sulla forma delle relative code e nuclei.	'Mem. Spettr. ital.' xiii. 17–22.
R. v. Kövesligethy .	Spectroskopische Beobachtungen des Cometen Pons-Brooks. (Feb. 10.)	'Astron. Nachr.' cviii. 169–174.
E. von Gothard .	Beobachtungen der hellen Linien in dem Spectrum von γ Cassiopeiæ und β Lyræ. (Feb. 10.)	'Astron. Nachr.' cviii. 233–236.
C. A. Young . .	Observations of Comet Pons-Brooks. (Feb. 1884.)	'Astron. Nachr.' cviii. 305–308.
S. J. Perry . .	Observations of Sun-spot Spectra in 1883. (Feb. 21.)	'Monthly Not. Astr. Soc.' xliv. 244–248.
E. Wiedemann .	Note on the Temperature of Sun Spots. (Feb. 25.)	'Phil. Mag.' [5] xvii. 247–248; 'Beiblätter,' viii. 768 (Abs.)
N. von Konkoly .	Spectroscopic Observation of the Red-coloured Sky at Sunset, 1884, Jan. 9, 5h. 20m.	'Monthly Not. Astr. Soc.' xliv. 250–251.
" . .	Spectroscopic Observations of Comet Pons-Brooks made at the Observatory O-Gyalla, Hungary.	'Monthly Not. Astr. Soc.' xliv. 251–253.
J. N. Lockyer . .	On the most Widened Lines in Sun-Spot Spectra. First and Second Series, from November 12, 1879, to October 15, 1881. (Recd. Feb. 22. Read March 20.)	'Proc. Roy. Soc.' xxxvi. 443–446 (Abs.)
A. Riccò . . .	Sullo spettro della cometa Pons-Brooks. (March 20.)	'Mem. Spettr. ital.' xiii. 39–40.
G. D. Liveing and J. Dewar.	The Temperature of Sun Spots. Reply to Prof. Wiedemann.	'Phil. Mag.' [5] xvii. 302–304; 'Beiblätter,' viii. 768 (Abs.)
E. v. Gothard . .	Spectroskopische Beobachtungen des Cometen 1884. I. (Pons 1812.) (April 24.)	'Astron. Nachr.' cix. 99–106.
	Visitation of the Royal Observatory	'Nature,' xxx. 147–148.

METEOROLOGICAL.

1881.

S. P. Langley . .	The Bolometer and Radiant Energy. (Read Jan. 12.)	'Proc. Am. Acad.' xvi. 342–358; 'Zeitschr. f. Instrumentenkunde,' iv. 27–32 (Abs.)
W. G. Adams . .	Magnetic Disturbances, Auroras, and Earth Currents. (Lect. Roy. Inst. June 3.)	'Nature,' xxv. 66–71.

METEOROLOGICAL, 1881, 1882.

N. Egoroff . .	Recherches sur les raies telluriques du spectre solaire. (Read Aug. 22.)	'C. R.' xciii. 385–387; 'Beiblätter,' v. 871–872 (Abs.)
A. S. Herschel . .	The Progress of Meteor Spectroscopy. (Sept. 12.)	'Nature,' xxiv. 507–508; 'Beiblätter,' v. 871 (Abs.)
J. R. Capron . .	The Aurora and its Spectrum. (Nov. 1.)	'Nature,' xxv. 53; 'J. de Phys.' [2] ii. 97–98 (Abs.)
" . .	A Plea for the Rain Band. (Nov. 1881.)	'Observatory,' 1882, 42–47, 71–77; 'Beiblätter,' vi. 485 (Abs.)
N. Egoroff . .	Recherches sur le spectre d'absorption de l'atmosphère terrestre, à l'Observatoire de Paris. (Read Nov. 14.)	'C. R.' xciii. 788–790; 'Chem. News,' xliv. 256 (Abs.); 'Beiblätter,' vi. 100–101 (Abs.)
	1882.	
C. H. Romanes .	The Solar Spectrum in a Hail Storm. (March 22.)	'Nature,' xxv. 507; 'Beiblätter,' vi. 486 (Abs.)
S. P. Langley . .	The Mount Whitney Expedition. (July 13.)	'Nature,' xxvi. 314–317.
E. B. Kirk . .	Spectrum of Aurora. (Aug. 5) .	'Observatory,' 1882, 271–272; 'Beiblätter,' vii. 193 (Abs.)
Egoroff . . .	Recherches sur le spectre d'absorption de l'atmosphère terrestre. (Read Sept. 4.)	'C. R.' xcv. 447–449; 'Beiblätter,' vi. 937–938 (Abs.); 'J. Chem. Soc.' xliv. 137–138 (Abs.)
J. F. D. Donnelly .	A Meteorological Spectroscope. (Sept. 14.)	'Nature,' xxvi. 501; 'Beiblätter,' vii. 25 (Abs.); 'J. de Phys.' [2] iii. 44 (Abs.)
G. Müller . .	Untersuchungen über die Helligkeitsänderungen in verschiedenen Theilen des Sonnenspectrums bei abnehmender Höhe der Sonne über dem Horizont. (Sept. 23.)	'Astron. Nachr.' ciii. 241–252; 'Beiblätter,' vii. 111–112 (Abs.)
C. Piazzi Smyth .	Spectroscopic Weather Discussions.	'Nature,' xxvi. 551–554; 'Beiblätter,' vi. 877 (Abs.)
R. Abercromby .	The Spectroscope and Weather Forecasting. (Oct. 2.)	'Nature,' xxvi. 572–573.
W. de W. Abney .	Sunlight and Skylight at High Altitudes. (Brit. Assoc.)	'Nature,' xxvi. 586; 'Beiblätter,' vii. 28 (Abs.); 'J. de Phys.' [2] iii. 47–48 (Abs.)
S. P. Langley . .	Sunlight and Skylight at High Altitudes. (Brit. Assoc.)	'Nature,' xxvi. 586–589; 'Am. J.' [3] xxiv. 393–398; 'Beiblätter,' vii. 28 (Abs.); 'J. de Phys.' [2] iii. 47–48 (Abs.)
A. Cornu . . .	Sur l'observation comparative des raies telluriques et métalliques, comme moyen d'évaluer les pouvoirs absorbants de l'atmosphère. (Read Nov. 6.)	'C. R.' xcv. 801–806; 'Beiblätter,' vii. 110 (Abs.); 'Am. J.' [3] xxv. 78 (Abs.)

METEOROLOGICAL, 1882, 1883.

J. Janssen . .	Note sur les raies telluriques et le spectre de la vapeur d'eau. (Read Nov. 13.)	'C. R.' xcv. 885–890; 'Beiblätter,' vii. 111 (Abs.); 'Am. J.' [3] xxv. 78–79 (Abs.)
H. Robinson . .	The Aurora. (Nov. 18) . . .	'Nature,' xxvii. 85.
T. G. Elger . .	The Aurora. (Nov. 18) . . .	" xxvii. 85–86.
C. H. Romanes .	The Aurora. (Nov. 18) . . .	" xxvii. 86.
W. H. M. Christie .	Magnetic Storm, Aurora, and Sun Spot. (Nov. 20.)	" xxvii. 83.
J. R. Capron . .	The Aurora. (Nov. 18) . . .	" xxvii. 83–84.
" . .	Swan Lamp Spectrum and the Aurora. (Nov. 30.)	'Nature,' xxvii. 149; 'Beiblätter,' vii. 108–109 (Abs.)
" . .	The Aurora. (Dec. 1) . . .	'Nature,' xxvii. 139.
A. Cornu . . .	Sur l'observation comparative des raies telluriques et métalliques, comme moyen d'évaluer les pouvoirs absorbants de l'atmosphère. (Read Dec. 1.)	'Soc. Franc. de Phys.' 1882, 241–247; 'J. de Phys.' [2] ii. 58–63; 'Zeitschr. f. Instrumentenkunde,' iii. 290 (Abs.)
R. Abercromby .	The Aurora and its Spectrum. (Dec. 18.)	'Nature,' xxvii. 173; 'Beiblätter,' vii. 193 (Abs.)
J. Munro . . .	Swan Lamp Spectrum and the Aurora. (Dec. 18.)	'Nature,' xxvii. 173; 'Beiblätter,' vii. 193 (Abs.)
J. R. Capron . .	The Aurora and its Spectrum. (Dec. 23.)	'Nature,' xxvii. 198.
S. P. Langley . .	The Selective Absorption of Solar Energy. (Dec. 30.)	'Am. J.' [3] xxv. 169–196; 'Ann. Phys. u. Chem.' N.F. xix. 226–244; 384–400; 'Phil. Mag.' [5] xv. 153–183; 'Ann. Chim et Phys.' [5] xxix. 497–542; 'Zeitschr. f. Instrumentenkunde,' iv. 27–32 (Abs.); 'J. de Phys.' [2] ii. 371–374 (Abs.); 'J. Franklin Inst.' lxxxviii. 157–158 (Abs.)

1883.

H. R. Mill . . .	Observations of the Rain Band from June 1882 to Jan. 1883. (Read Jan. 29.)	'Proc. Roy. Soc. Edinb.' xii. 47–56.
A. Cornu . . .	Sur l'observation comparative des raies telluriques et métalliques, comme moyen d'évaluer les pouvoirs absorbants de l'atmosphère.	'J. de Phys.' [2] ii. 58–63.
J. R. Capron . .	On the Auroral Beam of Nov. 17, 1882. (April 6.)	'Phil. Mag.' [5] xv. 318–339.
S. Lemström . .	The Aurora Borealis . . .	'Nature,' xxviii. 60–63, 107–109, 128–130; 'J. de Phys.' [2] ii. 315–317 (Abs.)

METEOROLOGICAL, 1883, 1884.—CHEMICAL RELATIONS, 1881.

C. H. Koyl	On Professor Langley's 'Selective Absorption' (Univ. Scientif. Assoc. May 2.)	'Johns Hopkins Univ. Cir.' ii. 145–146; 'Phil. Mag.' [5] xvi. 317–318; 'Beiblätter,' vii. 899 (Abs.)
Tresca	Sur les observations de M. Lemström en Laponie. (Read May 7.)	'C. R.' xcvi. 1335–1336.
F. W. Cory	The Spectroscope as an Aid to Forecasting Weather. (Read June 20.)	'Quart. J. Meteorol. Soc.' ix. 234–239.
W. de W. Abney and R. Festing.	The Influence of Water in the Atmosphere on the Solar Spectrum and Solar Temperature. (Recd. June 14. Read June 21.)	'Proc. Roy. Soc.' xxxv. 328–341; 'J. Chem. Soc.' xlvi. 241 (Abs.); 'Beiblätter,' viii. 507 (Abs.)
T. W. Backhouse	The Spectrum of the Aurora	'Nature,' xxviii. 209–212.
Egoroff	Sur la production des groupes telluriques fondamentaux A et B du spectre solaire par une couche absorbante d'oxygène. (Read Aug. 27.)	'C. R.' xcvii. 555–557; 'Beiblätter,' vii. 859–860 (Abs.); 'Am. J.' [3] xxvi. 477 (Abs.)
N. v. Konkoly	Spectra of two hundred and fourteen Flashes of Lightning observed at the Astrophysical Observatory, Herény, Hungary.	'Observatory,' 1883, 267–268; 'Beiblätter,' vii. 862 (Abs.)
W. R. Manley	The Green Sun. (Sept. 24)	'Nature,' xxviii. 611–612.
C. Michie Smith	The Green Sun. (Oct. 10)	,, xxix. 28.
Thollon and Trépied	Études faites au sommet du Pic du Midi, en vue de l'établissement d'une station astronomique permanente. (Read Oct. 15.)	'C. R.' xcvii. 834–836; 'Nature,' xxix. 7–8; 'Beiblätter,' viii. 824 (Abs.)
Winslow Upton	The Use of the Spectroscope in Meteorological Observations. (United States War Department. Signal Service Notes, No. 4, 1883.)	'Mem. Spettr. ital.' xiii. 113–118.

1884.

C. Michie Smith	The Remarkable Sunsets. (Jan. 23.)	'Nature,' xxix. 381–382.
A. Cornu	Étude spectrale du groupe de raies telluriques nommé α par Ångström. (Read Jan. 28.)	'C. R.' xcviii. 169–176; 'Nature,' xxix. 351 (Abs.); 'Beiblätter,' viii. 305–307 (Abs.)
,,	Étude spectrale du groupe de raies telluriques nommé α (Alpha) par Ångström.	'J. de Phys.' [2] iii. 109–117.
C. Piazzi Smyth	Rain-band Spectroscopy Attacked Again. (March 25.)	'Nature,' xxix. 525.

CHEMICAL RELATIONS.

1881.

H. Settegast	Bestimmung der Salpetersäure und Phosphorsäure auf spectralanalytischem Wege.	'Zeitschr. anal. Chem.' xx. 116–117.

CHEMICAL RELATIONS, 1881.

B. Hasselberg . .	Beiträge zur Spectroscopie der Metalloide. (Read April 28.)	'Bull. Acad. Imp. S.-Pétersb.' xxvii. 405–417.
R. Thalén . .	Spektral undersökningar rörande Skandium, Ytterbium Erbium och Thulium. (Read June 8.)	Öfversigt af Kgl. Vetensk. Akad. Förhandlingar,' xxxviii. No. 6, 13–21; 'J. de Phys.' [2] ii. 35–40; 'Ber.' xvi. 776 (Abs.); 'Chem. News,' xlvii. 217 (Abs.); 'J. Chem. Soc.' xliv. 954 (Abs.)
W. N. Hartley . .	Note on Certain Photographs of the Ultra-Violet Spectra of Elementary Bodies. (Read June 16, 1881.)	'J. Chem. Soc.' xli. 84–90; 'Chem. News,' xliii. 289 (Abs.); 'Beiblätter,' v. 659–660 (Abs.); vi. 789–790 (Abs.)
O. W. Huntington .	On the Spectrum of Arsenic. (Read June 28.)	'Proc. Am. Acad. Boston' [2] ix. 35–38; 'Am. J.' xxii. 214–217; 'Beiblätter,' v. 868 (Abs.)
W. Wleügel . .	Zur spectralanalytischen Ermittelung des Indiums.	'Zeitschr. anal. Chem.' xx. 115.
Fiévez . . .	Recherches sur le spectre du magnésium en rapport avec la constitution du Soleil.	'Ann. Chim. et Phys.' [5] xxiii. 366–372.
L. Thollon . .	Longueur d'ondes des bandes spectrales données par les composés du carbone. (Read Aug. 1.)	'C. R.' xciii. 260; 'Ann Chim. et Phys.' [5] xxv. 287–288.
A. Wüllner . .	Ueber die Spectra des Wasserstoffs und des Acetylens. (Aug. 10.)	'Ann. Phys. u. Chem.' N.F. xiv. 355–362; 'J. Chem. Soc.' xlii. 129–130 (Abs.)
W. de W. Abney .	On the Spectrum impressed on Silver Chloride, and its bearing on Silver Printing in Photography. (Brit. Assoc.)	'Chem. News,' xliv. 184–185; 'J. Chem. Soc.' xlii. 2 (Abs.)
J. H. Gladstone .	Observations on the Specific Refraction and Dispersion of Light by Liquids. (Brit. Assoc.)	'Nature,' xxiv. 468 (Abs.); 'Beiblätter,' vi. 21 (Abs.)
Mendelejeff . .	Notice sur les nouveaux métaux obtenus du gadolinite. (Read Oct. 8.20. In Russian.)	'J. soc. phys.-chim. russe,' xiii. 517–520; 'Bull. Soc. Chim.' xxxviii. 139–143.
J. W. Brühl . .	Ueber den Zusammenhang zwischen den optischen und den thermischen Eigenschaften flüssiger organischer Körper. (Read Nov. 3.)	'Sitzungsb. Wien. Akad.' lxxxiv. II. 817–875; 'Monatsh. f. Chem.' ii. 716–774; 'Ann. der Chem.' ccxi. 121–178; 'J. Chem. Soc.' xlii. 263 (Abs.); 'Beiblätter,' vi. 377–378 (Abs.)
" . . .	Berichtigung	'Ann. der Chem.' ccxi. 371–372; 'Beiblätter,' vi. 377–378 (Abs.)
K. Hock . . .	Alkaloïdreactionen im Spectralapparate.	'Arch. Pharm.' xix. 358–359; 'Ber.' xiv. 2844 (Abs.)

CHEMICAL RELATIONS, 1881, 1882.

H. Schröder	Untersuchungen über die Abhängigkeit der Molecular-refraction flüssiger Verbindungen von ihrer chemischen Zusammensetzung. (Read Nov. 5.)	'Situngsb. Akad. München,' 1882, 57–104; 'Ann. Phys. u. Chem.' N.F. xv. 636–675; 'J. Chem. Soc.' xlii. 1153–1154 (Abs.)
"	Untersuchungen über die Abhängigkeit der Molekularrefraktion von der chemischen Constitution der Verbindungen. (Nov. 7. Read Nov. 14.)	'Ber.' xiv. 2513–2516; 'J. Chem. Soc.' xlii. 351–352 (Abs.)
J. W. Brühl	Die Beziehung zwischen den physikalischen Eigenschaften organischer Körper und ihrer chemischen Constitution. (Read Nov. 14.)	'Ber.' xiv. 2533–2539; 'Am. J.' [3] xxiii. 234–235 (Abs.)
P. P. Bedson and W. C. Williams.	Ueber die Bestimmung des specifischen Brechungsvermögens fester Körper in ihren Lösungen. (Recd. Oct. 18. Read Nov. 14.)	'Ber.' xiv. 2549–2556; 'J. Chem. Soc.' xlii. 351 (Abs.); 'Beiblätter,' vi. 91–93 (Abs.); 'J. de Phys.' [2] i. 377–378 (Abs.)
B. Hasselberg	Bemerkung zu Hrn. Wüllner's Aufsatz: 'Ueber die Spectra des Wasserstoffs und des Acetylens.' (Nov. 1881.)	'Ann. Phys. u. Chem.' N.F. xv. 45–49.
S. Capranica	Le reazioni dei pigmenti biliari	'Gazz. chim. ital.' xi. 430–431; 'Ber.' xv. 262–263 (Abs.); 'J. Chem. Soc.' xlii. 232–233 (Abs.)
C. Hock	Sur quelques réactions spectrales d'alcaloïdes et des glucosides. (Read Nov. 21.)	'C. R.' xciii. 849–851; 'J. Chem. Soc.' xlii. 349 (Abs.); 'Beiblätter,' vi. 232 (Abs.); 'Ber.' xiv. 2844 (Abs.)
J. W. Brühl	Ueber die Molekularrefraktion der Citracon- und Mesaconsäureäther. (Dec. 8. Read Dec. 12.)	'Ber.' xiv. 2736–2744; 'J. Chem. Soc.' xlii. 829–830; 'Beiblätter,' vi. 376 (Abs.)
W. de W. Abney	On the Effect of the Spectrum on the Haloid Salts of Silver and on Mixtures of the same. (Recd. Dec. 6. Read Dec. 15.)	'Proc. Roy. Soc.' xxxiii. 164–186; 'J. Chem. Soc.' xlii. 565 (Abs.)
H. Moissan	Sur le chromocyanure de potassium. (Read Dec. 19.)	'C. R.' xciii. 1079–1081; 'Chem. News,' xlv. 22 (Abs.); 'Ber.' xv. 243 (Abs.)
J. W. Brühl	Ueber die Molekularrefraktion der Methacryl- und der Crotonsäure. (Recd. Dec. 22.)	'Ber.' xiv. 2797–2801; 'J. Chem. Soc.' xlii. 827 (Abs.); 'Beiblätter,' vi. 477–478 (Abs.)
F. Flawitzky	Das molekulare Brechungsvermögen der Terpene. (Dec. 18, 1881. Read Jan. 9, 1882.)	'Ber.' xv. 15–16.
	1882.	
J. Thomsen	Brechungsvermögen und Verbrennungswärme. (Jan. 1882.)	'Ber.' xv. 66–69; 'J. Chem. Soc.' xlii. 567 (Abs.); 'Beiblätter,' vi 377–378 (Abs.)
H. Kruss	Zur quantitativen Spektralanalyse.	'Repert. analyt. Chem.' ii. 17–22.

CHEMICAL RELATIONS, 1882.

H. Landolt . .	Ueber die Molecularrefraction flüssiger organischer Verbindungen. (Read Jan. 19.)	'Sitzungsb. Berl. Akad. 1882, 64–91; 'Ann. der Chem.' ccxiii. 75–112; 'Beiblätter,' vii. 843–848 (Abs.)
W. N. Hartley. .	Contributions to the Chemistry of Cerium Compounds. (Read. Jan. 19.)	'J. Chem. Soc.' xli. 202–209; 'Chem. News,' xlv. 40 (Abs.)
" . .	The Analysis of Rhabdophane, a New British Mineral. (Read Jan. 19.)	'J. Chem. Soc.' xli. 210–220; 'Chem. News,' xlv. 40 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of Water. No. II. (Recd. Jan. 14. Read Jan. 26.)	'Proc. Roy. Soc.' xxxiii. 274–276; 'J. Chem. Soc.' xliv. 140 (Abs.); 'Beiblätter,' vi. 481 (Abs.)
Piazzi Smyth . .	On the Constitution of the Lines forming the Low-Temperature Spectrum of Oxygen. (Read Jan. 30.)	'Trans. Roy. Soc. Edinb.' xxx. 419–425; 'Nature,' xxv. 403 (Abs.); 'Phil. Mag.' [5] xiii. 330–337; 'J. de Phys.' [2] ii. 289 (Abs.)
W. N. Hartley . .	Researches on the Relation of Molecular Structure of Carbon Compounds to their Absorption Spectra. Part VI. On the Constitution of Pyridine, Picoline, Quinoline, and Cyanuric Acid.	'J. Chem. Soc.' xli. 45–49; 'Beiblätter,' vi. 375–376 (Abs.)
Dieulafait . .	Existence de l'acide borique en quantité notable dans les lacs salés de la période moderne et dans les eaux salines naturelles, qu'elles soient ou non en relation avec des produits éruptifs. (Deuxième mémoire.)	'Ann. Chim. et Phys.' [5] xxv. 145–167.
C. H. Wolff . .	Einige neuen Absorptionsspektren.	'Repert. anal. Chem.' ii. 55–56; 'Zeitschr. anal. Chem.' xxii. 96–97; 'Ch. News,' xlvii. 178 (Abs.)
Lecoq de Boisbaudran.	Matière colorante se formant dans la colle de farine. (Read Feb. 27.)	'C. R.' xciv. 562–563; 'J. Chm.Soc.' xlii. 739(Abs.)
Wiedemann . .	Ueber einige von der Herren J. W. Brühl und V. Zenger aufgestellte Beziehungen zwischen physikalischen Constanten chemischer Verbindungen. (Feb.24. Recd.Feb.28.)	'Ber.' xv. 464–470; 'Beiblätter,' vi. 370–371 (Abs.), 377–378 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of Carbon. (Recd. Feb. 23. Read March 9.)	'Proc. Roy. Soc.' xxxiii. 403–410; 'Chem. News,' xlv. 155–156 (Abs.); 'Nature,' xxv. 545–546; 'J. Chem. Soc.' xliv. 1–2 (Abs.); 'Beiblätter,' vi. 675 (Abs.)
" . .	On the Disappearance of some Spectral Lines and the Variations of Metallic Spectra due to Mixed Vapours. (Recd. March 11. Read March 16.)	'Proc. Roy. Soc.' xxxiii. 428–434; 'J. Chem. Soc.' xliv. 2–3 (Abs.); 'Beiblätter,' vi. 676 (Abs.)

CHEMICAL RELATIONS, 1882.

R. Meldola . .	Contributions to the Chemical History of the Aromatic Derivatives of Methane. (Read March 16.)	'J. Chem. Soc.' xli. 187-201.
J. Chappuis . .	Sur le spectre d'absorption de l'ozone. (Read March 27.)	'C. R.' xciv. 858-860; 'Chem. News,' xlv. 163 (Abs.); 'J. Chem. Soc.' xlii. 1017 (Abs.); 'Beiblätter,' vi. 482-483 (Abs.); 'Am. J.' [3] xxiv. 56-57 (Abs.)
,, . .	Étude spectroscopique sur l'ozone .	'Ann. de l'école norm.' [2] xi. 137-186; 'Beiblätter,' vii. 458 (Abs.)
,, . .	Sur le spectre d'absorption de l'acide pernitrique. (Read April 3.)	'C. R.' xciv. 946-948; 'J. Chem. Soc.' xlii. 1017 (Abs.); 'Beiblätter,' vi. 483 (Abs.); 'Am. J.' [3] xxiv. 58-59 (Abs.)
B. Hasselberg . .	Untersuchungen über das zweite Spectrum des Wasserstoffs. (Read April 13.)	'Mém. Acad. Imp. S.-Pétersb.' xxx. No. 7, 24 pp.; 'Phil. Mag.' [5] xvii. 329-353 (Abs.); 'Beiblätter,' vii. 691-694 (Abs.)
H. Schröder . .	Fernere Untersuchungen über die Abhängigkeit der Molekularrefraction flüssiger Verbindungen von ihrer chemischen Constitution. (April 22.)	'Ber.' xv. 994-998; 'J. Chem. Soc.' xlii. 910-911 (Abs.)
H. Landolt . .	Ueber die Molekularrefraktion flüssiger organischer Verbindungen. (Read April 24.)	'Ber.' xv. 1031-1040; 'J. Chem. Soc.' xlii. 909-910 (Abs.)
H. Schröder . .	Fernere Untersuchungen über die Abhängigkeit der Molecularrefraction flüssiger Verbindungen von ihrer chemischen Constitution. (Aug. 24.)	'Ann. Phys. u. Chem.' N.F. xviii. 148-175; 'J. Chem. Soc.' xliv. 538-539 (Abs.)
T. W. Engelmann .	Ueber Sauerstoffausscheidung von Planzenzellen im Mikrospektrum. (April 1882.)	'Onderzoekingen physiol. Lab. Utrecht' [3] vii. 191-199; 'Pflüger's Archiv,' xxvii. 485-490; 'Ber.' xv. 2753-2754 (Abs.); 'Proc. Verb. K. Akad. v. Wetenschappen, Amsterdam,' Feb. 25, 1882, 3-7 (Abs.); 'Beiblätter,' vii. 377 (Abs.); 'Chem. News,' xlvii. 11 (Abs.); 'Centralblatt f. Agricultur,' xi. 673 (Abs.)
,, . .	Ueber Assimilation von Hæmatococcus. (May 10.)	'Onderzoekingen physiol. Lab. Utrecht' [3] vii. 200-208; 'Proc. Verb. K. Akad. v. Wetenschappen, Amsterdam,' March 25, 1882, 3-6 (Abs.); 'Beiblätter,' vii. 377-378 (Abs.)

CHEMICAL RELATIONS, 1882.

Dieulafait . . .	Existence de la lithine et de l'acide borique dans les eaux de la mer Morte. (Read May 15.)	'C. R.' xciv. 1352–1354; 'J. Chem. Soc.' xlii. 1037–1039 (Abs.)
G. Krüss . . .	Ueber die Constitution von Lösungen. (Recd. May 15. Read May 22.)	'Ber.' xv. 1243–1249; 'J. Chem. Soc.' xlii. 1018–1019 (Abs.); 'Beiblätter,' vi. 677–678 (Abs.); 'Am. J.' [3] xxiv. 141–142 (Abs.)
E. Jessen . . .	Photometrie des Absorptionsspectrums der Blutkörperchen.	'Zeitschr. f. Biol.' xvii. 251–272; 'Ber.' xv. 952 (Abs.)
G. G. Stokes . .	On the Causes of a Light Border frequently noticed in Photographs just outside the Outline of a Dark Body seen against the Sky; with some Introductory Remarks on Phosphorescence. (Recd. May 20. Read May 25.)	'Proc. Roy. Soc.' xxxiv. 63–68; 'Nature,' xxvi. 142–143; 'Beiblätter, 682–685 (Abs.)
P. Plósz . . .	Ueber einen neuen krystallinischen farbigen Harnbestandtheil. (May 31.)	'Zeitschr. physiol. Chem.' vi. 504–507; 'Ber.' xv. 2626–2627 (Abs.)
H. E. Roscoe and A. Schuster.	The Spectrum of Terbium . .	'J. Chem. Soc.' xli. 283–287; 'Ber.' xv. 1280–1284; 'Beiblätter,' vi. 790–792 (Abs.)
W. J. Russell and W. Lapraik	A Spectroscopic Study of Chlorophyll. (Read June 1.)	'J. Chm. Soc.' xli. 334–341; 'Nature,' xxvi. 636–639; 'Ber.' xv. 2746 (Abs.)
P. T. Clève . .	Note préliminaire sur le didyme. (Read June 5.)	'C. R.' xciv. 1528–1530; 'Chem. News,' xlv. 273; 'J. Chem. Soc.' xliv. 18 (Abs.); 'Ber.' xv. 1750 (Abs.); 'Beiblätter,' vi. 771–772 (Abs.)
W. N. Hartley . .	Researches on Spectrum Photography in relation to New Methods of Quantitative Chemical Analysis. Preliminary Note. (Recd. May 19. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 81–84; 'Ber.' xv. 2924–2925 (Abs.); 'J. Chem. Soc.' xliv. 263–264 (Abs.); 'Beiblätter,' vii. 109–110 (Abs.) 'Zeitschr. anal Chem.' xxii. 539–540 (Abs.)
" . .	On the Reversal of the Metallic Lines as seen in Over-exposed Photographs of Spectra. (Recd. May 19. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 84–86; 'J. Chem. Soc.' xliv. 263 (Abs.); 'Am. J.' [3] xxiv. 471–472 (Abs.); 'Beiblätter,' vii. 27 (Abs.)
G. D. Liveing and J. Dewar.	On the Ultra-Violet Spectra of the Elements. Part I. (Recd. June 8. Read June 15.)	'Phil. Trans.' clxxiv. 187–222; 'Proc. Roy. Soc.' xxxiv. 122–123 (Abs.); 'Beiblätter,' vi. 934 (Abs.), vii. 849–856 (Abs.); 'J. Chem. Soc.' xliv. 262 (Abs.)
" . .	Part II. (Recd. June 15. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 123 (Abs.)

CHEMICAL RELATIONS, 1882.

G. D. Liveing and J. Dewar.	General Observations on the Spectra of Carbon and its Compounds. (Recd. June 12. Read June 15.)	'Proc. Roy. Soc.' xxxiv. 123–130; 'J. Chem. Soc.' xliv. 261–262 (Abs.)
B. Brauner . .	Sur le didyme. (Read June 26) .	'C. R.' xciv. 1718–1719; 'Chem News,' xlvi. 16–17; 'J. Chem. Soc.' xliv. 18 (Abs.); 'Ber.' xv. 2231 (Abs.)
C. H. Wolff . .	Ueber den Nachweis von Fuchsin in damit gefärbten Weinen durch Stearin.	'Repert. anal. Chem.' ii. 193–194; 'Chem. Centr.' [3] xiii. 670 (Abs.); 'J. Chem. Soc.' xliv. 384–385 (Abs.)
C. Zimmermann .	Untersuchungen über das Uran .	'Ann. der Chem.' ccxiii. 285–329; 'Chem. News,' xlvi. 172 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 220–222 (Abs.)
P. T. Clève . .	Quelques remarques sur le didyme. (Read July 3.)	'C. R.' xcv. 33; 'J. Chem. Soc.' xlii. 1165 (Abs.); 'Beiblätter,' vi. 772 (Abs.)
E. Neusser . .	Substances colorantes de l'urine .	'Les Mondes' [3] ii. 468–469; 'J. Chem. Soc.' xlvi. 93 (Abs.)
W. A. Tilden . .	Hydrocarbons of the Formula $(C_5H_8)_n$. (Brit. Assoc.)	'Chem. News,' xlvi. 120–121; 'J. Chem. Soc.' xliv. 75–76 (Abs.)
K. Wesendonck .	Untersuchungen über die Spectra der Kohlenverbindungen.	'Ann. Phys. u. Chem.' N.F. xvii. 427–467; 'J. Chem. Soc.' xliv. 761 (Abs.)
A. Tschirch . .	Mikrochemische Reactionsmethoden im Dienste der technischen Mikroskopie (General-Versammlung des deutschen Apotheker-Vereins). (Read Sept. 6.)	'Arch. Pharm.' [3] xx. 801–812; 'J. Chem. Soc.' xliv. 376–378 (Abs.)
E. Wiedemann .	Ueber die Molecularrefraction der geschwefelten Kohlensäureäther, nebst einigen Bemerkungen über Molecularrefractionen im Allgemeinen.	'Ann. Phys. u. Chem.' N.F. xvii. 577–580; 'J. Chem. Soc.' xliv 762 (Abs.); 'J. de Phys.' [2] ii. 139–140 (Abs.)
E. Branly . .	Dosage de l'hémoglobine dans le sang par les procédés optiques.	'Ann. Chim. et Phys.' [5] xxvii. 238–273; 'J. Chem. Soc.' xliv. 394–395 (Abs.); 'Zeitschr. anal. Chem.' xxii. 629–632 (Abs.); 'J. de Phys.' [2] ii. 430 (Abs.)
L. Saarbach . .	Ueber das Methämoglobin . .	'Pflüger's Archiv,' xxviii. 382–388; 'Ber.' xv. 2752 (Abs.)
T. W. Engelmann .	Bacterium photometricum. Ein Beitrag zur vergleichenden Physiologie des Licht- und Farbensinnes. (Oct. 1882.)	'Onderzoekingen physiol. Lab. Utrecht [3] vii. 252–290; 'Pflüger's Archiv,' xxx. 95–124; 'Proc. Verb. K. Akad. v. Wetenschappen, Amsterdam,' Mar. 25, 1882, 3–6 (Abs.); 'Beiblätter,' vii. 381–382 (Abs.)

CHEMICAL RELATIONS, 1882.

M. Nencki and N. Sieber.	Ueber das Uroroseïn, einen neuen Harnfarbstoff. (Oct. 1882.)	'J. pr. Chem.' xxvi. 333–336; 'Chem. News,' xlvii. 12 (Abs.); 'J. Chem. Soc.' xliv. 101 (Abs.); 'Ber.' xv. 3087 (Abs.)
C. Binz . . .	Ueber das Verhalten von Blut und Ozon zu einander. ('Med. C.-Bl.' xx. 721–725. Oct. 14.)	'Chem. Centr.' 1882, 810–811; 'J. Chem. Soc.' xliv. 486–487 (Abs.)
T. W. Engelmann .	Farbe und Assimilation . . .	'Onderzoekingen physiol. Lab. Utrecht [3] vii. 209–233; 'Beiblätter,' vii. 378–380 (Abs.); 'Centr. f. Agricultur-chemie,' 1883, 174–178 (Abs.); 'J. Chem. Soc.' xliv. 819–820 (Abs.)
R. Möhlau . .	Ueber Diphenyldiisoindolazofarbstoffe. (Recd. Sept. 18. Read Oct. 23.)	'Ber.' xv. 2490–2497; 'J. Chem. Soc.' xliv. 342–343 (Abs.)
J. Chappuis . .	Sur les spectres d'absorption de l'ozone et de l'acide pernitrique.	'J. de Phys.' [2] i. 494–504.
W. de W. Abney .	Work in the Infra-red of the Spectrum.	'Nature,' xxvii. 15–18; 'Beiblätter,' vii. 695–697 (Abs.); 'J. de Phys.' [2] iii. 48 (Abs.)
T. L. Phipson . .	On the Colouring Matter (Ruberine) and the Alkaloid (Agarythrine) contained in *Agaricus ruber*.	'Chem. News,' xlvi. 199–200; 'J. Chem. Soc.' xliv. 100 (Abs.); 'Ber.' xvi. 244 (Abs.)
P. Friedländer and A. Weinberg.	Ueber einige im Pyridinkern substituirte Chinolinderivate. (Recd. Nov. 9. Read Nov. 13.)	'Ber.' xv. 2679–2685.
J. Herschel . .	Soda Flames in Coal Fires . .	'Nature,' xxvii. 78.
Dieulafait . .	La lithine, la strontiane et l'acide borique dans les eaux minérales de Contrexeville et Schinznach (Suisse). (Read Nov. 20.)	'C. R.' xcv. 999–1001; 'J. Chem. Soc.' xliv. 301 (Abs.)
Sm. . . .	Flame in Coal Fire. (Nov. 24) .	'Nature,' xxvii. 103.
R. Nasini . .	Ueber die Atomrefraktion des Schwefels. (Read Nov. 27.)	'Ber.' xv. 2878–2892; 'J. Chem. Soc.' xliv. 264–266 (Abs.); 'Beiblätter,' vii. 281–284 (Abs.)
W. G. Levison .	Note on the Application of the Spectropolariscope to Sugar Analysis.	'Am. J.' [3] xxiv. 469–470.
Schlagdenhauffen .	Sur l'origine de l'arsenic et de la lithine dans les eaux sulfatées calciques.	'J. de Pharm.' [5] vi. 457–463; 'J. Chem. Soc.' xliv. 302 (Abs.)
G. D. Liveing and J. Dewar.	On the Origin of the Hydrocarbon Flame Spectrum. (Recd. Dec. 14. Read Dec. 21.)	'Proc. Roy. Soc.' xxxiv. 418–429; 'Nature,' xxvii. 257–259; 'Chem. News,' xlvi. 293–297; 'Beiblätter,' vii. 288–289 (Abs.); 'J. Chem. Soc.' xliv. 641–642 (Abs.)

CHEMICAL RELATIONS, 1883.

K. Hock . .	Ueber gefärbte ätherische Oele .	'Archiv der Pharm.' [3] xxi. 17–18; 437–438; 'Zeitschr. anal. Chem.' xxiii. 241 (Abs.)
E. Salfeld . .	Ueber die Dauer der spektralanalytischen Reaktion von Kohlenoxyd.	'Repert. anal. Chem.' 1883, 35–37; 'Archiv der Pharm.' [3] xxi. 289 (Abs.); 'J. Chem. Soc.' xlvi. 343–344 (Abs.)
P. T. Clève . .	Sur le poids atomique de l'yttrium.	'Bull. Soc. Chim.' xxxix. 120–122; 'Am. J.' [3] xxv. 381–382 (Abs.)
,, . .	Sur le poids atomique du lanthane.	'Bull. Soc. Chim.' xxxix. 151–155; 'Chem. News,' xlvii. 154–155; 'Am. J.' [3] xxv. 381–382 (Abs.)
G. D. Liveing .	The Ultra-Violet Spectra of the Elements. (March 9.)	'Proc. Roy. Inst.' x. 245–252; 'Beiblätter,' vii. 598–599 (Abs.)
J. Kanonnikoff .	Sur le pouvoir réfringent des substances organiques dans les dissolutions. (In Russian.)	'J. soc. phys.-chim. russe,' xv. 112–113; 'Ber.' xvi. 950 (Abs.); 'J. pr. Chem.' N.F. xxvii. 362–364.
W. N. Hartley. .	On Homologous Spectra. (Read March 15.)	'J. Chem. Soc.' xliii. 390–400; 'Nature,' xxvii. 522 (Abs.); 'Chem. News.' xlvii. 138 (Abs.); 'Am. J.' [3] xxvi. 401–402 (Abs.); 'Ber.' xvi. 2659–2660 (Abs.); 'Beiblätter,' viii. 217–218 (Abs.)
H. W. Vogel . .	Ueber die verschiedenen Modificationen des Bromsilbers und Chlorsilbers. (April 1883.)	'Ber.' xvi. 1170–1179; 'Beiblätter,' vii. 536–538 (Abs.)
C. A. MacMunn .	Observations on the Colouring-Matters of the so-called Bile of Invertebrates, and on some unusual Urine Pigments, &c. (Recd. March 8. Read April 5.)	'Proc. Roy. Soc.' xxxv. 370–403; 'J. Chem. Soc.' xlvi. 194–198 (Abs.)
B. Brauner .	Contribution to the Chemistry of the Cerite Metals. (Read April 5.)	'J. Chem. Soc.' xliii. 278–289; 'Chem. News,' xlvii. 175 (Abs.)
P. Barbier . .	Sur les chlorhydrates liquides de térébenthène. (Read April 9.)	'C. R.' xcvi. 1066–1069; 'J. Chem. Soc.' xliv. 809 (Abs.)
W. N. Hartley and W. E. Adeney.	Measurements of the Wave-lengths of Lines of High Refrangibility in the Spectra of Elementary Substances. (Recd. March 20. Read April 19.)	'Phil. Trans.' clxxv. 63–137; 'Proc. Roy. Soc.' xxxv. 148–149 (Abs.); 'Chem. News,' xlvii. 193–194 (Abs.); 'Beiblätter,' vii. 599–600 (Abs.)
W. N. Hartley .	On the Spectrum of Beryllium, with Observations relative to the Position of that Metal among the Elements. (Read April 19.)	'J. Chem. Soc.' xliii. 316–319; 'Ber.' xvi. 1859–1860 (Abs.); 'Am. J.' [3] xxvi. 316–317 (Abs.); 'Beiblätter,' vii. 895 (Abs.)

CHEMICAL RELATIONS, 1883.

J. Kanonnikoff	Ueber das Brechungsvermögen organischer Verbindungen in Lösungen.	'J. pr. Chem.' N.F. xxvii. 362–364; 'Beiblätter,' vii. 593–594 (Abs.); 'J. Chem. Soc.' xliv. 1041 (Abs.)
S. Reformatsky	Untersuchungen über einen aus Allyldipropylcarbinol erhaltenen Kohlenwasserstoff: $C_{10}H_{18}$.	'J. pr. Chem.' N.F. xxvii. 389–407: 'Beiblätter,' vii. 689 (Abs.) (Error in Title.)
R. Nasini	Sulla refrazione atomica dello zolfo.	'Gazz. chim. ital.' xiii. 296–311; 'J. Chem. Soc.' xlvi. 149–151 (Abs.)
Bernheimer and Nasini.	Sulle relazioni esistenti tra il potere rifrangente e la constituzione chimica delle combinazioni organiche. (Read May 6.)	'Atti della R. Acc. dei Lincei, Transunti' [3] vii. 227–230; 'Gazz. chim. ital.' xiii. 317–320; 'Beiblätter,' vii. 528–529 (Abs.)
B. Hasselberg	Untersuchungen über das zweite Spectrum des Wasserstoffs. Zweite Abhandlung. (Read May 10.)	'Mém. Acad. Imp. S. Pétersb.' xxxi. No. 14. 30 pp.; 'Beiblätter,' viii. 381–384 (Abs.); 'Mem. Spettr. ital.' xiii. 97–105 (Abs.)
J. Emerson Reynolds	Note on the Atomic Weight of Beryllium. (Recd. May 8. Read May 24.)	'Proc. Roy. Soc.' xxxv. 248–250; 'Beiblätter,' viii. 3–4 (Abs.)
W. Crookes	On Radiant Matter Spectroscopy. The Detection and Wide Distribution of Yttrium. (Bakerian Lecture. Recd. May 24. Read May 31.)	'Phil. Trans.' clxxiv. 891–918; 'Proc. Roy. Soc.' xxxv. 262–271 (Abs.); 'Chem. News,' xlvii. 261–264 (Abs.); 'Ber.' xvi. 1689 (Abs.); 'J. Franklin Inst.' lxxxvi. 118–128; 'Beiblätter,' vii. 599 (Abs.); 'J. Chem. Soc.' xlvi. 241–242 (Abs.); 'Chem. News,' xlix. 159–160, 169–171, 181–182, 194–196, 205–208; 'Ann. Chim. et Phys.' [6] iii. 145–187.
J. G. Otto	Beiträge zur Kenntniss der Blutfarbstoffe.	'Pflüger's Archiv f. Physiol.' xxxi. 240–244; 'Ber.' xvi. 2688–2689 (Abs.)
,,	Studien über das Methämoglobin	'Pflüger's Archiv f. Physiol.' xxxi. 245–267; 'Ber.' xvi. 2689 (Abs.)
A. Poehl	Zur Lehre von den Fäulnissalkaloïden. (June 6.)	'Ber.' xvi. 1975–1988.
W. N. Hartley	On Line Spectra of Boron and Silicon. (Recd. May 28. Read June 21.)	'Proc. Roy. Soc.' xxxv. 301–304; 'Chem. News,' xlviii. 1–2; 'J. Chem. Soc.' xlvi. 242 (Abs.); 'Beiblätter,' viii. 120 (Abs.)

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W. N. Hartley .	Researches on Spectrum Photography in relation to New Methods of Quantitative Chemical Analysis. Part I. (Recd. June 20. Read June 21.)	'Phil. Trans.' clxxv. 49–62.
T. S. Humpidge .	Reply to a Note by Professor J. E. Reynolds on the Atomic Weight of Glucinum or Beryllium. (Recd. June 7. Read June 21.)	'Proc. Roy. Soc.' xxxv. 358–359; 'Chem. News,' xlvii. 297; 'Beiblätter,' viii. 3–4 (Abs.)
C. Auer von Welsbach.	Über die Erden des Gadolinits von Ytterby. (Read July 5.)	'Sitzungsb. Wien. Akad.' lxxxviii. II. 332–344.
H. Becquerel . .	Spectres d'émission infra-rouges des vapeurs métalliques. (Read July 9.)	'C.R.' xcvii. 71–74; 'Chem. News,' xlviii. 46 (Abs.); 'Nature,' xxviii. 287 (Abs.); 'Beiblätter,' vii. 701–702 (Abs.); 'Am. J.' [3] xxvi. 321 (Abs.); 'Ber.' xvi. 2487 (Abs.); 'J. Chem. Soc.' xlvi. 1 (Abs.); 'Zeitschr. anal. Chem.' xxiii. 49 (Abs.)
O. Jacobsen and F. Wierss.	Ueber einige Derivate der Orthotoluylsäure. (Read July 23.)	'Ber.' xvi. 1956–1962; 'J. Chem. Soc. xliv. 1121 (Abs.)
C. Piazzi Smyth .	Cyanogen in Small Induction Sparks in Free Air. (July 25.)	'Nature,' xxviii. 340–341.
G. Krüss and S. Oeconomides.	Beziehungen zwischen der Zusammensetzung und der Absorptionsspektren organischer Verbindungen. (Recd. Aug. 10.)	'Ber.' xvi. 2051–2056; 'J. Chem. Soc.' xliv. 1041–1042 (Abs.); 'Beiblätter,' vii. 897–899 (Abs.)
P. T. Clève . .	On Samarium and its Compounds .	'J. Chem. Soc.' xliii. 362–370; 'Chem. News,' xlviii. 74–76; 'Ber.' xvi. 2493 (Abs.)
P. Plósz . . .	Ueber einige Chromogene des Harns und deren Derivate. (Recd. Sept. 6.)	'Zeitschr. physiol. Chem.' viii. 85–94; 'Ber.' xvi. 2933–2934 (Abs.)
R. Thalén . .	Om de lysande spektra hos Didym och Samarium. (Read Sept. 12.) (Sur les spectres brillants du didyme et du samarium.)	'Öfversigt K. Vetensk. Akad. Förhandl.' xl. No. 7, 3–16; 'J. de Phys.' [2] ii. 446–449; 'Ber.' xvi. 2760 (Abs.); 'Beiblätter,' vii. 893–895 (Abs.)
P. T. Clève . .	Om Samarium. (Read Sept. 12) .	'Öfversigt K. Vetensk. Akad. Förhandl.' xl. No. 7, 17–26; 'Beiblätter,' viii. 264 (Abs.)
J. Kanonnikoff .	Sur la relation du pouvoir réfringent et la composition des composés organiques. (In Russian. Read Sept. 15–27.)	'J. soc. phys.-chim. russe,' xv. 434–479; 'Ber.' xvi. 3047–3051 (Abs.); 'Bull. Soc. Chim.' xli. 318–319 (Abs.); 'Beiblätter,' viii. 375–377 (Abs.)
W. N. Hartley .	The Investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements and their Combinations under Varying Conditions. (Brit. Assoc.)	'Chem. News,' xlviii. 195–196; 'Nature,' xxix. 89–90; 'J. Chem. Soc.' xlvi. 137–138 (Abs.); 'Beiblätter,' viii. 302 (Abs.)

CHEMICAL RELATIONS, 1883, 1884.

A. Albitsky . .	Sur le pouvoir réfringent de l'hydrocarbure, $C_{12}H_{20}$. (In Russian. Read Aug. 20–Sept. 1.)	'J. soc. phys.-chim. russe,' xv. 524–526.
C. H. Wolff . .	Spectralanalytische Werthbestimmung verschiedener reiner Indigotinsorten. (Oct. 1883.)	'Zeitschr. anal. Chem.' xxiii. 29–32.
A. Tschirch . .	Die Reindarstellung des Chlorophyllfarbstoffes. (Read Nov. 12.)	'Ber.' xvi. 2731–2736; 'J. Chem. Soc.' xlv. 57–62.
,, . .	Untersuchungen über das Chlorophyll und einige seiner Derivate. (Dec. 1883.)	'Ann. Phys. u. Chem.' N.F. xxi. 370–383.
C. Auer von Welsbach.	Über die Erden des Gadolinits von Ytterby. II. Abhandlung. (Read Dec. 20.)	'Sitzungsb. Wien. Akad.' lxxxviii. II. 1237–1251; 'Monatshefte,' v. 1–15; 'Zeitschr. anal. Chem.' xxiii. 520 (Abs.); 'Chem. News,' li. 25 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iv. 429–430 (Abs.)

1884.

E. Wiedemann .	Note on an Observation by Professor Hartley. (Feb. 1884.)	'Chem. News,' xlix. 117; 'J. Chem. Soc.' xlvi. 801 (Abs.); 'Beiblätter,' viii. 581 (Abs.)
K. Wesendonck .	Ueber die Spectra des Fluorsiliciums und des Siliciumwasserstoffs.	'Ann. Phys. u. Chim.' N.F. xxi. 427–437; 'J. Chem. Soc.' xlvi. 649 (Abs.)
J. Kanonnikoff .	Sur les relations entre la composition et le pouvoir réfringent des composés chimiques. (Second mémoire.) (Read Jan. 5–17.) (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 119–131; 'Ber.' xvii. Referate, 157–159 (Abs.); 'Nature,' xxx. 84 (Abs.); 'Beiblätter,' viii. 493–496 (Abs.); 'Bull. Soc. Chim.' xli. 549 (Abs.); 'J. Chem. Soc.' xlviii. 1–2 (Abs.)
R. Nasini . .	Sulla questione dei doppi legami tra carbonio e carbonio dal punto di vista della chimica ottica. (Read March 2.)	'Atti R. Accad. dei Lincei,' viii. 169–173; 'Beiblätter,' viii. 577–578 (Abs.)
W. N. Hartley .	Researches in Spectrum Photography in Relation to New Methods of Quantitative Chemical Analysis. Part II. (Recd. Feb. 28. Read March 13.)	'Proc. Roy. Soc.' xxxvi. 421–422 (Abs.); 'Chem. News,' xlix. 128 (Abs.); 'Beiblätter,' viii. 705–706 (Abs.)
J. H. Stebbins. .	On the Spectra of the Azo-Colours. (Read April 1.)	'J. Am. Chem. Soc.' vi. 117–120.
F. Flavitsky . .	Note concernant le mémoire de M. J. Kanonnikoff sur le pouvoir réfringent des substances organiques. (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 260–267.
W. N. Hartley .	Remarks on the Atomic Weight of Beryllium. (Recd. March 19. Read April 3.)	'Proc. Roy. Soc.' xxxvi. 462–464; 'Chem. News,' xlix. 171–172; 'Beiblätter,' viii. 820–821 (Abs.)

CHEMICAL RELATIONS, 1884.—THEORETICAL PAPERS, 1880, 1881.

A. Schrauf . .	Ueber das Dispersionsäquivalent von Diamant. (April 1884.)	'Ann. Phys. u. Chem.' N.F. xxii. 424–429; 'J. Chem. Soc.' xlviii. 14 (Abs.)
H. W. Vogel . .	Ueber die Hilfsmittel, photographische Schichten für grüne, gelbe und rothe Strahlen empfindlich zu machen. (Recd. May 14.)	'Ber.' xvii. 1196–1203; 'J. Chem. Soc.' xlvi. 1081 (Abs.); 'Beiblätter,' viii. 583–585 (Abs.)
J. H. Gladstone .	Refraction-equivalents of Organic Compounds. (Read May 15.)	'J. Chem. Soc.' xlv. 241–259; 'Chem. News,' xlix. 233 (Abs.); 'Nature,' xxx. 119 (Abs.); 'Ber.' xvii. Referate, 556 (Abs.)
R. Nasini . .	Sulla questione dei doppi legami tra carbonio e carbonio dal punto di vista della chimica ottica. (May 1884.)	'Gazz. chim. ital.' xiv. 150–156; 'Ber.' xvii. Referate, 559–561 (Abs.)
J. Parry . . .	The Spectroscopic Examination of the Vapours Evolved on Heating Iron, &c., at Atmospheric Pressure.	'Chem. News,' xlix. 241–242; 'Ber.' xvii. Referate, 337 (Abs.); 'J. Chem. Soc.' xlvi. 801–802 (Abs.); 'Beiblätter,' viii. 646–647 (Abs.)
A. Morghen . .	Lo Spettro di assorbimento del vapore di jodio. (June 1884.)	'Mem. Spettr. ital.' xiii. 127–131; 'Beiblätter,' viii. 822–823 (Abs.)
J. Kanonnikoff .	Réponse à la note de M. Flavitsky. (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 448–450.
A. Morghen . .	Lo Spettro di assorbimento del vapore di jodio. (Read June 15.)	'Atti R. Accad. Lincei, Transunti' [3] viii. 327–330; 'Beiblätter,' viii. 822–823 (Abs.)
Dieulafait . .	Les salpêtres naturels du Chili et du Pérou au point de vue du rubidium, du cæsium, du lithium et de l'acide borique. Conséquences relatives aux terrains à betteraves du nord de la France. (Read June 23.)	'C. R.' xcviii. 1545–1548; 'Chem. News,' l. 45 (Abs.)

THEORETICAL PAPERS.

1880.

N. Hesehus . .	Démonstration élémentaire des conditions du minimum de déviation d'un rayon par le prisme. (In Russian.)	'J. soc. phys.-chim. russe,' xii. 226–231; 'J. de Phys.' x. 419–420 (Abs.); 'Beiblätter,' vi. 227–228 (Abs.)

1881.

C. Pulfrich . .	Photometrische Untersuchungen über Absorption des Lichtes in isotropen and anisotropen Medien. (July 1881.)	'Ann. Phys. u. Chem,' N.F. xiv. 177–218; 'Am. J.' [3] xxiii. 50 (Abs.); 'J. de Phys.' [2] i. 285–286 (Abs.)
A. Schuster . .	On the Dynamical Theory of Radiation. (Brit. Assoc.)	'Phil. Mag.' [5] xii. 261–266; 'Beiblätter,' v. 793–795 (Abs.)

THEORETICAL PAPERS, 1881, 1882.

F. Kessler . .	Das Minimum der Ablenkung eines Lichtstrahls durch ein Prisma. (Nov. 1881.)	'Ann. Phys. u. Chem,' N.F. xv. 333-334.
E. Ketteler and C. Pulfrich.	Photometrische Untersuchungen. (Nov. 1881.)	'Ann. Phys. u. Chem' N.F. xv. 337-378; 'Am. J.' [3] xxiii. 486-487 (Abs.)

1882.

J. Fröhlich . .	Experimentaluntersuchungen über die Intensität des gebeugten Lichts; II. (Jan. 1.)	'Ann. Phys. u. Chem.' N.F. xv. 576-613; 'J. de Phys.' [2] i. 559-560 (Abs.)
E. Lecher . .	Ueber Ausstrahlung und Absorption. (Read March 2.)	'Sitzungsb. Wien. Akad.' lxxxv. II. 441-490; 'Ann. Phys. u. Chem.' N.F. xvii. 477-518 (Abs.)
E. Lommel . .	Zur Theorie des Lichts. (April 1882.)	'Ann. Phys. u. Chem.' N.F. xvi. 427-441.
H. A. Rowland .	Preliminary Notice of the Results accomplished in the Manufacture and Theory of Gratings for Optical Purposes. (May 25.)	'Johns-Hopkins Univ. Circular,' 1882, 248-249; 'Phil. Mag.' [5] xiii. 469-474; 'Nature,' xxvi. 211-213; 'Am. J.' [3] xxiv. 63 (Abs.); 'Observatory, 1882, 224-228; 'Zeitschr. f. Instrumentenkunde,' ii. 304 (Abs.)
A. Wüllner . .	Zur Dispersion farblos durchsichtiger Medien. (Sept. 6.)	'Ann. Phys. u. Chem.' N.F. xvii. 580-587; 'J. de Phys.' [2] ii. 231 (Abs.)
M. Weinberg . .	Interferenzstreifen im prismatischen und im Beugungsspectrum.	'Carl. Repert.' xviii. 600-608.
H. W. Vogel . .	Ueber Lockyer's Dissociationstheorie. (Read Nov. 2.)	'Sitzungsb. Berl. Acad.' 1882, 905-907; 'Nature,' xxvii. 233; 'Ann. Phys. u. Chem.' N.F. xix. 284-287; 'Phil. Mag.' [5] xv. 28-30; 'J. Chem. Soc.' xliv. 762 (Abs.); 'Chem. Centralblatt,' xiv. 34-35 (Abs.); 'Zeitschr. anal. Chem.' xxii. 539 (Abs.); 'Chem. News,' xlix. 201 (Abs.)
E. Ketteler . .	Optische Controversen. (Nov. 1882.)	'Ann. Phys. u. Chem.' N.F. xviii. 387-421, 631-663.
Mascart . . .	Sur les réseaux métalliques de M. H. A. Rowland. (Read Nov. 17.)	'Soc. franç. de Phys.' 1882, 232-238; 'J. de Phys.' [2] ii. 5-11; 'Beiblätter,' vii. 466-468 (Abs.)
W. Baily . . .	On the Spectra formed by Curved Diffraction-Gratings. (Read Jan. 27.)	'Proc. Phys. Soc.' v. 181-185; 'Phil. Mag.' [5] xv. 183-187; 'Beiblätter,' vii. 465-466 (Abs.); 'J. de Phys.' [2] iii. 152-154 (Abs.)

THEORETICAL PAPERS, 1883, 1884.

1883.

Faye . . .	Sur la constitution physique et mécanique du Soleil. (Read Feb. 5.)	'C. R.' xcvi. 355–361.
" . . .	Sur une objection de M. Tacchini relative à la théorie du Soleil dans les 'Memorie dei Spettroscopisti italiani.' (Read March 26.)	" xcvi. 811–816.
J. Maurer . .	Sur la théorie de l'absorption atmosphérique de la radiation solaire.	'Arch. de Genève' [3] ix. 374–391.
R. T. Glazebrook .	On Curved Diffraction-gratings. (Read April 14.)	'Proc. Phys. Soc.' v. 243–253; 'Phil. Mag.' [5] xv. 414–423; 'Am. J.' [3] xxvi. 67 (Abs.); 'Beiblätter,' viii. 34 (Abs.); 'J. de Phys.' [2] iii. 152–154 (Abs.)
L. Lorenz . .	Theorie der Dispersion . . .	'Ann. Phys. u. Chem.' N.F. xx. 1–21.
H. A. Rowland .	On Concave Gratings for Optical Purposes.	'Am. J.' [3] xxvi. 87–98; 'Phil. Mag.' [5] xvi. 197–210; 'Beiblätter,' vii. 862–863 (Abs.); 'Zeitschr. f. Instrumentenkunde,' iv. 135–136 (Abs.); 'J. de Phys.' [2] iii. 184–185 (Abs.)
" . .	On Mr. Glazebrook's Paper on the Aberration of Concave Gratings.	'Am. J.' [3] xxvi. 214; 'Phil. Mag.' [5] xvi. 210; 'Beiblätter,' viii. 34 (Abs.); 'J. de Phys.' [2] iii. 184–185 (Abs.)
C. E. de Klercker .	Recherches sur la dispersion de la lumière. (Read Sept. 24.)	'C. R.' xcvii. 707–708 (Abs.)
R. T. Glazebrook .	On Curved Diffraction-gratings; II.	'Phil. Mag.' [5] xvi. 377–381; 'Beiblätter,' viii. 34 (Abs.); 'J. de Phys.' [2] iii. 152–154 (Abs.)
A. Sokoloff . .	Sur la théorie des réseaux courbes. (In Russian.)	'J. soc. phys.-chim. russe,' xv. 293–305.

1884.

K. Kraiewitsch .	Nouvelles démonstrations des conditions du minimum de déviation d'un rayon dans le prisme. (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 8–13.
Wolkoff . . .	Notes à propos de l'article de M. Kraiewitsch sur le minimum de déviation des rayons dans le prisme. (In Russian.)	'J. soc. phys.-chim. russe.' xvi. 174.
K. Kraiewitsch .	Réponse à M. Wolkoff. (In Russian.)	'J. soc. phys.-chim. russe,' xvi. 269–271.
W. Voigt . . .	Ueber die Theorie der Dispersion und Absorption, speciell über die optischen Eigenschaften des festen Fuchsins. (June 1884.)	'Göttinger Nachr.' 1884, 262–283.

Report of the Committee, consisting of Professor Sir H. E. ROSCOE, Mr. J. N. LOCKYER, Professors DEWAR, WOLCOTT GIBBS, LIVEING, SCHUSTER, *and* W. N. HARTLEY, Captain ABNEY, *and* Dr. MARSHALL WATTS (*Secretary*), *appointed for the purpose of preparing a new series of Wave-length Tables of the Spectra of the Elements.*

IN the following tables are brought together the chief measurements of the wave-lengths of the bright lines constituting the spectra of the elements, and of certain compounds, so far as they are known to the Committee or have proved accessible. The measurements are given in ten-millionths of a millimetre (or tenth-metres), and are based upon the measurements of the Fraunhofer lines by Ångström for the visible rays, and the extension of the same series of measurements into the ultra-violet portion of the spectrum made by Cornu and other observers. It will be well to bring together here these fundamental values of wave-length of the chief solar lines. The small corrections indicated at page 29 of Ångström's Memoir, 'Le Spectre Normal du Soleil,' have been applied to his numbers—but they are uncorrected for the dispersion of air. Hence the numbers in the tables represent wave-lengths in air of 760^{mm} pressure at Upsala, and 16° C. temperature. The numbers taken from Thalén's 'Détermination des Longeurs d'Onde des Raies Métalliques' in the same way have had applied to them the necessary small corrections to bring them into harmony with the numbers finally adopted by Ångström as 'Valeurs définitives' (pp. 25 and 31–32).

FRAUNHOFER LINES

A	7604·0		L (Fe)	3819·8	
B	6867·0		M (Fe)	3727·0	
C (H)	6562·1		N (Fe)	3580·5	
D (Na) . 5892·12	5895·13		O (Fe, double)	3439·8	
	5889·12		P (Fe & Ti)	3359·2	
E (Ca & Fe)	5269·13		Q (Fe)	3284·9	
b_1 (Mg)	5183·10		R (Fe & Ca)	3179·0	
b_2 (Mg)	5172·16		r (Fe, double)	3144·3	
b_3 (Ni & Fe)	5168·48		S_1 (Ni, double)	3100·6	3100·0
b_4 (Mg & Fe)	5166·88		S_2 (Fe, triple)	3099·5	
F (H)	4860·72		s (Fe)	3046·4	
G (Fe)	4307·25		T (Fe, double)	3019·7	
H (Ca)	3968·1		t (Fe)	2994·3	
K (Ca)	3933·0		U (Fe)	2947·8	

The following symbols are employed in the tables to indicate the character of the lines:

s denotes that the line is sharply defined.
n denotes that the line is ill-defined or nebulous.
b denotes a band, the position of the brightest part being given.
b' denotes a band sharply defined on the least refracted side, and fading away towards the blue.
b denotes a band sharply defined on its more refracted side, and fading away towards the red.
c denotes that the line is continuous.
d denotes that the line is discontinuous, or a 'short' line.
r denotes that the line is frequently 'reversed.'
A number within parentheses, thus: (3091·9), means that while a line in this position has been observed, no new measurement of wave-length was made—the wave-length being quoted from another observer.

The intensities of the lines are expressed upon an ascending scale from 1 to 10; 1 being the feeblest and 10 the brightest.

WAVE-LENGTH TABLES OF THE SPECTRA OF THE ELEMENTS.

AIR.

Spark Spectrum or Elementary Line Spectrum					Intensity and Character
Lecoq de Boisbaudran	Huggins	Kirchhoff	Thalén	Hartley and Adeney	
6606	6602N	6603·1	6602·3		4s
6560H	6562H	6562·1	6562·1		7s
6482	6482N	6479·9	6479·8		5s
6171	6171NO	6171·1	6170·7		5s
	5950N.	5949·6	5949·2		4s
δ5935	5942N	5940·2	5941·6		10n
	5930N	5931·9	5932·1		10n
	5925N	5929·2	5929·6		4s
	5768N		5767·1		4s
	5746N		5745·1		4s
	5726N				1s
5711	5709N	5710·8	5711·1		4s
	5686N	5685·6	5685·6		4s
β 5685	5680N	5678·1	5678·1		10n
	5675N	5674·6	5674·6		6s
5666	5668N	5666·6	5666·1		10n
	5550N		5549·1		4s
	5541N		5541·1		6s
5534	5534N		5534·1		8n
	5528N		5530·1		6s
	5524N				1s
5492	5495N		5495·1		7n
	5479N		5479·1		6s
	5462N		5461·6		4s
5454	5453N		5453·1		3s
	5350N		5351·1		2s
	5338N		5339·6		2s
	5319N		5320·1		2s
	5205O				1s
	5190O		5189·6		4s
γ5177	5179N		5184·6		5n
	5176N		5178·1		4s
	5172N		5172·1		2s
	5163O				4s
	5071N				2s
5044	5045N	5043·3	5045·1		8s
	5024N		5025·1		8s
	5016N		5016·1		6s
	5010N		5010·2		6s
	5007N		5006·7		4s
α5003	5003N	5004·6	5005·2		10n
	4999N	5000·6	5002·2		10n
	4993N		4993·7		6s
	4986N		4987·2		6s
	4953O				3s
4941	4943O		4941·2		3n
	4831N				1s
	4925O		4924·5		4s
	4907O		4906·1		4s
	4895N		4895·6		4s
	4892O				4s

AIR—*continued.*

Spark Spectrum or Elementary Line Spectrum					Intensity and Character
Lecoq de Boisbaudran	Huggins	Kirchhoff	Thalén	Hartley and Adeney	
	4880N				1s
	4872O				3s
	4866N				1s
	4858N				4s
	4853O				2s
	4849N				4s
4805	4804N		4803·1		8s
4788	4788N		4788·1		8s
	4781N		4779·1		10s
			4712·2		4s
4706	4705O		4706·7		7s
	4699O		4698·2		8s
	4677O		4675·2	4674·2	3s
	4662O		4661·7	4660·2	3s
ε 4648	4648O	4648·9	4649·2	4647·2	6s
	4640NO	4641·4	4642·2	4641·2	7s
			4640·2		6s
ε 4633	4629N	4629·8	4630·7	4628·9	8s
	4621N	4620·7	4621·2	4619·9	5s
	4613N	4612·8	4613·2	4612·3	5s
ε 4665	4608N	4606·6	4606·7	4605·6	6s
	4600N	4601·0	4601·2	4600·1	6s
	4596O		4596·1	4595·0	4s
	4588O		4590·6	4589·3	4s
	4553N			4553·2	2b
				4543·4	2s
				4530·1	3b
	4533 N			4523·0	2n
	4506 N			4513·7	3s
				4506·6	3s
	4496N				1s
	4490N				1s
	4477N			4476·6	3s
	4467O			4466·1	3b
				4458·7	3s
ζ 4449	4448N	4446·3	4446·6	4446·0	7s
ζ 4434	4437 N		4432·1	4432·6	3b
	4422 N			4425·9	3n
ζ 4417	4416O		4418·1	4415·5	6s
	4414O		4414·1	4413·6	6s
				4402·6	2s
	4398N			4394·9	3s
				4386·3	1s
				4378·0	3s
	4364O		4368·1	4365·8	3s
				4356·4	1n
			4350·5	4350·5	4s
4347	4347ON		4347·5	4348·2	6s
			4346·0	4343·9	4s
			4333·0	4335·9	4s
				4330·8	2s
				4326·9	2s
				4324·6	2s
4318	4318O		4319·0	4318·7	6s
			4316·5	4316·2	5s

AIR—*continued*.

Spark Spectrum or Elementary Line Spectrum					Intensity and Character
Lecoq de Boisbaudran	Huggins	Kirchhoff	Thalén	Hartley and Adeney	
				4306·9	2n
				4302·0	2n
				4290·0	2n
	4278O			4275·3	2n
				4274·3	1s
				4265·4	1n
				4253·4	2s
4240	4238N			4240·6	6n
				4236·4	6n
			4230·0	4228·9	6n
				4222·6	2n
				4216·5	2n
	4206N			4206·3	2n
				4197·9	2n
	4190O		4189·5	4189·3	5s
	4183O		4184·5	4185·1	5s
	4170N			4176·8	4n
				4169·2	4n
			4155·0	4157·9	1n
	4149O		4149·0	4152·7	3s
	4142N		4137·0	4145·4	5s
	4130N			4132·5	5s
			4123·0	4123·7	4s
	4117O			4119·0	5s
				4110·9 ?	2s
	4101N			4104·3	5s
				4102·6	5s
	4094N			4096·5	5s
				4092·6	1s
				4084·8	2s
			4075·5	4075·1	6s
	4073O		4074·0		6n
			4071·5	4071·4	6s
	4069O		4069·5	4069·2	6s
				4063·5	1s
				4057·2	1s
	4038N		4040·1	4041·7	5n
				4034·4	4n
				4025·3	2s
	4000N		3995·1	3994·5	6s
				3988·5	1s
				3983·0	2s
				3972·5	6s
				3967·3	2s
				3954·8	6s
				3944·5	2n
				3939·2	4n
				3932·9	1n
				3929·0	1n
				3918·5	6s
				3911·7	4s
				3892·4	1s
				3881·9	4s
				3863·8	2s
				3856·2	3n
				3850·0	2s

AIR—*continued.*

Spark Spectrum or Elementary Line Spectrum — Hartley and Adeney	Intensity and Character	Spark Spectrum or Elementary Line Spectrum — Hartley and Adeney	Intensity and Character
3841·7	2n	3265·2	3s
3839·3	4n	3259·9	3s
3831·0	4s	3219·7	1s
3804·0	2s	3157·5	1s
3791·6	2s	3139·3	5s
3782·1	2s	3134·2	5s
3771·5	2s	3122·4	1s
3759·4	2s	3058·5	1s
3753·7	2s	3046·4	2s
3749·0	6s	3042·5	1s
3739·7	1s	3035·0	2s
3726·6	6s	3024·1	3s
3712·2	5s	3016·1	2s
3639·0	2s	3007·0	6s
3613·6	2s	2982·8	3s
3609·0	3s	2959·5	2s
3595·0	3s	2884·5	2s
3589·6	3s	2880·3	2s
3583·4	3s	2823·1	3n
3576·0	3s	2799·5	2s
3560·3	3n	2748·8	1s
3550·3?	1n	2733·2	2s
3545·2	3n	2710·0	2n
3514·3	1s	2598·4	1s
3509·0?	1s	2591·8	2s
3490·7	3s	2580·0	2s
3478·1	2s	2522·1	3n
3471·2	3s	2478·1	4s
3456·1	1s	2463·0	1n
3448·2	1s	2453·8	2s
3437·0	6s	2445·2	5s
3408·0	5s	2433·6	5s
3389·9	5s	2423·8	3n
3376·9	4s	2418·6	2s
3373·6	2s	2416·2	1s
3370·3	2s	2411·7	1s
3366·7	5s	2407·7	1s
3365·7	5s	2398·3	1s
3353·7	5s	2390·7	1s
3342·7	1n	2332·2	1n
3331·2	6s	2318·1	5n
3329·3	6s	2304·4	1s
3324·7	2s	2301·8	2s
3320·1	3s	2298·0	2s
3313·3	1s	2294·2	2s
3307·1	1s	2291·0	1s
3301·1	1s	2289·3	1s
3289·9	2n	2250·2	1n
3274·2	2n	2186·0	1n

NOTE.—All the air-lines are continuous.

Aluminium.

* Observed also by Lockyer.
† Not identified by Lockyer; the 'indices' attached to these numbers represent the comparative lengths of the lines as given by Lockyer. ‡ 3960·6 and 3943·0 Lockyer. § See Cadmium.

I. Spark Spectrum				II. Arc Spectrum	Intensity and Character	
Lecoq de Boisbaudran	Thalén	Kirchhoff	Cornu	Liveing and Dewar	I.	II.
	†6371·3				6sd	
	†6344·8				6sd	
6244	*6244·2(2)	6244·6		(6244·2)	8nc	
6233	*6234·2(2)	6233·8		(6234·2)	8nc	
	*5722·6(1)	5722·3			10sc	
	*5695·6(1)	5696·1			10sc	
5591	*5592·7(1)				4nc	
	*5056·6(1)				10nc	
Bands	*4662·2(1)	4662·1			10nc	
of Oxide	*4529·6(1)	Hartley and Adeney			6nc	
	*4511·1(1)	4511·0			6sd	
	*4478·6(2)	4477·2			6sd	
		4445·2			6sd	
3962	‡3961·1(4)	3960·9	3960·5	(3961·1)	9sc	r
3943	‡3943·1(4)	3943·4	3943·2	(3943·1)	9sc	r
	Liveing and Dewar	3713·4			6sd	
		3701·6			5sd	
	3605	3612·6			9sd	
	3598	3601·2			9sd	
	3585	3584·4			9sd	
		3091·9	3091·6	3091·5	9sc	r
		3081·2	3080·6	3080·5	9sc	r
		3065·0			5sd	
		3062·8			5sd	
		3058·5			5sd	
		3056·4			6sd	
		3053·6			5sd	
		3049·2			5sd	
		§2880·1			5sc	
		2815·3			9sd	
		2659·3		2659·8	5sd	8r
		2651·2		2652·0	5sd	8r
		2630·6			9nd	
		2574·1		2574·5	7sd	8r
		2566·9		2567·5	7sd	8r
				2378·4		8
		2373·3		2373·2	7nd	10r
		2372·0			7nd	
		2370·0			4sd	
		2367·2		2366·9	4sd	8
		2364·5			7nd	
				2268·7		8n
				2263·1		8n
				2257·3		8n
				2216·0		
				2210·0		8n
				2205·0		n
			2024·2			
			1988·1			
			1933·5			
			1928·7			
			1860·2			
			1852·2			

Note.—Becquerel has observed infra-red bands in the Arc Spectrum of Aluminium at 11280 and 13615.

Antimony.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Antimony Chloride solution.
† Observed also by Lockyer. ‡ 4710·9 Kirchhoff. § Not identified by Lockyer.
‖ See Tellurium. ¶ See Bismuth.

I. Spark Spectrum.			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.
7020				5	
6840				2	
6803				5	
6780				5	
6742				1	
6712				2	
6645				2	
6513				2	
6500				2	
6461				2	
6392				4	
6320				2	
6301	†6301·8(1)	6302·1		8sd	
6283				4	
6243	†6244·7(2)	6243·9		4sd	
6204	†6209·2(2)			4sd	
6189	†6193·5(2)			4sd	
6153	†6155·2(2)			4sd	
6125	†*6128·7(4)	6128·5		10sc	
6076	†*6078·2(4)	6074·7		10sc	
6050	†*6051·2(2)	6050·6		4sd	
6002	†*6003·7(4)	6002·7		10sc	
5982	†5979·7(2)	5976·4		4sd	
5920				1	
5912	†*5909·1(3)	5907·6		8nc	
5895	†5893·6(3)	5893·6		8nc	
5840				1	
5822				1	
5790	†*5791·6(3)			4nd	
5714				1	
5700				1	
5663				1	
5644				1	
5635	†*5638·1(2)	5639·8		8nc	
5629				1	
	†*5607·1(2)			2nd	
5565	†*5567·6(2)	5567·1		8nc	
5460	§*5463·6	5463·7		6nc	
5392				1	
5379	§*5379·2			6nc	
	§5371·6			2sd	
5352	§*5352·7			2nd	
5238	§*5241·7			6nd	
5219	§5208·2			2sd	
5177	§*5177·2			6nd	
5139	†*5141·2(2)			4nd	
5112	†*5112·7(2)			4nd	
5080				1sc	
5044				2sc	
5031	†*5036·1(2)			2nd	
4948	†*4948·7(2)			8nc	
4878	†*4877·7(2)			6nd	

ANTIMONY—*continued.*

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
4832	†4835·1(2)			4nd	
4787	†*4786·1(2)			4nd	
4768				2	
4757				2	
4735	†4734·6(2)			4nd	
4712	†*4711·1(2)	‡4714		5nd	
4693	†4691·2(2)	4692·5		4nd	
4622				1sc	
4600		4599·0		3sd	
4588	†4591·6(1)			6nc	
4506		4506·5		3sd	
4457		4457·0		3sd	
		4427·5		3sd	
4376		4375·0		3sd	
4349	†4352·0(1)	4351·5		7sd	
		4316·1		3sd	
4264	†4265·0(1)	4264·4		6sd	
4249				1sc	
		4218·5		3sd	
4193		4194·5		3sd	
		4170·0		2sd	
		4140·2		2sd	
		4132·8		2sd	
			4032·0		
		4026·0		2sd	
		3984·9		3sd	
		3968·4		2sd	
		{3964·1		2sd	
		{3960·3		2sd	
		3933·2		3sd	
		3907·5		2sd	
		3849·7		4sd	
		3840·2		4sd	
		3825·0		2sd	
		3771·6		2sd	
		3739·0		8sd	
		3722·4		4sc	
		3720·5		2sd	
		3686·0		5sd	
		3651·6		5sd	
		3637·5	3637·0	5sc	
		3629·4		5sd	
		3597·8		8nd	
		{3566·0		6nd	
		{3559·1		6nd	
		{3533·7		5sd	
		{3520·3		5sd	
		3504·6		6nd	
		3498·3		6nd	
		3473·9		6nd	
		3459·0		2sd	
		3451·1		2sd	
		3425·9		6nd	
		3414·7		2sd	
		3403·1		4sd	

ANTIMONY—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Liveing and Dewar	I.	II.
3397·9		4sd	
3382·0		4sc	
3336·4		8nd	
3303·2		6sd	
‖3279·7		4sc	
‖3273·0		6sc	
3267·6	3265·0	6sc	
‖3246·6		6sc	
3240·5		8nd	
3231·6	3230·8	6sc	
	3228·0		
3195·6		2sd	
3186·0		2sd	
3167·6		2sd	
3085·2		2sd	
3039·8		6nd	
3029·0	3028·0	6sd	
3023·7		4sd	
3021·1		5sd	
3010·4		5sd	
2979·8		6nd	
2965·2		6nd	
2921·6		4sd	
2912·7		6sd	
2890·3		6nd	
2878·3		4sd	
2877·1	2876·5	7sc	
2861·9		4sd	
2855·3		5sd	
2849·9		4sc	
2836·0		4sd	
2824·7		4sc	
2796·9		4sd	
2789·6		8nd	
2788·5		5sd	
2785·3		5sd	
2775·7		4sd	
‖2768·9		7sc	
2763·2		4sd	
2760·8		4sd	
2754·9		4sd	
2740·1		6sd	
2726·1		5sc	
2717·9		6sc	
2714·0		2sd	
2702·6		2sd	
2700·2		2sd	
2691·3		5sc	
2685·5		4sd	
2681·7		7sc	
2674·0		2sd	
2668·9		7sc	
2668·3		7nd	
2656·3		5nd	
¶2651·7		7sc	
2631·2		6sd	
2616·3		6sd	
2613·7		2sc	
2611·3		7sc	
2597·2	2597·5	9sc	
2589·4		8sd	
2572·7		5sc	
2570·1		5sd	
2566·7		5sd	
2564·6		6nc	
2557·4		2nd	
2556·6		2nd	
2553·3		4sc	
	2528·0		
2549·8		2sd	
2542·9		6sd	
2527·6		9sc	
2519·5		1sc	
2518·8		4nd	
2514·5		4nd	
2509·5		4sc	
2506·5		6sd	
2500·2		2nd	
2490·7		2sd	
2489·2		2sd	
2485·7		2sd	
2480·4		2sc	
¶2479·4		4sc	
2477·3		6sc	
2476·7		2nd	
‖2473·4		2sc	
2470·2		2nd	
2464·4		2nd	
2462·0		2nd	
2458·8		2nd	
2454·5		2nd	
2445·7		2nd	
2444·8		6sc	
‖2438·0		2sd	
2425·7	2426·0	4sc	
2423·0		2nd	
2421·5		4sc	
2410·3		2sd	
2408·3		2sd	
2405·3		4nd	
2403·8		2sd	
2399·9		2sd	
2395·3		4sd	
2383·2	2383·3	6sc	
2374·3		6sc	
‖2370·0		6sd	
2361·3		6nd	
2360·7		4sc	
2353·0		2sd	
2350·6		2sd	

ANTIMONY—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Liveing and Dewar	I.	II.	Hartley and Adeney	Liveing and Dewar	I.	II.
2334·2		4nd		2209·0		4nc	
2331·8		2nd		2203·8		2sd	
2329·7		2nd		2202·2		4sc	
2325·3		2nd		2200·3		2sd	
2322·1		2nd		2192·6		4sd	
2316·4	2313·0	4sd	10r	2191·6		4sd	
2311·8	2310·0	7sc		2189·3		2sd	
2306·8		5sc		2179·0		6nc	
2297·0		5sd		2175·8		6nc	
2294·0		5sc		2170·1		6sd	
2288·8		5sc		2159·4		2sc	
2280·8		2sd		2156·0		2sd	
2278·3		2sd		2148·8		2sd	
2277·1		2sd		2144·4		4nc	
2271·1		2sd		2142·0		2sc	
2263·5		6sc		2139·3		4sc	
2248·0		6sc		2135·7		4sd	
2243·5		6sc		2126·1		2sd	
2234·5		2ds		2122·5		2sd	
2231·3		2ds		2118·0		2sd	
2230·3		2ds		2110·4		2sd	
2229·0		2ds		2104·2		2sd	
2226·3		4nc		2096·4		2nc	
2223·5		2sd		2086·3		1sd	
2221·5		4nc		2075·3		1sd	
2218·7		4nd		2064·8		4nc	
2216·3		4sd		2050·5		2sd	
2211·3		2sd		2045·3		2sd	

ARSENIC.

Spark Spectrum				Intensity and Character
Huggins	Thalén	Kirchhoff	Huntingdon	
6404				1nc
6342				1nc
6252				1nc
6164	6169·7	6170·0		8sc
6131				1nc
6108	6110·2	6111·2		8nc
6078				2nc
6020	6021·7	6021·5	6023	4sd
			6013	?
			5853	?
5839				1nc
			5833	?
			5813	?
5781				1nc
			5743	?
5647	5651·1	5650·3	5653	8nc
5616				1nc

ARSENIC—*continued.*

Spark Spectrum				Intensity and Character
Huggins	Thalén	Kirchhoff	Huntingdon	
5590				1nc
5554	5558·1	5556·8	5563	8nc
5495	5498·1	5497·6	5498	6nc
5404				1nc
5384				1nc
5324	5331·1	5331·8	5323	6nc
5287				1nc
			5245	?
5229			5230	5nc
			5195	?
5162			5163	1nc
5104			5103	5nc
			5013	?
4983				2nc
			4941	?
4888				1nc
4732				1nc
	Hartley		4623	?
	and Adeney		4593	?
4551	4550·0			3nc
4537	4538·4			3nc
4497	4494·3		4493	8sd
	4474·0			8sd
4464	4466·3		4463	8sd
	4458·7			8sd
	4431·0			8sd
	4415·0			3sd
4369	4368·7			3sd
	4349·0			3sd
4335	4335·2			3sd
	4315·2		4313	3sd
	4307·0			3sd
	4244·0			3sd
	4229·3			3sd
	4207·3			3sd
	4197·7			5sd
	4188·9			3sd
	4120·0			3sd
	4081·8			5sd
	4064·3			3sd
	4036·0			8sd
	4007·0			3sd
	3985·0			2sd
	3948·5			6sd
	3930·7			6sd
	3921·6			8sd
	3824·5			8sd
	3800·7			2sd
	3784·4			6sd
	3772·0			2sd
	3671·2			3sd
	3622·4			2sd
	3591·9			3sd
	{ 3551·6			3sd
	{ 3545·8			3sd
	3510·8			2sd
	3471·1			3sd

Arsenic—*continued.*

Spark Spectrum Hartley and Adeney	Intensity and Character	Spark Spectrum Hartley and Adeney	Intensity and Character	Spark Spectrum Hartley and Adeney	Intensity and Character
3260·1	2sd	2779·5	10nc	2435·0	3nd
3256·2	3sd	2770·4	2sd	2432·5	3sc
3187·7	2sd	2744·1	10sc	2415·8	3nd
3181·7	2sd	2690·5	2sd	2403·4	3nd
3125·4	2sc	2677·0	2sd	2402·6	3nd
3119·2	8nc	2673·8	2sd	2381·0	8sc
3116·1	8nc	2669·5	2sd	2370·8	8nc
3107·7	2nd	2663·5	2sd	2369·7	8nc
3075·0	6sc	2651·5	2sd	2362·8	3sc
3057·3	8nc	2630·2	2sd	2350·1	10nc
3052·6	8nc	2611·2	2sd	2344·3	8sc
3032·2	8sc	2600·8	8nc	2320·7	3sc
3003·2	3sc	2597·1	3sc	2288·9	10nc
2990·2	6sc	2593·9	2sc	2279·0	2nd
2981·1	3nc	2576·0	2sd	2272·3	6sc
2958·7	10nd	2571·6	2sd	2267·5	3sd
2925·6	3sd	2559·5	3sd	2230·0	6nc
2898·2	8sc	2527·9	8sc	2207·0	3sd
2889·1	3sc	2526·0	8sc	2182·5	3sd
2884·2	3sc	2496·9	3sc	2176·8	3sd
2859·7	10sc	2491·9	8sc	2165·4	8nc
2843·6	2sd	2489·1	3sd	2156·7	8sd
2836·9	2sd	2464·1	3nc	2147·8	8sd
2829·8	8nc	2461·0	3nc	2144·5	8nc
2788·5	2sc	2456·2	8sc	2135·2	8nd
		2436·9	8sc	2112·2	8nd

Barium.

* Observed in the Spark Spectrum of Barium Chloride solution by Lecoq de Boisbaudran, who gives also the following lines :—5506, 5457, 5385, 5349, 5312, α5242, 5205, 5170, β5136, 5105, 5064, 4556.

† Observed by Lockyer—the 'indices' attached to these numbers, and to those in the fourth column, denote the comparative 'lengths' of the lines as given by Lockyer.

‡ See Iron. § See Strontium.

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Lockyer	Liveing and Dewar	I.	II.
6889					1sc	
6780					1sc	
6697					1sc	
6677				6677	1sc	
6589					1sc	
6523	†*6526·3(1)				6sd	
6499	†*6496·3(4)	6496·0		(6496·3)	10sc	r
	†6483·3(3)				6sd	
6452	†*6449·3(1)				6sd	
6344	†*6343·3(1)				6sd	
	†*6140·8(4)	6141·1			10sc	
6113	†*6110·1(3)	6111·1			6sc	
6064	†*6062·2(1)	6061·4			6sd	
6021	†*6018·2(1)	6018·4			6sd	
5998	†*5991·7(1)				6sd	
5973	†*5971·2(1)	5968·7			6sd	
5904	†5904·7(1)				2sd	

BARIUM—*continued.*

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Lockyer	Liveing and Dewar	I.	II.
5889					1sc	
5850	†*5852·6$^{(4)}$	5853·1			10sc	
5823	†*5827·1$^{(1)}$	5827·3			6sd	
	†5808·6$^{(1)}$				2sd	
	†*5803·6$^{(1)}$				2sd	
5774	†*5779·6$^{(3)}$	5780·0			6sc	
5744					1sc	
5538	†*5534·3$^{(4)}$	5534·2		(5534·3)	10sc	r
5518	†5518·5$^{(3)}$	5518·7		(5518·5)	4sc	r
5490					1sc	
	†5425·2$^{(3)}$	5424·3			6sc	
4934	†*4933·6$^{(4)}$	4933·3		(4933·6)	10nc	r
4898	†*4899·5$^{(4)}$	4890·2			8nc	
4727					1sc	
4690					1sc	
4553	†*4553·5$^{(4)}$	4553·1		(4553·1)	10nc	r
4524	†*4524·5$^{(4)}$	4524·4			6sc	
			4493·0$^{(1)}$			2n
			4488·0$^{(1)}$			2n
			4433·0$^{(1)}$			2
			4401·5$^{(2)}$			4
			4351·0$^{(4)}$			8
			4332·0$^{(2)}$			4
			§‡4325·0$^{(3)}$			6
			4323·0$^{(3)}$			6n
			4290·6$^{(3)}$			6
			4282·5$^{(5)}$			10
			4264·0$^{(3)}$			6n
			4241·5$^{(2)}$			4
			4239·0$^{(2)}$			4
			4224·0$^{(3)}$			6
4174	†4165·0$^{(3)}$		4165·5$^{(4)}$		8nc	8
			4131·5$^{(3)}$			6
4130	†*4130·5$^{(3)}$		4130·5$^{(5)}$		10nc	10
			4087·0$^{(1)}$			2n
			‡4084·0$^{(1)}$			2n
			4081·0$^{(1)}$			2n
			3996·2$^{(3)}$			6
			3995·0$^{(4)}$			8
			3992·7$^{(2)}$	3991·8		4
			3937·2$^{(1)}$			6
			‡3934·7$^{(3)}$			
			3909·2	3908·5		
				3891·0		
				3793·5		
				3660·7		
				3598·7		
				3592·8		
				3579·1		
				3544·0		
				3524·5		10r
				3499·2		
				3419·3		
				3375·6		
				3354·8		
				3347·7		
				3320·9		

BARIUM—*continued.*

II. Arc Spectrum Liveing and Dewar	Intensity and Character	II. Arc Spectrum Liveing and Dewar	Intensity and Character
3279·8		2647·0	
3261·0		2634·5	
3070·3		2596·7	
2785·1		2542·7	
2771·0		2347·0	8
2739·0		2335·0	10
2702·0		2304·5	8

BERYLLIUM.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Thalén	Kirchhoff	Lockyer	Cornu	I.	II.
4572·1	4571·9				
4488·6	4487·9				
		3904·7			
	Hartley & Adeney				
	3320·1			8s	
			3130·4		
			3130·1		
	3129·9			10n	
	2649·4			8s	
	2493·2			8s	
	2477·7			8s	

BISMUTH.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Bismuth Chloride solution.
† 4721 Mascart. ‡ See Antimony. § See Tellurium. ‖ See Arsenic.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
6808					
6590	6599·3			4sd	
6571					
6499	6492·8			6sc	
6125	*6129·2			8nc	
6057	6056·7			8nc	
6055	*6050·2			4sd	
6034	6038·7			4sd	
5980					
5972					
5862	5861·6			8nc	
5819	5816·1			6sd	
5717	*5716·6			8nc	
5656	5655·1			4sd	
5552	*5553·1			4sd	
5538					
5449	5450·1			8nc	
5394	5396·7			4sd	
5357					
5271	*5270·1			8nc	

BISMUTH—*continued.*

I. Spark Spectrum.			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
5208	*5208·2			10nc	
5199	5201·2			4nd	
5144	*5143·7			10nc	
5124	*5123·7			10nc	
5089	5090·1			2nd	
5078	5077·6			4nd	
4991	4993·1			10sc	
4970	*4970·1			2sd	
4915					
4907	4905·1			4sd	
4798	4796·7			4sd	
4752	4752·7			2sd	
4729	4730·1			2sd	
4723	†*4722·1	4724·5	(4722·1)	3sc	r
4705	4705·1	4707 0		3sd	
	4691·6			4sd	
4560	4560·1	4560·0		7sd	
4476		4477·0		3sd	
·4389		4391·0		3sd	
4338	4339·5	4339·4		5sd	
4329	4327·5	4328·7		5sd	
4301	*4302·0	4301·5		9b'd	
		4271·3		7sd	
4259	*4259·5	4259·2		9sd	
4120	*4119·0	4121·2	(4119·0)	7sc	
4080	4081·5	4079·0		7sd	
		3863·7		7sd	
		3848·5		5sd	
		3845·4		3sd	
		3815·9		3sd	
		3810·5		5sd	
		3792·7		9nc	
		3780·6		5sd	
		3757·0		7sd	
		3732·7		3sd	
		3711·0		3sd	
		3704·0		5sd	
		3695·3		9nd	
		3684·5		2sd	
		3653·9		7sd	
		3647·4		2sd	
		3631·9		3sd	
		3613·8		9nd	
		3595·7	3595·3	7sc	
		3541·5		7sd	
		3527·9		5sd	
		3517·9		2nd	
		3510·5	3510·4	7sc	
		3485·0		7nd	
		3473·0		7nd	
		3454·8		3sd	
		3450·7		7sd	
		3430·9		7sd	
		3396·7	3396·2	7sc	
		3393·2		3nd	
		§3381·9		3sd	
		3315·3		2sd	

BISMUTH—*continued*.

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Liveing and Dewar	I.	II.	Hartley and Adeney	Liveing and Dewar	I.	II.
3297·9		3sd		2663·6		1nd	
3287·4		3nd		‡2651·8		7sd	
§3279·9		3sc		2641·4		2nd	
3255·4		2nd		2628·3		3sd	
3236·8		3sd		2627·0		7sc	
3187·7		2nd			2593·0		
3170·0		2sd		2583·5		1sd	
3160·0		2sd		2581·5		3sc	
3130·8		2sd		2575·5		2nd	
3114·8		7nd		§2543·3		3nd	
3110·4		3sd		2531·9		3nd	
3075·7		5sc		§2529·7		3sd	
3067·1	3066·0	10b^r c	10r	2523·5	2524·0	7sc	
3041·3		3sd		2514·3	2515·4	3sc	
3038·0		7sd		2503·9		3nd	
3034·5		7sc		2500·6		2sd	
3023·8	3023·5	10sc		2499·1		2sc	
3009·0		3nd		2489·1		3nc	
3001·2	3000·0	2sd		‡2479·1		3sd	
2992·2	2996·0	7sc		2447·2	2448·0	3sc	
2988·1		8sc		2437·5	2435·5	3sd	
2982·9		3sc		2429·3	2431·0	2sc	
2973·4		2sd		2414·8		9nd	
2968·9		2sd		2412·7		2sd	
2951·0		3nd		2400·7	2400·8	7sc	10
2942·4		2sd		2378·0		2nd	
2937·5	2937·4	10sc		2368·0		7sc	
2931·4		3sd		2347·0		2nd	
2923·2		2sd		2331·8		2sd	
2917·5		3sd		2327·0		2brd	
2897·2	2897·0	10sc		2325·4		2sd	
2862·5	2862·0	5sc		2321·7		3sd	
2854·8		9nd		2317·4		2sd	
2846·1		5sd		2313·7		2nd	
§2840·1		3sd		2310·5		2nc	
2832·8		2sd		2301·3		3sc	
2822·2		5sd		2297·6		3sc	
2816·3		5sd		2294·1		3sc	
2808·4	2810·0	7sc		2291·6		1nd	
2805·4		2sd		2281·0		2sd	
2802·6		7sc		2276·9	2277·0	7sc	4r
2798·0	2799·0	3sc		2252·5		2nd	
2784·0		7sd		2250·5		3sd	
‖2779·3	2780·0	8sc		2247·0		3sd	
2773·5		3sd		⎧2231·4		9nc	
2772·5		3sd		⎩2229·1		9nc	
2766·3		7sd		2214·8		7sc	
2757·3		2sd		2203·3		7nc	
2746·0		3sd		2190·4		2nc	
2733·2		2sd		2187·0		7nc	
2729·3	2730·0	7sc		2176·6		1nd	
2727·1		2sd		2168·5		2nd	
2713·1		3nd		2144·3		3nd	
2695·6		7sc		2133·8		3nc	
2693·2		2nd		2109·8		3nc	
2679·5		2nd		2070·2		2nd	
2676·6		2nd		2058·2		2nc	

NOTE.—Becquerel has observed infra-red lines in the Arc Spectrum of Bismuth at 9730, 8370, 8250, and 7710.

Boron.

Spark Spectrum	Intensity and Character
Hartley	
3450·1	
2497 0	
2496·2	

Bromine.

* Double.

Line Spectrum		Intensity and Character	Line Spectrum		Intensity and Character
Salet	Plücker and Hittorf		Salet	Plücker and Hittorf	
6990		6	5185	5168	10
	6862	6	5165	5150	8
6630	6628	6		5122	2
6580	6576	6		5106	2
6555	6555	6		5092	4
α6356	6357	10	η5060	5054	6
β6165	6158	10		5035	6
	6151	2		5010	6
	6131	2		4990	6
	6128	2		4982	1
5880	5868	6		4960	2
γ5840*	5827	10		4945	2
	5824	2	θ4930	4932	8
	5792	1		4924	2
	5739	2		4868	1
δ5720	5722	6		4852	2
	5712	2		4847	1
	5696	6	μ 4815	4818	8
	5662	2		4807	2
	5626	2	4785	4787	10
	5622	2		4778	2
ε5600	5598	10		4771	6
	5566	1		4746	1
	5552	1		4736	1
5515	5515	8		4730	1
5500	5502	8	4720	4721	4
5495	5492	8	ν4705	4706	10
5450	5446	10		4695	2
	5436	10	4675	4680	10
5425	5428	1		4676	1
	5422	8		4644	1
	5391	1	4620	4625	10
	5383	1	4542	4543	4
5335	5326	10	4485		6
	5299	1	π4367	4365	10
5310	5292	10	4287	4288	2n
5275	5263	8	4230	4241	1n
5265	5250	8		4228	2
ζ 5240	5225	10	4180	4198	1n
	5220	1		4181	1
	5216	2		4142	1
	5187	1	ρ3980		
	5180	2			

Cadmium.

* Observed also by Huggins.
† Observed by Lecoq de Boisbaudran in the Flame Spectrum of Cadmium Chloride and Bromide.
‡ Undoubtedly an air-line. See 'Air'; Thalén 3995, Hartley and Adeney 3994·5.
§ Observed by Lecoq de Boisbaudran in the Spark Spectrum of Cadmium Chloride solution.
‖ Observed also by Lockyer in the Spectrum of the Spark between metallic poles: the 'indices' attached to these numbers denote the relative 'lengths' of the lines.
¶ Origin doubtful. ** See Aluminium. †† See Thallium. ‡‡ See Copper.

I. Spark Spectrum					II. Arc Spectrum	Intensity and Character	
Thalén	Kirchhoff	Mascart	Liveing and Dewar	Hartley and Adeney	Liveing and Dewar	I.	II.
	*6727·0						
*‖6466·3(1)	6466·1					6nc	
*‖§6438·3(2)	6438·5	6137·0	6437·7		(6438·3)	10sc	10scr
*‖6056·7(1)						2sd	
*‖6003·7(1)						2sd	
*‖5957·7(1)						2sd	
*‖5913·1(1)						2sd	
‖5790·1(1)						2sd	
‖5687·1(1)						4sd	
‖5489·1(1)						2sd	
‖5471·2(1)						4sd	
*‖§5378·2(3)	5378·8	5377·1	5378·0			10nc	
*‖§5337·7(3)	5337·6	5336·3	5337·4			10nc	
*‖5304·6(1)						2sd	
*‖§5153·2(1)						4sd	
*‖†§5085·1(4)	5084·3	5084·4	5085·3		(5085·1)	10sc	10scr
*‖†§4799·1(4)	4799·7	4798·6	4799·4	4799·0	(4799·1)	6sc	10scr
*‖†§4677·0(4)	4677·6	4676·5	4677·6	4676·7	(4677·0)	7sc	10scr
*‖§4415·6(4)	4415·2	4414·5	4415·0	4414·5	(4415·6)	5sc	6sc
				4215·3		2sd	
	Cornu			4158·0		2sd	
				4141·0		2sd	
				4127·4		2sd	
				4115·2		2sd	
		‡3985·6		3987·6		2sd	
				3976·3		4sd	
				3974·5		4sd	
				3940·0		4sd	
				3851·0		2sd	
				3810·0		2sd	
				¶3682·6		2sc	
	{3611·7	3607·5	{3612·2	{3611·8		9nc	
	{3609·0		{3609·8	{3609·6		10nc	
				3535·0		4sd	
				3498·2		4nd	
	{3466·5	3464·5	{3467·0	{3466·8		8nc	
	{3465·5		{3465·6	{3465·4		10nc	
	3401·5	3403·0	3403·1	3402·9		10nc	
				{3384·7		4sd	
		3287·5		{3285·3		2sd	
				{3282·9		4sd	
				3276·4		4sd	
				3264·1		4sd	
	{3258		{3260·5	{3260·2		7sc	
	{3248		{3252·1	{3251·8		5sc	
	{3247		{3249·8	{3249·5		7sc	
				3233·6		2sd	
				{3222·6		2sd	
				{3219·9		2sd	

CADMIUM—*continued.*

I. Spark Spectrum					II. Arc Spectrum	Intensity and Character	
Thalén	Cornu	Mascart	Liveing and Dewar	Hartley and Adeney	Liveing and Dewar	I.	II.
				3216·0		4sd	
				3211·8		2sd	
				3209·0		4sd	
				3200·6		2sd	
				{3196·8		4sd	
				{3194·9		4sd	
				{3185·1		7sd	
				{3181·5		2sd	
				{3177·9		2sd	
				{3176·1		2sd	
				3172·9		7sd	
				3161·0		7sd	
				3156·0		4sd	
				3152·7		2sd	
				3132·5		5sc	
				3129·6		7sd	
				{3123·6		4sd	
				{3120·9		4sd	
				{3117·8		6sd	
				3112·0		4sd	
				{3095·0		7sd	
				{3090·5		2sd	
				{3087·7		2sd	
				{3084·3		7sd	
				3080·2		4sc	
				{3076·7		4sd	
				{3073·2		2sd	
				{3067·8		6sd	
				{3064·0		7sd	
				{3058·4		6sd	
				{3052·3		6sd	
				{3048·2		6sd	
				3034 9		2sd	
				3023·8		2sd	
				{3016·1		4sd	
				{3013·8		2sd	
				3002·5		2sd	
				2994·8		4sd	
				2986·1		4sd	
				2979·9		7sc	
				2970·2		4sd	
				2964·5		2sd	
				{2951·4		2sd	
				{2947·1		6sd	
				2909·9		4sd	
				**2880·1		7sc	
				2868·0		4sc	
				2836·1		7sc	
				2833 0		2sd	
				2832 3		2sc	
				2807·3		2sd	
				2804·0		4sd	
				2779·8		2sd	
				2774·5		2sc	
				2766·5		4sd	

CADMIUM—*continued.*

I. Spark Spectrum					II. Arc Spectrum	Intensity and Character	
Thalén	Cornu	Mascart	Liveing and Dewar	Hartley and Adeney	Liveing and Dewar	I.	II.
				2763·1		4sc	
	2747·7	2743·4		2747·7		9nc	
				2726·9		4sd	
				2706·0		2sd	
				2677·2		4sc	
				2658·5		1sd	
				2649·4		1sd	
				2645·4		1sd	
				2639·7		1sd	
				2639·5		4sc	
				2635·3		1sd	
				2632·7		1sd	
				2632·3		1sc	
				2630·2		1sd	
				2629·1		1sc	
				2624·8		1sd	
				2618·0		4sd	
				2614·0		2sc	
				2611·0		1sd	
				2600·8		1sd	
				2598·8		1sd	
				2595·3		1sd	
				2592·0		1sd	
				2587·8		1sd	
				2585·0		1sd	
	2572·3	2574·2	2572·6	2572·2		9nc	
				2563·2		1sd	
				2557·4		1sd	
				2555·0		1sd	
				††2551·6		4sd	
				2547·2		1sd	
				2544 5		2sc	
				2499·6		4sd	
				2488·2		4sd	
				2469·3		6sd	
				2418·5		4sd	
				2377·3		2sd	
				2376·6		2sd	
				2329·5		7sc	
	2321·8		2320·9	2321·6		9nc	
	2313·5	2318·3	2312·8	2313·6		10nc	
			2306·6	2307·0		8sc	
	2288·5			2288·9		9nc	
				2268·6		4sd	
	2265·5	2265·6	2264·6	‡‡2265·9		9nc	
				2249·2		4sd	
				2241·4		6sd	
				2227·0		4sd	
				2206·2		4sc	
	2194·5	2217·1	2194·3	2196·4		8nc	
	2144·1			2146·8		8nc	
				2111·5		2nd	

Cæsium.

† Probably due to Lithium.—Liveing and Dewar, *Proc. Roy. Soc.* Feb. 27, 1879.

I. FlameSpectrum	II. Spark Spectrum		III. Arc Spectrum	Intensity and Character		
Lecoq de Boisbaudran	Thalén	Lockyer	Liveing and Dewar	I.	II.	III.
6975				2s		
ε 6723				5s		
6602				1n		
6465				1n		
6361				3s		
γ 6219				7s		
δ 6007				6s		
			5990			
η 5850				4s		
ζ {5662				5s		
ζ {5637				5s		
5572				2n		
θ {5501				4n		
θ {5464				4n		
5410				3n		
5345				2n		
5310				1n		
5257				1n		
	†4971·7				10nc	
β 4597		4592·2		9s		
α 4560		4554·9	4555·0	10s		r

Calcium.

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of Calcium Chloride solution.
† The numbers attached as 'indices' in this column denote the comparative 'lengths' of the lines.
‡ 4226 Mascart. § Origin doubtful—probably Iron lines. ‖ Compare Titanium.
** Compare Chromium. †† See Strontium.

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Thalén	Lockyer	I.	II.
			6725·9			
6710		(6716·2)	6716·2			
6498	6498·3	6498·2	6498·3		8sc	
6492	6492·4	(6492·4)	6492·4		10sc	
6468	6468·8	6468·9	6468·8		8sc	
6458	*6462·0	(6462·0)	6462·0		10sc	
6445	6449·3	6449·7	6449·3		8sc	
6434	*6438·5	(6438·5)	6438·5		10sc	
6352						
6336						
6311						
		6206·7				
		6193·7				
		6177·2				
6163	6168·4	6168·8			10sc	
6154	6161·4	(6161·4)			10sc	r
6116	*6121·4	6120·9	6121·4		10sc	r

CALCIUM—*continued.*

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Thalén	Lockyer	I.	II.
	6101·9	6102·1	6101·9		8sc	
6093						
6087						
6060						
6002		6003·1				
5986						
5854	*5856·6	5857·3	5856·6		6sc	
5600	5601·8	(5601·8)	5601·8		4sd	
5598	5600·3	5600·2	5600·3		6sd	
5594	5597·4	5597·2	5597·4		6sd	
5591	5593·6	5593·4	5593·6		8sc	
5588	5589·1	5588·9	5589·1		4sd	
5587	*5587·7	5587·2	5587·7		10sc	
5581	5580·9	5580·9	5580·9		4sd	r
5509						
5348	*5348·8	5347·8	5348·8		8sc	
E5269	*5269·6	5269.7	5269·6		8sc	
5264	5264·7	(5264·8)	5264·7		6sc	
	5263·5	(5263·5)	5263·5		4sd	
5261	5261·3	5261·7	5261·3		2sc	
5258	5261·0	5261·2	5261·0		2sc	
5187	*5188·4	5188·3	5188·4		6sc	r
5040	*5041·3	5041·1	5041·3		8sc	
5021						
4877	*4877·6	4878·0	4877·6		6sc	r
	4848·2		4848·1		4sd	
	4831·9				2sd	
	4811·7		4811·7		4sd	
	4607·7		4607·7		4sd	
4584	*4585·5		4585·5		4sd	r
4581	4580·9		4580·9		4sd	r
4578	4578·4		4578·4		4sd	r
	‖4535·6		4535·6		2sd	
	‖4534·3		4534·3		2sd	
	‖4532·2		4532·2		2sd	
	4455·3				2sc	
4454	*4454·1	4455·0	4454·1	†4454·2(4)	10sc	8 r
	4435·4				2sc	
4434	*4434·6	4435·2	4434·6	4434·5(4)	10sc	8 r
4424	*4425·1	(4425·2)	4425·1	4425·0(4)	10sc	6 r
		4418·9				
	§4407·7		4407·7		2sd	
	4407·1		4407·1		2nd	
	4405·8		4405·8		2sd	
	4393·0		4393·0		4sd	
	4389·4		4389·4		4sd	
	4384·7		4384·7		4sd	
	§4379·1		4379·1		4sd	
				4354·0(2)		4n
4318	*4318·0	4318·6	4318·0	4318·0(3)	8sc	6 r
G4306	*4306·5	4306·9	4306·5	4306·5(4)	6sd	6 r
4302	*4302·3	4301·6	4302·3	4302·0(3)	10sc	6 r
4298	4298·5	4298·8	4298·5	4298·5(3)	6sd	6 r
4288	*4289·4		4289·4	4289·4(3)	8sc	6 r
4282	*4282·5		4282·5	4282·4(3)	8sc	6 r

CALCIUM—*continued.*

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Liveing and Dewar	Lockyer	I.	II.
	**4274·5				2sd	
	§4271·5				2sd	
	**4253·9				2sd	
	§4249·8				4sd	
	4247·5				2sd	
	4237·5			4237·5(1)	2sd	2n
	§4233·0				2sd	
4227	‡4226·3			4226·3(5)	12nc	10 r
	††4215·3				8nc	
	4192·5				2sd	
	4188·5				4sd	
	§4143·0				4sd	
	§4131·5				4sd	
	4098·0			4097·5(2)	2sd	4n
	4095·5			4093·3(1)	2sd	2n r
	4091·8			4091·8(1)	2sd	2n
	††4077·0				6sc	
				3972·8(2)		4
3969	H_1*3968·1		3967·7	3967·4(5)	10nc	10s r
			3972·3	3956·0(1)		2s
			3956·0			
			3947·9	3947·8		
	H_2*3933·0		3933·0	3932·7(5)	10nc	10s r
				Cornu		
			3736·4	3736·5		
			3705·5	3705·5		
			3644·0			10 r
			3631·0			10 r
			3623·5			10 r
			3486·5			s
			3474·5			s
			3468·0			s
			3359·5			10
			3347·5			10
			3342·0			10
			3285·0			s
			3273·5			s
			3268·5			s
			3224·5			n
			3213·0			n
			3208·0			n
			3181·0	3181·1		
			3179·0	3179·0		
				3168·5		
			3158·8	3158·8		
			3151·0			2n
			3141·0			2n
			3136·0			2n
			3117·5			2n
			3108·0			2n
			2398·0			2n

Becquerel has observed infra-red bands from 8880 to 8830 and from 8760 to 8580 in the Arc Spectrum of Calcium.

Carbon.

* Observed also by Morren. † Observed also by Salet. ‡ Observed also by Plücker and Hittorf.
|| Observed in the Hydrocarbon Flame by Lecoq de Boisbaudran, who, however, gives the yellowish-green band as 5629.
¶ Observed in the Arc by Liveing and Dewar. ** Double. †† Triple.
‡‡ 3905·0 Lockyer. §§ 4266·3 Hartley and Adeney.

I. Band Spectrum			II. Line Spectrum		Intensity and Character	
Watts	Ångström and Thalén	Piazzi-Smyth	Watts	Ångström and Thalén	I.	II.
			6578	6583·0		10s
			6562	6577·5		12s
*‡†6190	6187·3	6183·4			$3b^r$	
			6165			$4b^r$
*‡†6110	6119·0	6116·0			$4b^r$	
			6095			4s
*‡†6050	6056·3	6054·2			$3b^r$	
*‡5990	6000·8	5999·7			$2b^r$	
*‡5955	5953·5	5955·6			$1b^r$	
			**5954			1s
		†‡5918·8			$1b^r$	
			**5855			
			5688	5694·1		6s
			5652	5660·9		6s
			5640	5646·5		8s
			**5635	5638·6		2s
*‡†‖5634·7	α5633·0	5636·1			$8b^r$	
	?					
	5604·0				$3b^r$	
	5602·0				$3b^r$	
	5600·0				$3b^r$	
	5597·5				$2b^r$	
	5594·5				$2b^r$	
	5592·0				$1b^r$	
	5589·0				$1b^r$	
	5585·5				$0·5b^r$	
*‡†‖5585·5	β5583·0	5585·5			$7b^r$	
	5580·4				$7b^r$	
	5577·2				$6b^r$	
	5574·3				$6b^r$	
	5570·9				$5b^r$	
	5568·3				$5b^r$	
	5564·8				$4b^r$	
	5561·4				$3b^r$	
	5557·6				$3b^r$	
	5553·5				$2b^r$	
	5549·8				$2b^r$	
	5546·1				$1b^r$	
	5542·3				$1b^r$	
*‡†‖5542·3	γ5538·0	5542·1			$3b^r$	
	?	5539·3			$2b^r$	
		5536·9			$1b^r$	
	5534·5	5534·1			$1b^r$	
	5530·6	5530·4			$0·05b^r$	
	5526·7	5527·0			$0·05b^r$	
	5522·3	5525·0			$0·05b^r$	
	5517·7	5521·4			$0·05b^r$	
	5513·6	5517·8			$0·05b^r$	
	5509·5	5513·3			$0·05b^r$	
	5504·3	5508·1			$0·05b^r$	

CARBON—*continued.*

I. Band Spectrum			II. Line Spectrum		Intensity and Character	
Watts	Ångström and Thalén	Piazzi-Smyth	Watts	Ångström and Thalén	I.	II.
*‡†‖5503·5	δ5500·0	5492·8			2b^r	
	5496·0				1b^r	
	5491·5				0·05b^r	
	5486·0				0·05b^r	
	5479·5				0·03b^r	
	5476·0				0·03b^r	
	5471·0				0·03b^r	
*‡†5478·4	ε5466·0	5473·0			2b^r	
	5461·0				0·1b^r	
	5455·5				0·05b^r	
	5450·0				0·03b^r	
	5444·5				0·02b^r	
*‡5440	?	5448·8			1b^r	
*‡5425		5434·8 } 5423·8 }	**5426		0·5b^r	4s
			††5385	5379·0		2s
			5306			4s
*‡†‖5165·5	α5164·0	5165·3			10b^r	
	?		{ 5152	5150·5		5s
			{ 5140	5144·2		6s
	5144·0				5b^r	
	5142·5				4b^r	
	5141·0				3b^r	
	5139·2				3b^r	
	5137·3				2b^r	
	5135·5				2b^r	
	5133·8				1b^r	
				5133 0		3s
	5132·0					
	5129·7				1b^r	
*‡†‖5130·4	β5128·0	5129·8			5b^r	
		5128·3			4b^r	
		5126·8			3b^r	
		5125·1			2b^r	
		5123·6			1b^r	
	?	5122 2			0·3b^r	
		5120·7			0·4b^r	
		5118·9			0·3b^r	
		5117·1			0·2b^r	
		5115·6			0·1b^r	
		5114·1			0·1b^r	
		5112·5			0·1b^r	
		5111·0			0·1b^r	
	5106·3	5108·5			0·1b^r	
	5103·0	5105·7			0·1b^r	
	5100 0	5103·1			0·1b^r	
*‡†‖5100·0	γ5097·7	5100·0			3b^r	
		5098·1			1b^r	
	5095·5	5095·0			0·3b^r	
	5092·1	5092·3			0·3b^r	
	5089·3	5089·4			0·1b^r	
	5085·9	5086·3			0·1b^r	
		5082·0			0·1b^r	
‡†5082	{ 5082·4 { 5079·2	5079·5			1b^r	

CARBON—*continued.*

I. Band Spectrum			II. Line Spectrum		Intensity and Character	
Watts	Ångström and Thalén	Piazzi-Smyth	Watts	Ångström and Thalén	I.	II.
		5076·9			0·2b^r	
	5076·0	5074·6			0·1b^r	
	5072·7	5071·9			0·1b^r	
	5069·4	5069·0			0·3b^r	
	5066 5	5066·5			0·3b^r	
			††5065			3b^r
	5062·8	5063·0			0·05b^r	
	5059·5	5058·6			0·05b^r	
	5055·6	5055·6			0·1b^r	
	5052·2	5051·9			0·1b^r	
	5048·5	5048·2			0·05b^r	
	5044·7	5043·8			0·05b^r	
	5040·2	5039·8			0·1b^r	
	5036·7	5036·4			0·1b^r	
	5033·0	5032·8			0·03b^r	
	5029 0	5028·0			0·03b^r	
	5024·5	5023·6			0·03b^r	
	5021·5	5019·0			0·03b^r	
	5016·7	5014·7			0·03b^r	
	5012·5	5009·8			0·03b^r	
	5008·5				0·05	
	5004·5				0·05	
	5000·0				0·05	
	4996·0				0·05	
	4991·5				0·05	
	4987·5				0·05	
	4983·0				0·05	
	4978·0				0·05	
	4973·5				0·05	
	4969·0		4969		0·05	2b^r
	4964·0				0·05	
	?		**4960			1b^r
			4947			6s
			4927			5s
			4911			4s
			4900			3s
			4874			1s
			**4860			1s
*‡†‖4739 8	4736·0	4739·6			4b^r	
*‡†4717·2	4714·0	4717·7			3b^r	
			**4730			8s
*‡†4698·4	4697·0	4700·2			2b^r	
			4696			8s
*‡†4684·2	4682·0	4687·3			1b^r	
*‡†‖4677		4680 2			1b^r	
			4674			1s
			4656			1s
			4646			10s
			4637			10s
			4632			8s
			4590			4s
			4585			4s
			4417			6s
		4382·3			0·5b	
		4373·2			1b	

CARBON—*continued.*

I. Band Spectrum			II. Line Spectrum		Intensity and Character	
Watts	Ångström and Thalén	Piazzi-Smyth	Watts	Ångström and Thalén	I.	II.
		4368·7	4368		2b	2b^v
		4364·2			1b	
		4359·7			0·5b	
		4356·7			0·3b	
			4350			2b^r
		4334·4			1s	
			**4320			2s
*‖‡4313	4311·0	4316·7			5b^r	
?		4308·7			3b^r	
		4305·7			2b^r	
		4302·8			3b^r	
		4299·2			2b^r	
		4295·5			2b^r	
‡4290		4292·0			1b^r	
‡4285		4288·3			1b^r	
‡4279		4281·8			1b^r	
‡4274		4277·8			1b^r	
‡4268		4273·9			1b^r	
‡4261		4268·9	4272	§§4266·0	0·5b^r	10n
‡4256		4263·1			0·5b^r	
‡4249		4256·0			0·5b^r	
‡4243		4248·1			0·3b^r	
‡4239		4241·0			0·3b^r	
‡4232		4234·0			0·2b^r	
			4196			4s
			4192			4s
			4141			2s
			4130			2s
			4089			2s
			Liveing and Dewar	Hartley and Adeney		
			3919·3	‡‡3919·5		8sd
				3881·9		3sd
			3876·5	3875·7		5sd
				3870·7		5sd
				3589·9		5sd
				3584·8		5sd
				3583·3		5sd
				3167·7		4sd
				3166·0		4sd
			2995·0	2993·1		4b^{r}d
			2968·0	2967·3		3sd
			2837·2	2836·7		8sd
			2836·3	2835·9		8sd
			2746·5	2746·6		6nd
			2733·2			1n
			2740·7	2640·0		4sd
			2511·9	2511·6		7sd
			2509·0	2508·7		7sd
			¶2478·3	2478·3		6sd
			2296·5	2297·7		7nd

Cerium.

I. Spark Spectrum		Intensity and Character	I. Spark Spectrum		Intensity and Character
Kirchhoff	Thalén		Kirchhoff	Thalén	
	5654·1	2sd	4561·8	4562·1	10sc
5636·3		1sc	4560·6	4560·6	8nc
	5600·2	2sd	4539·1	4539·6	8nc
5563·5	5564·2	2sd	4527·4	4527·6	8nc
5555·1			4526·5	4526·6	10nd
	5511·2	8sc	4523·1	4523·1	8sc
5471·8	5472·2	6sd		4486·1	2sd
5466·8	5467·2	4sd		4482·6	2sd
5463·5	5463·2	2sd		4479·1	2sd
5409·9	5408·7	8sc	4471·2	4471·6	8nc
5392·4	5392·7	8sc		4467·1	2sc
5352·6	5352·2	10sc		4462·5	2sc
5330·0	5330·2	6sd	4460·6	4459·6	10nc
5273·4	5273·2	10sc		4448·6	6nc
5230·6		1n		4443·6	6sc
5229·5		3s		4428·1	8sc
5191·0	5190·7	4sd		4419·1	8sc
5186·4	5187·2	6sd		4410·1	2sd
	5161·2	2sd		4398·1	2sd
5146·6		1sc	4390·3	4391·5	8sc
5116·1		1sc	4385·2	4385·5	8sc
5078·9	5079·1	6sc	4381·9	4382·0	8sc
5075·3	5072·2	4sd		4365·0	2sd
4970·7	4970·2	2sd		4296·0	10nc
4882·1		1s		4289·0	10nc
4735·3		1s		4185·5	6nd
4712·8	4713·6	8nc		4165·0	4nd
4627·5	4628·2	10sc		4149·0	4nd
	4624·2	2sd		4136·5	4sd
	4605·7	2sd		4132·5	4sd
4594·0	4594·1	6sc	Lockyer	4127·0	2sd
	4582·6	2sd		4124·0	2sd
	4578·6	2sd	4012·0		
4572·5	4572·6	10sc	3928·7		
	4564·6	2sd			

Lockyer has observed the following lines in the Arc Spectrum of Cerium between the wave-lengths 4000 and 3900:—3998·7, 3997·3, 3993·2, 3992·4, 3991·7, 3991·0, 3984·0, 3980·0, 3977·8, 3974·3, 3971·5, 3971·2, 3966·6, 3962·1, 3959·8, 3955·0, 3951·6, 3941·8, 3941·4, 3939·2, 3937·2, 3930·5, 3930·2, 3923·9, 3922·2, 3919·1, 3917·5, 3911·9, 3911·6, 3910·4, 3907·8, 3901·3.

Chlorine.

Spark Spectrum				Intensity and Character
Salet	Plücker	Thalén	Hasselberg	
	6758·8			
	6711·1			2
6670	⎧6681·4			2
	⎩6657·1			2
6110	6093·4			8
	5937·6			1
	5930·5			1
	5785·4			2

CHLORINE—*continued.*

Spark Spectrum				Intensity and Character
Salet	Plücker	Thalén	Hasselberg	
	5714·0			2
	5681·1			2
	5669·0			2
	5635·1			2
	5596·2	5593·5		2
	5572·4			2
	5536·4			2
	5529·3	5527·7		2
5460	(5456·1)	5455·5	5456·7	7
5445	(5443·5)	5443·5	5443·6	8
5420	(5423·5)	5423·0	5424·0	9
5390	(5391·9)	5391·5	5392·4	9
	5362·1	5355·0		2
	5332·7	5332·0		2
		5312·5		1
	5284·3	5285·0	5284·7	3
5215	(5219·9)	{5220·0	{5219·8	8
	(5216·3)	5216·5}	5216·2}	10
	5194·6	5205·5		1
	5190·1	5188·0	5188·8	2
	5177·1	5174·0		2
	5174·7	5172·0	5172·2	2
	5168·6	5160·0	5160·8	2
	5162·8	5142·0		2
	5124·2	5112·0	5112·8	2
	5106·2	5102·7	5102·4	6
5097	5101·2	5098·2	5098·2	6
5075	5082·2	5077·0	5077·6	8
	5071·5			1
	5049·2			1
		5030·5		1
		5020·5		1
	5009·2			2
	5005·2			2
5000	4998·7	4994·0	4997·7	5
4975	4973·1	4967·5	4972·4	3
	4947·8	4941·0	4945·3	2
	4941·6	4935·0	4937·9	2
	4932·7			2
4920	(4924·4)	4923·5	4925·3	5
4903	(4917·8)	4916·5	4917·2	6
4895	(4900·0)	{4903·2	{4904·4	7
		4895·5}	4896·9}	7
4820	(4818·7)	4817·7	4819·8	10
4810	(4809·7)	4809·7	4809·7	10
4795	(4793·4)	4793·0	4793·9	10
	4782·3			2
4785	4778·5	4779·5	4780·8	5
	4773·6	4773·5		2
4770	4768·6	4768·0	4769·0	4
	4767·3			6
	4753·1			2
4740	4736·6	4739·0	4739·7	5n
	4700·0	4704·5		3
		4698·0		1
		4660·0		2

CHLORINE—*continued.*

Spark Spectrum				Intensity and Character
Salet	Plücker	Thalén	Hasselberg	
		4648·0		4
	4641·2	4640·0		4
		4638·0		4
	4627·3			
	4606·2	4608·0		1
	4595·1	4596·0		2
4575	4589·8	4590·5		2b
	4581·8			
	4571·4			
	4565·7			
	4545·2			1
	4536·1			1
	4525·1	4527·0		2
	4504·8			1
	4496·5			1
	4489 6			1
4352	4346·6			8n
	4338·8			2
4315	4313·1			4n
	4295·0			2
	4282·1			1
	4278·3			1
4260	4259·3			3b
4130				2n

Ångström gives lines of Chlorine at 5460, 5399, 5213, 4940, 4895, 4820, 4808, 4793, 4647, 4630.

CHROMIUM.

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of Chromium Chloride solution.
† Double.

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Thalén	Liveing and Dewar	I.	II.
6659					1	
6499					1	
6461					1	
6436					1	
6157					1	
6116					2	
6100					1	
5790					1	
5784					1	
5780					1	
5638					1	
5605					1	
5411	*5409·1	5108·9	5409·1		8sc	
5346	5342·6				2sd	
5342	*5341·1				2sd	
5321	*5318·1				2sd	

CHROMIUM—*continued.*

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Thalén	Liveing and Dewar	I.	II.
	5313·1				2sd	
5295	*5296·7				2sd	
	5296·2				2sd	
5274	*5274·4				4sd	
5265					1sc	
5264	*5263·5				4sd	
5252	5254·1				4sd	
5246	5246·5				4sd	
5236					1	
5224					1	
5207	*5207·8	5207·6	5207·8	(5207·8)	10sc	r
5203	*5206·4	5205·4	5206·4	(5206·4)	10sc	r
5202	*5203·9	5203·9	5203·9	(5203·9)	10sc	r
5152					2	
5104					1	
4921	4924·1				4sd	
4886					1	
4876					1	
4871					1	
4862					1	
4829					1	
4824					2	
4788					1	
4756					1	
4753					1	
4738					1	
4730					1	
4718					1	
4652	4654·0		4654 0		4sd	
4648				4650·5	1	
4646	*4646·5		4646·5	(4646·4)	4sd	
4631					1	
4615					1	
4600					1	
4587					1	
4559					1	
4546					1	
4541					1	
4535					1	
4529					1	
4524					1	
4497	4495 3		4495·3		4sd	
	4381·9		4381·9		4sd	
	4369·2		4369·2		4sd	
	4359·1		4359·1		4sd	
4350	4351·8		4351·8		8sc	
4343	*4344·4		4344·4		8sc	
4341	4338·2		4338·2		8sc	
4337	4337·5		4337·5		8sd	
	4336·8		4336·8		6sd	
4289	*4289·4		4289·4	(4289·4)	10sc	r
4274	*4274·6		4274·6	(4274·6)	10sc	r
4255	*4253·9		4253·9	(4253·9)	10sc	r
4227						
4216						

CHROMIUM—*continued.*

Arc Spectrum			Intensity and Character
Lockyer	Lockyer	Liveing and Dewar	
3992·1	3918·3		
3991·0	3915·6		
3989·2	3908·2		
3983·6		3606	r
3983·2		3593	r
3975·5		3578	r
3968·8		†3446	r
3967·8		3217 ?	r
3962·7		2799·8	r
3940·5		2797	r
3927·8		2794	r
3920·1		2779·6	r

COBALT.

* Observed in the Spark Spectrum of Cobalt Chloride solution by Lecoq de Boisbaudran, who gives also lines at 5524, 4663, 4629, 4599, 4471, 4372, 3997.

† Observed also by Lockyer. The 'indices' attached to these numbers, and to those by Schuster, represent the comparative 'lengths' of the lines.

‡ Not identified (Lockyer). § Double. ‖ See Calcium and Iron.

I. Spark Spectrum.				II. Arc Spectrum.	Intensity and Character.	
Huggins.	Thalén.	Kirchhoff.	Schuster.	Thalén.	I.	II.
§*6453					1n	
6349					1s	
6298					1s	
6275					1s	
6247					1s	
	†6142·7$^{(2)}$	6143·0			6sc	
	†6121·4$^{(2)}$	6120·9			6sc	
*6116					1n	
*6084					1s	
*6047					1s	
*6002	‡6003·7	6002·6			8nc	
6000					1s	
*5989					1s	
5983					1s	
5915					2s	
5843					2s	
5838					1s	
*5644					1s	
*5634					1s	
*5590					1s	
*5481	†5482·5$^{(4)}$	5482·5	(5482·5)$^{(5)}$		4sd	
	†*5452·1$^{(2)}$	5452·4	5452·1$^{(3)}$		6sc	
*5443	†5443·1$^{(2)}$	5443·0	(5443·1)$^{(4)}$		6sc	
5379						
*5368	†5368·1$^{(2)}$	5368·5	(5368·1)$^{(4)}$	5368·1	6sc	
5360	†5362·7$^{(2)}$	5362·2	(5362·7)$^{(3)}$	5362·7	2sd	
*5356	†5359·6$^{(2)}$	5358·6	(5359·6)$^{(2)}$	5359·6	2sd	
5351	†5352·5$^{(4)}$	5352·5	(5352·5)$^{(5)}$	5352·5	6sc	
5350	†5351·3$^{(4)}$	5351·2	(5351·3)$^{(5)}$	5351·3	6sc	
*5344	†5342·6$^{(4)}$	5342·3	(5342·6)$^{(6)}$	5342·6	2sd	
§5338	†5342·1$^{(4)}$	5341·6	(5342·1)$^{(6)}$	5342·1	2sd	
5329					1s	

COBALT—*continued.*

I. Spark Spectrum				II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Kirchhoff	Schuster	Thalén	I.	II.
5320					1s	
5317					1s	
5313					1s	
5309					1s	
5290					1s	
5285					1s	
5281 } *5279	§†5279·6(4)	5279·8	(5279·6)(5)	5279·6	6sc	
5274			5275·2		1s	
*5267	†5267·2(4)	5267·7	(5267·2)(3)	5267·2	2sd	
5265	§†5265·9(4)	5265·6	(5265·9)(5)	5265·9	6sc	
*5254			(5254)(1)		1s	
5252			(5252)(1)		1s	
5249			(5249)(1)		1s	
5247			(5247)(1)		1s	
*5234	†5234·6(4)	5234·5	(5234·4)(3)	5234·3	2sd	
5228	†5230·2(2)	5230·2	(5230·2)(3)	5230·2	2sd	
*5213	†5212·2(3)		(5212·2)(4)		2sd	
5200						
*5190					1s	
*5184					1s	
*5156			5158·6(2)		1s	
*5147			{ 5155·1(3) 5134·3(3) }		1s	
*5128			5127·1(5)			
5105			5110·2(5)		1n	
5074					1n	
5061					1n	
5054					1s	
5028					1s	
4967					1s	
*4870	†4867·1(4)	4867·6	(4867·1)(5)	4867·1	10sc	
*4841	†4839·1(4)	4839·9	(4839·1)(5)	4839·1	10sc	
*4814	†4813·6(2)	4813·4	(4813·6)(5)	4813·6	10sc	
*4793	†4791·8(4)	4791·7	(4791·8)(5)	4791·8	10sc	
	*†4778·8(4)	4778·9	4779·1(5)	4778·8	10sc	
*4751	‡4748·6	4749·2	(4748·6)(3)	4748·6	4sd	
4737					1s	
4720					1s	
			4716·8		1s	
			4694·1		1s	
*4683			4683·1		1s	
			4664·3		1s	
*4581	‖†4580·8(2)	4580·8			4sd	
*4565					5n	
*4549					1s	
*4530	†4530·6(4)	4530·4		4530·6	4sd	
*4120					2n	
4119					1s	
4113					1s	
*4097				Lockyer	1n	
				3997·3		
				3994·6		
				3991·0		
				3989·7		
				3978·8		

COBALT—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character
Lockyer	Lockyer	Cornu	
3977·8	3934·9		
3973·8	3928·3		
3972·4	3921·8		
3971·5	3919·8		
3960·3	3916·5		
3957·0	3909·2		
3951·9	3905·8		
3951·1		3501·8	
3946·0		3462·0	
3940·8		3453·2	
3939·7		3443·0	
3937·7		3403·8	

COPPER.

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of solution of Copper Chloride.
† Observed (together with the Bands of the Oxide) by Lecoq de Boisbaudran in the Spectrum given by Copper Chloride in the flame of a Bunsen burner.
§ See Silver. || See Tellurium. ** See Cadmium.

I. Spark Spectrum		II. Arc Spectrum	Intensity and Character		I. Spark Spectrum		II. Arc Spectrum	Intensity and Character	
Thalén	Kirchhoff	Liveing and Dewar	I.	II.	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
6380·0			8sc			3265·2		3sd	
6218·5			2sd			3260·2		2sd	
†*5781·4	5782·0		8sc			‖3246·9		10sc	
*5700·5			10sc			?3243·9		2sd	
*5292·1	5291·7		8sc			?3233·4		2sd	
†*5217·3	5217·7		10sc			3139·7		2sd	
*5152·8	5152·7	(5152·8)	10scr			3134·2		2sd	
†*5105·0	5104·9	(5105·0)	10scr			3123·7		3sd	
5011·5			4sd			3115·7		2sd	
4955·6			6nd			3107·4		3sd	
4932·6			6nd			3097·8		2sd	
4911·6			6nd			3035·6		2sd	
4703·1			6sd			3023·4		2sd	
*4650·7	4650·3		6sd			2959·6		3sd	
	Hartley					2882·4		2sd	
	and					2877·4		3sd	
	Adeney						2852·0		
4275·0	4274·2		4sd			2836·5		3sd	
	3598·9		3sd			2823·2		3sd	
	3596·6		3sd				2802·4		
	3523·6		2sd				2795·2		
	3510·4		2sd				2779·4		
	3483·2		2sd			2769·1		7sd	
	3478·8		2sd		§*	* 2766·2		3sd	
	3471·6		2sd			2745·9		3sd	
	3455·8		2sd			2721·2		4sd	
	3450·1		2sd			2718·4		4sd	
	§3381·0		1sd			2713·1		6sd	
	‖3306·8		5sd			2702·7		7sd	
	‖3289·9		5sd			2700·5		7sd	
	3282·1		4sd			2688·8		7sd	
	§‖3280·1		2sd			2666·0		3sd	
	‖3273·2		9sc			2643·5		1sd	

COPPER—*continued.*

I. Spark Spectrum		II. Arc Spectrum	Intensity and Character	
Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
	2617·8		3sd	
	2608·9		2sd	
	2599·7		7sd	
	2598·3		7sd	
	2590·1		3sd	
	2573·0		2nd	
	2572·0		2nd	
	2570·9		2sd	
	2565·3		2nd	
	2553·7		1nd	
	2552·2		2nd	
	2544·6		8sd	
	2538·2		2nd	
	2533·9		2nd	
	2531·4		2nd	
	2528·8		6sd	
	2526·2		6sd	
	2522·7		1nd	
	2522·1		1nd	
	2518·3		1nd	
	2517·5		1nd	
	2513·2		1nd	
	2512·2		1nd	
	2508·7		3sd	
	§2506·2		6sd	
	2497·4		1sd	
	2495·9		1sd	
	2491·4		3sc	
	2489·1		6sd	
	§2485·6		6sd	
	2481·8		3sd	
	2478·2		2sd	
	2475·1		1sd	
	§2473·2		5sd	
	2468·4		3sd	
	2465·2		1nd	
	2461·5		1nd	
	2458·2		1nd	
	2452·5		1nd	
	2446·7		1nd	
	2444·1		3sd	
	2441·6		3sd	
	2439·8		1sd	
	2435·7		1sd	
	2430·3		1sd	
	2428·2		1sd	
	2425·1		3sd	
	2422·0		1sd	
	2412·2		3sd	
	2404.8		3sd	
	2403·3		6sd	
	2400·1		6sd	
	2393·0		1sd	
	2392·2		1sd	
	2385·2		1sd	
	2376·7		3sd	
	2371·6		2sd	
	2370·1		9b^r	
	2368·7		2sd	
	**2365·8		1	
	2357·2		5sd	
	2355·0		2sd	
	2348·8		2sd	
	2346·2		2sd	
	2336·6		3sd	
	2303·8		1sd	
	2300·5		1sd	
	2297·5		1sd	
	2295·0		6sd	
	2294·6	2294·1	3sd	
	2291·4		3sd	
	2286·7		3sd	
	2279·6		2sd	
	2277·0	2276·0	6sd	
	2265·8		2sd	
	2263·9	2263·6	3nd	
	2263·2		3nd	
	2257·7		2sd	
	2250·0		2sd	
	2248·2		9sd	
	2247·7		3nd	
		2246·6		
	2244·0		9sd	
	2243·5	2242·2	3nd	
	2233·0		3sd	
	2232·2		3sd	
	2231·2		5sd	
	2230·0		5sd	
	2229·1	2229·6	3sd	
	2228·1	2228·3	3sd	
	2227·0		1sd	
	2226·0		1sd	
	2219·3		6sd	
	2218·5		3nd	
		2217·5		
	2216·5		3nd	
	2215·8		3sd	
	2214·1		2sd	
	2211·3		6sd	
	2210·8		3nd	
		2209·7		
	2208·8		2sd	
	2200·3		3sd	
	2199·8	2199·2	1nd	
	2196·5		3sd	

COPPER—*continued.*

I. Spark Spectrum		II. Arc Spectrum	Intensity and Character		I. Spark Spectrum		II. Arc Spectrum	Intensity and Character	
Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
	2192·0	2191·8	6sd			2135·8	2135·7	3sd	
	2191·2		3nd			2134·2		2nd	
	2189·6	2189·2	6sd			2124·4		3sd	
	2188·5		3nd			2124·0		2nd	
	2181·0		1sd			2122·1		3sd	
	2179·0	2178·8	5sd			2121·5		2nd	
	2178·0		3nd			2116·0		1sd	
	2174·5		3sd			2110·5		1sd	
	2148·8	2148·9	3sd			2103·0		1sd	

DIDYMIUM.

* These lines occur in Roscoe and Schuster's Terbium Spectrum.
† Air? ‡ See Samarium. § Possibly due to Chlorine.

Spark Spectrum		Intensity and Character	Spark Spectrum		Intensity and Character
Thalén	Kirchhoff		Thalén	Kirchhoff	
6740·0		4s		‡5795·9 Di. La.	2s
6385·0		4s		5790·0 Di. La.	
6346·0		1s		5786·1 Di. La.	
6309·0		1s		5767·7 Di. La.	
6301·0		1s	5707·0		2s
6296·0		2s	5701·5		1s
	6293·7 Di. La.		5688·0		4s
6256·0		1s	5675·0		4s
6222·0		2s	5645·0		1s
6177·0		2s	5639·0		2s
6165·5		2s	5634·0		2s
6148·0		2s	5619·5		3s
6132·0		1s	5604·0		1s
6120·0		1s	5601·0		1n
6113·0		2s	5593·5	5593·2	4s
§6107·0		1s	5586·5	5587·1	2s
6072·0		2s	†5561·0		2s
6071·0		2s		5501·9 Di. La.	
6064·5		2s		5500·6 Di. La.	
6033·0		2s	‡5485·0	5484·1 Di. La.	6s
6007·0		1s	5478·5		1s
5995·5		1s		‡5452·6 Di. La.	
5993·0		1s	5450·0		2s
5988·0		1s	5448·5		1n
5867·0		1n	5447·0		2s
	5860·6 Di. La.		5442·5		2n
5857·0		1n	5430·5	5431·2	3n
5845·0		1n	5422·0		1n
5841·0		1n	5416·0		1s
5826·0		1n	5409·0		1s
5822·0		1n	5393·0		1n
5814·0		1n	5382·5		1n
	5806·2 Di. La.	2sc	5380·0		1n
5803·0	5805·1 Di. La.		5376·5		1n

DIDYMIUM—*continued.*

Spark Spectrum		Intensity and Character	Spark Spectrum		Intensity and Character
Thalén	Kirchhoff		Thalén	Kirchhoff	
*5371·0		6s	*4912·0		2s
*5360·5	5359·9	6s	4901·0		4s
5356·5		4s		4899·1 Di. La.	
5322·0		4s	4896·5		5s
*5319·0	5319·1	8s	4890·0		5s
5311·5		2n	4888·0		2s
*‡5302·0	5301·3 Di. La.	2n	4881·0		5s
*5292·5		8s	4866·0		1s
5286·0		1s		4860·2 Di. La.	
5276·0		2n	4858·5		4s
*5272·5	5272·7	6s	4824·0		4s
*5268·5		2n		4822·7 Di. La.	
*5263·5		1n	4811·0		4s
5258·5	5258·4	4s	4788·0		3s
*5254·5	5254·6	4s	4778·0		3s
5249·5		1s	4763·0		3s
*5248·5	5247·9	8s		4746·5 Di. La.	
5239·5		2s		4741·0 Di. La.	
*5233·5	5233·7	3s		4740·0 Di. La.	
5219·5		2s	4731·0		1s
5211·5		1n	4724·0		2s
5203·5		2s	4718·5		2s
5199·0		2s	4715·0		1s
5194·5		2s	4709·0		1s
*5191·5	5191·8 Di. La.	6s	4706·0		4s
*5190·5	5190·7 Di. La.	6s	*‡4703·5		2n
5179·0		4s	4695·0		2b
5173·0		4s	‡4688·0		1b
5164·5		1s	4682·5		4s
5132·5		2s	4679·5		2s
5131·5		1s	4670·5		1b
*5129·5	5127·7	6s	4653·5		2s
5123·0	5122·2 Di. La.	4s	4633·0		4s
	5113·8 Di. La.		4621·5		4s
5110·5		4s	4578·0		2s
5107·0		2s	4563·0		2s
5105·0		1s	4542·5		2s
5102·0		4s	*4541·5		2s
*5092·0		3s	4516·0		2s
5086·0		1s	4509·0		2s
5079·0		3s	4501·5		2s
5076·0		3s	4496·0		2s
5063·5		2n	*4462·5		7s
5034·0		2n	4455·5		2s
	4999·8 Di. La.		4451·5		7s
	4994·2 Di. La.		4446·0		7s
4989·0		3s	‡4429·0		4n
	4969·6 Di. La.		4410·0		4s
4960·5		2s	*4401·0		1s
4958·0		4s	4385·5		5s
4954·0		4s	4375·0		1s
4943·0		4s	4368·0		2s
	4933·9 Di. La.		4357·5		4n
4923·5		6s	4351·0		3n
	4921·5 Di. La.		4338·5		2s
4920·0	4920·7 Di. La.	4n	4334·5		1s
‡4913·0		2s	4327·5		6s

DIDYMIUM—*continued.*

Spark Spectrum		Intensity and Character	Spark Spectrum		Intensity and Character
Thalén	Kirchhoff		Thalén	Kirchhoff	
*4325·0		4s	4252·5		2n
4303·0		6n	4247·5		4n
4285·0		2n	4181·0		4n
‡4282·0		2n	4155·0		4s
4277·5		n	4109·0		6s
4272·0		1n	4060·0		6s
4261·0		2s			

The following lines between the wave-lengths 3900 and 4000 have been observed by Lockyer in the arc-spectrum of Didymium, 3994·0, 3985·5, 3978·8, 3975·8, 3972·4, 3964·5, 3963·9, 3963·3, 3962·9, 3962·1, 3961·3, 3961·1, 3957·0, 3950·9, 3950·1, 3940·5, 3937·9, 3926·1, 3920·1, 3918·1, 3917·0, 3910·4, 3907·8, 3905·3, 3901·3.

ERBIUM.

Spark Spectrum	Intensity and Character	Spark Spectrum	Intensity and Character	Spark Spectrum	Intensity and Character	Spark Spectrum	Intensity and Character
Thalén		Thalén		Thalén		Thalén	
6076·0	4	5732·0	2	5041·5	2	4674·0	8
6044·0	2	5626·0	1	4951·0	8	4605·5	8
6014·5	2	5485·0	4	4899·0	8	4565·5	1
5881·0	4	5456·0	2	4871·5	6	4562·5	2
5871·0	4	5343·5	6	4830·0	4	4552·5	2
5854·0	2	5256·0	8	4819·0	6	4500·5	6
5850·0	1	5217·0	6	4794·5	4	4474·5	1
5826·0	8	5188·0	6	4762·0	2	4458·5	2n
5762·0	6	5164·0	4	4758·0	2	4419·0	4
5756·0	4	5133·0	2	4750·0	1	4409·0	
5738·0	2	5070·0	2	4678·0	2	4326·0	

FLUORINE.

I. Flame Spectrum	II. Spark Spectrum	Intensity and Character	
Liveing	Salet	I.	II.
	6920		
	6860		
	6780		
	6400		
6230	6230		
6090			
6010			
5570			
5320			

GALLIUM.

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Lecoq de Boisbaudran	Liveing and Dewar	I.	II.
4170	4170	10sc	r
4030	4031	6sc	r

Gold.

* Observed also in the Spark Spectrum of solution of Gold Chloride by Lecoq de Boisbaudran, who gives also lines at 5725, †5601, †5458, †5347, †5310, †5287, 5259, †5242, †5212, 5172, †5143, †5125, 4608, 4437, 4338, 4314 and 4064.

† Observed by Lecoq de Boisbaudran in the Flame Spectrum of Gold Chloride, as well as lines at 5477, 5437, 5418, 5364, 5328, 5263, 5222, 5179, 5158, 5102, 5080, 5044, 4996, 4516, 4430.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.
6710				1s	
6670				1s	
6660				1s	
6457				1s	
6428				1s	
6304				1s	
6291				1s	
*6276	6276·7	6276·9		8sc	
5961	5960·2	5958·2		6sc	
*5954	5955·2	5954·4		6sc	
†*5920				1s	
5880				1n	
*5862				2s	
*5835	5836·1	5837·7		10sc	
5790				1s	
†5758				1s	
*5653				1s	
5580				1n	
*5231	5230·2	5230·2		10sc	
†*5067				1s	
*4811				1s	
*4793	4792·1	4791·6		6sc	
*4489				3s	
			3122·8		
			2675·4		r
			2427·5		r

Hydrogen.

Elementary Line Spectrum		Intensity and Character
Ångström	Vogel	
6562·1		
4860·7		
4340·1		
4101·2		
	3968	
	3887	
	3834	
	3795	
	3769	

Note.—Certain lines measured by Huggins in the photographic spectra of the stars are, in all probability, due to Hydrogen. They have the following wave-lengths —3767·5, 3745·5, 3730, 3717·5, 3707·5, 3699.

Hydrogen.

* Double. † Probably due to Mercury.

Compound Line Spectrum Hasselberg	Intensity and Character	Compound Line Spectrum Hasselberg	Intensity and Character	Compound Line Spectrum Hasselberg	Intensity and Character	Compound Line Spectrum Hasselberg	Intensity and Character
6422·7	2	6022·9	4	5822·0	4	5622·9	1
6394·3	2	6020·4	4	5818·8	3	5621·2	1
6358·5	1	6017·5	6	5816·1	1	5619·1	2
6337·6	2	*6011·0	1	5814·5	3	5615·3	1
6323·9	4	6006·4	1	5812·0	6	5610·8	4
6300·8	2	6004.2	1	5804·5	2	5607·8	1
6296·9	4	6002·3	4	5803·1	1	5602·5	2
6283·4	3	5997·4	1	5799·9	2	5598·6	3
6273·0	1	5993·7	3	5797·8	1	5595·6	4
6269·6	1	5991·9	3	5795·2	1	5590·3	2
6237·3	4	5989·9	3	5793·3	2	5578·3	2
6232·1	1	5988·4	3	5790·5	2	5573·1	2
6224·0	4	5982·2	4	5786·3	1	5571·2	2
6200·8	2	5974·9	5	5784·5	4	5563·5	1
6198·7	4	5969·2	3	5778·2	3	5560·8	1
6196·1	3	5966·6	4	5773·8	4	5554·0	2
6182·2	4	5962·6	3	5772·0	1	5551·5	3
6175·6	2	5959·0	4	5765·4	3	5546·7	1
6173·6	4	5955·5	1	5761·9	1	5542·3	3
6169·5	3	5949·2	4	5759·4	4	5536·4	4
6167·1	1	5946·8	4	5756·4	4	5532·8	1
6164·0	2	5942·9	1	5739·6	1	5529·0	1
6161·2	4	5941·2	1	5737·9	1	5526·0	2
6158·7	2	5937·9	5	5734·8	4	5523·0	1
6154·9	2	5935·4	1	5733·3	2	5520·5	1
6152·7	2	5930·8	5	5729·8	4	5517·2	3
6150·7	2	5927·5	1	5726·6	4	5514·3	1
6145·7	2	5924·2	4	5721·6	1	5506·8	1
6143·3	2	5920·1	4	5714·2	2	5504·5	4
6140·7	1	5915·6	4	5711·8	2	5498·5	4
6138·8	1	5911·3	1	5708·2	1	5494·8	3
6134·5	6	5909·0	3	5702·3	3	5493·1	1
6126·6	4n	5904·7	1	5699·4	2	5480·0	4
6121·0	6	5903·1	2	5696·1	2	5473·8	2
6118·4	2	5900·0	2	5693·0	2	5470·6	1
6112·0	1	5897·5	1	5688·1	4	5464·3	1
6107·5	1	5895·4	1	5683·1	4	†5459·9	
6097·7	2	5893·4	2	5681·6	4	5456·2	1
6095·2	4	5891·2	1	5675·4	1	5454·0	1
6093·0	1	5887·9	6	5673·6	1	5451·5	2
6090·0	4	5883·5	6	5671·9	2	5445·9	1
*6083·9	1n	5878·1	4	5669·7	2	5439·0	1
6080·0	5	5875·5	1	5666·4	2	5433·8	4
6078·4	1	5871·4	4	5662·5	1	5430·0	1
6073·8	3	5868·8	4	5660·8	3	5427·8	1
6069·6	5	5863·9	2	5658·6	2	5425·0	4
*6066·8	3	5861·0	2	5656·7	2	5419·0	4
6062·9	3	5859·3	1	5654·6	3	5417·4	2
6055·7	2	5856·7	1	5651·5	2	5409·3	1
6052·1	4	5851·0	2	5646·4	1	5408·2	1
6047·2	3	5848·6	2	5645·2	1	5406·3	1
6044·4	2	5846·8	1	5641·5	3	5404·5	1
6042 3	2	5835·4	4	5633·4	3	5400·5	2
6040·2	2	5832·3	3	5631·0	1	5398·6	2
6031·1	6	5830·5	3	5629·3	3	5397·6	1
6027·2	4	5824·0	1	5625·8	3	5394·2	1

HYDROGEN—*continued.*

Compound Line Spectrum — Hasselberg	Intensity and Character	Compound Line Spectrum — Hasselberg	Intensity and Character	Compound Line Spectrum — Hasselberg	Intensity and Character	Compound Line Spectrum — Hasselberg	Intensity and Character
5391·7	1	5094·2	1	4883·1	2	4633·6	1
5390·5	1	5089·5	1	4877·2	1	4633·1	5
5387·5	4	5084·6	4	4875·2	3	4630·7	4
5386·1	2	5081·0	3	4872·4	3	4626·9	4
5372·6	2	5079·8	3	4868·8	1	4624·4	3
5365·0	3	5074·9	2	4866·4	1	4619·9	1
5355·8	1	5071·8	2	Hβ4860·6		4617·5	3
5343·2	1	5069·5	2	4855·8	2	4616·8	3
5335·8	3	5067·5	4	4848·6	3	4606·6	2
5331·1	1	5063·3	4	4842·7	2	4582·0	3
5321·4	1	5061·2	2	4841·5	2	4580·8	1
5319·6	1	5054·2	5	4837·3	3	4579·4	4
5317·3	2	5048·7	2	4822·2	2	4577·1	2
5313·2	1	5047·1	2	4812·9	2	4574·8	3
5308·4	2	5040·9	3	4796·8	3	4571·7	4n
5302·6	4	5038·9	3	4796·1	2	4567·2	4
5290·8	3	5029·6	3	4793·0	2	4564·4	1
5283·6	3	5019·8	1	4789·9	2	4562·9	2
5277·8	1	5015·9	3	4788·4	2	4561·4	2
5272·0	3	5014·1	4	4785·0	2	4557·8	2n
5265·8	3	5012·2	5	4783·7	2	4556·5	2n
5263·6	3	5010·8	2	4781·7	1	4553·3	3
5260·9	2	5007·5	3	4779·8	2	4550·3	2
5256·2	2	5002·7	4	4776·4	2	4549·0	1
5237·4	2	4997·3	2	4772·9	1	4547·1	1
5230·3	1	4995·8	2	4769·6	1	4542·9	2
5228·1	2	4989·5	2	4762·5	3	4538·4	2
5225·4	2	4988·6	2	4742·5	2	4537·1	2
5221·7	2	4982·5	1	4741·9	2	4533·7	3
5219·7	1	4979·6	3	4740·3	1	4532·1	2
5213·7	2	4978·2	1	4722·3	3	4528·1	2
5204·4	1	4977·3	1	4720·4	1	4523·0	2
5201·9	1	4975·6	1	4718·3	4	4522·3	2
5198·9	2	4972·5	4	4713·4	4	4520·4	1
5195·9	4	4968·4	3	4710·3	1	4514·8	1
5190·1	1	4966·1	3	4708·7	3	4509·8	1
5187·6	1	4960·4	1	*4701·6	1	4504·9	1
5180·1	2	4956·0	3	4691·2	2	4501·0	1
5174·3	2	4954·9	3	4689·4	2	4497·5	1n
5170·9	1	4952·0	1	4686·0	2	4492·8	1
5168·1	1	4944·2	1	4685·5	2	4489·7	3
5164·6	1	4941·7	1	4683·7	1	4485·2	2
5156·2	1	4938·8	2	4683·0	3	4476·6	1
5153·9	2	4935·8	1	4681·7	2	4473·7	3
5146·5	3	4933·5	5	4679·6	2	4466·6	3
5142·8	3	4931·5	2	4678·3	2	4460·6	3
5136·6	1	4927·9	5	4674·6	2	4458·5	1
5133·7	1	4924·8	2	4674·0	2	4456·4	2
5131·5	1	4923·6	1	4672·5	1	4455·3	1
5127·3	1	4918·4	2	4670·7	2	4452·6	1
5122·6	2	4908·2	2	4667·0	1	4450·3	1
5120·6	1	4905·5	2	4664·9	2	4449·2	1
5113·3	3	4901·0	1	4662·3	3	4447·2	3
5108·5	2	4900·2	1	4660·7	2	4444·7	3
5106·5	2	4895·6	2	4659·6	2	4443·6	1
5102·8	3	4890·5	2	4652·3	3	4417·0	2
5099·1	1	4887·7	1	4644·4	1	4412·0	
5095·6	1	4885·5	2				

INDIUM.

* A line observed here when the Spark was taken from the Chloride or Nitrate, but not from the metal itself.

† See Tellurium. ‡ See Tin.

§ 4511 and 4101, Lecoq de Boisbaudran; observed in the Flame Spectrum of Indium Salts, and in the Spectrum of the Spark between metallic poles.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Thalén	Clayden and Heycock	Hartley and Adeney	Liveing and Dewar	I.	II.
	6906			6s	
	6193			10s	
	6114			2n	
	6095			8n	
	5922			4n	
	5905			4n	
	5862			2n	
	5820			8n	
	5722			4n	
	5644			8n	
	5250			10n	
	4680	4681·5		8sd	
	4656	4655·2		8sd	
	4638	4637·0		8sd	
4531·6	*4532			8n	
§4509·6	4510	4510·2	(4509·6)	10sc	r
		4253·1		7sd	
§4101·0	4101	4101·3	(4101·0)	9sc	r
		4071·6		9sd	
		4063·5		9sd	
		4032·7		9sd	
		4025·6		5sd	
		3852·8		9sd	
		3840·5		5sd	
		3834·7		9sd	
		3794·8		2nd	
		3359·5		2nd	
		3257·8		9sc	
		3255·5		10nc	
		3246·1		3sc	
		3236·2		3sc	
		3186·2		3sd	
		3159·7		3nd	
		3148·6		3nd	
		3038·7		10b^{r}c	
		3008·0		9nd	
		2982·3		9nd	
		2956·1		2sc	
		†2940·8		9b^{r}c	
		†2932·3		7sc	
		2889·8		9sd	
		2857·1		2sc	
		2839·2		1sc	
		2836·0		2sc	
		2832·1		1sc	
		2752·8		5sc	
		2750·7		3nd	
		2738·1		2sd	
		2727·0		2nd	

INDIUM—*continued.*

Spark Spectrum Hartley and Adeney	Intensity and Character	Spark Spectrum Hartley and Adeney	Intensity and Character
2712·9	3sc	2423·2	3sd
2709·3	7sc	2422·8	3sd
2706·4	1sc	2416·3	3sd
2631·2	3nd	2403·5	3sd
2610·8	1sc	2397·6	3sd
2602·5	3sc	2389·8	2sc
2600·2	3sd	2388·0	2sd
2591·0	3sd	2385·9	3sd
2586·6	3sd	2381·0	3sd
2564·7	3sd	2370·7	3sd
2559·5	7sc	2357·0	2sd
2554·1	3sd	2355·8	1sc
‡2545·8	2sd	2355·4	2sd
2527·1	7sd	2353·8	2sd
2520·9	3sc	2351·3	7sd
2492·7	2sd	2332·2	2sc
2485·5	2sd	2306·9	9sc
2485·1	2sd	2289·3	2sd
2478·3	1nd	2287·8	2sd
2470·2	5sd	2264·4	3sd
2468·4	3sc	2263·8	3nd
2462·5	2nd	2249·2	3sd
2460·8	5sc	2245·7	3sd
2460·3	2nd	2205·5	2sd
2447·4	2nd	2202·0	2nd
2443·7	2nd	2194·0	3sd
2433·6	3nd	2191·2	3sd
2431·0	3nd	2181·0	3sd
‡2429·0	1sc	2155·8	2nd
2428·6	3sd	2137·8	2sd
		2078·1	2nd

IODINE.

Spark Spectrum Plücker	Spark Spectrum Salet	Intensity	Spark Spectrum Plücker	Spark Spectrum Salet	Intensity
6861		2	6073	β6075	9
6825		2	6067		2
6757		2	5956	γ5960	10
6690		2	5920		2
6640		2	5889		2
6576		2	5866		1
6494		2	5821		2
6339		2	5790	5790	5
6292		2	5777	5780	10
6257		4	5763	5765	10
6210	6210	4	5739	δ 5740	10
6169		2	5713	5715	10
6154		2	5705		2
6131	α6130	8	5696	5695	9
6087		2	5683	5685	10

IODINE—*continued*.

Spark Spectrum		Intensity	Spark Spectrum		Intensity
Plücker	Salet		Plücker	Salet	
5649		2	5176		2
5632	ε5630	10	5166		2
5620	5620	3	5150		2
5607	5610	3	5138	μ5158	10
5600		2	5107		2
5558		2	5102		2
5530		2	5064	ν5065	8
5511		4	5047		2
5499	5496	9	5028		2
5494		2	4990		2
5482		2	4972		2
5468	5470	10	4960		2
5460	ξ	2	4946		2
5441	5447	10	4922		2
5422		2	4886		2
5402	5407	10	4853		4
5377	5370	6	4838		1
5365		8	4832		1
5339	η 5348	10	4809		2
5330	5338	10		4675	
5314		2		4666	
5292		2	4636	π4634	6
5262		4		4480	
5257		4		4470	
5235	θ5243	10		4455	
5218		2		4450	
5209		6			

IRIDIUM AND RUTHENIUM.

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Kirchhoff	Lockyer	I.	II.
6347·1			
5449·7		2	
5299·2		2	
	3991·5		
	3975·3		
	3945·1		
	3934·0		
	3914·5		
	3901·8		

Iron.

I. Spark Spectrum.			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			7146·1				
			6662·5				
			6603·5				
			6573·6				
			6545·1				
			6494·2				
6497	6490·1	6489·7	6489·9			6sd	
6460			6461·6		6461·7	1s	
			6430·1				
			6420·6				
6414			6410·6			1s	
			6407·2		6407·4		
6401						1s	
6400	*6399·3	(6399·4)	6399·3			10nc	
6386						1s	
6360			6357·5			1s	
			*6354·0	(6354·0)			
6338			6336·2			1s	
			6334·5				
6320			6321·8			1s	
			6318·0				
			6313·8				
6306	*6300·6	6301·4	6300·6			6sd	
			6264·3				
6254			6255·2			1s	
			6253·1				
			6251·2				
6246	*6245·6		6245·6			8sd	
			6231·2				
6231	*6229·9	(6229·9)	6229·9			8sc	
			6212·4				
			6199·2				
6190	*6190·7	(6190·7)	6190·7			8sc	
			6179·1				
			6172·2				
			6154·1				
			6148·0				
			6136·8				
6138	*6135·8	(6135·8)	6135·8			8sc	
			6077·8				
6080 ?	6064·7	6064·1	6064·7			8sd	
			6055·1				
			6025·8	6026·1			
6020	6023·2	(6023·2)	6023·2	6023·2		6sc	
	*6019·3		6019·3	6019·2		4sc	
	6007·5		6007·5	6007·6		4sd	
	6002·3		6002·3	6002·0		4sd	
	5986·4		5986·4	5986·0		4sd	
	5984·4		5984·4	5983·7		4sd	
	5983·0		5983·0	5982·6		4sd	
	5976·3		5976·3	5975·6		4sd	
	5974·8		5974·8	5974·2		4sd	
5958				5955·7		1s	
				5951·9			

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of Ferric Chloride solution.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			5947·6	5947·7			
			5933·8	5933·5			
			5929·3	5929·0			
				5915·0			
		*5915·1	5913·3	5913·0			
5902			5904·3			1s	
*5880			5883·0			1s	
			5861·3				
5855			5858·4			1s	
			5815·6				
			5808·1				
			*5803·6				
			5797·1				
			*5790·2				
5780						1s	
			5774·1				
	*5762·0	(5762·0)	5762·0			6sd	
			5753·6				
			5730·5				
			5716·8				
			5713·9		5714·1		
			5710·9				
	*5708·4		5708·4			6sd	
			5705·0				
			5700·6				
			5685·5				
	5681·5		5681·5			6sd	
			5677·9				
	5661·6		5661·6			6sd	
	*5657·7		5657·7			10sc	
	5654·5		5654·5			6sd	
			5640·2				
			5637·2				
			5632·5				
5624	*5623·3	5623·3	5623·3			6sd	
5612	*5614·6	(5614·6)	5614·6		(5614·6)	10sc	r
5601	*5601·8	(5601·8)	5601·8			10sc	
5594	5597·3		5597·7			10sc	
	5591·3		5591·3			8sc	
5584	*5585·7	5585·3	5585·7		(5585·7)	10sc	r
			5583·8				
			5577·6				
	5575·0	(5575·0)	5574·9			8sc	
5571	*5571·8	(5571·7)	5571·8			10sc	
5569	5568·6	5568·0	5568·5			8sc	
			5561·8				
			5553·9				
			5545·4				
			5541·9				
			5531·6				
			5525·9				
§5503	{ 5506·0					6sc	
	{ 5500·6		5500·6			6sc	
	5496·5		5496·4			6sc	

§ Double.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			5489·0				
	5486·9		5486·9			4sd	
			5480·2				
			5473·2				
			5465·7				
5460		5462·0	5462·2			2s	
5454	*5454·8	(5454·8)	5454·8			10sc	
5444	*5446·0	5446·6	5446·0		(5446·0)	10sc	
		5444·7	5444·4				
5432		5433·3	5433·0			2s	
5426	*5428·9	(5428·9)	5429·0		(5428·9)	10sc	r
5424		5423·0	5423·7			2s	
5412		5414·6	5414·4			1s	
5409		5410·0	5410·0			1s	
	*5404·9	(5404·9)	5405·0		(5404·9)	8sc	r
5402	5403·2	(5403·2)	5403·1			8sc	
5401			5399·5			2s	
	5396·2	(5396·2)	5396·1		(5396·2)	8sc	r
5392	*5392·4	5392·0	5392·4			6sc	
5388			{ 5390·4 5388·6				
5383	*5382·4	(5382·4)	5382·4			6sc	
			5378·4				
§5370	*5370·6	5370·8	5370·6		(5370·6)	10sc	r
	5369·1	(5369·1)	5369·1			6sd	
5366	5366·6	(5366·6)	5366·6			6sd	
5365	5364·1	5363·8	5363·9			6sd	
5363	5362·0		5362·0			4sd	
	5352·5		5352·5			4sd	
	5348·7		5348·7			4sd	
	* { 5340·3	(5340·3)	5340·3			8sc	
	5339·3	(5339·3)	5339·3			8sc	
			5332·0				
			5329·2				
			5328·6				
	*5327·4	{ 5327·7	{ 5327·7			10sc	
		5327·2	5327·1		(5327·2)		r
5322							
5318	5323·5	(5323·4)	5323·5			8sc	
5314	5316·0	5316·1	5316·0			8sc	
5312	*5306·6		5306·6			6sd	
5299	5301·6	(5301·5)	5301·6			6sd	
5289			5287·5				
§5282	{ *5282·7	5283·0	5282·7			8sc	
	5281·0	(5281·0)	5281·0			6sd	
5274			5272·4			1s	
E { 5270	{ *5269·6	(5269·6)	5269·6			10sc	
5269	5268·6	(5268·6)	5268·6		(5268·6)	10sc	
5267	5265·9	5265·6	5265·9			8sc	
5262	5262·5		5262·5			4sd	
5256			5254·1			1s	
			5252·5				
*5250			{ 5251·0 5249·6			1s	

§ Double.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			5246·1				
			5242·8				
5241			5241·3			1s	
			5234·4				
5232	*5232·2	(5232·1)	5232·2			10sc	
			5229·0				
5226	5226·4	(5226·4)	5226·4		§(5226·0)	10sc	r
§5218			5216·4			1s	
			5215·4				
			5214·2				
	*5207·8		¶5207·8			6sd	
5202	5203·9		5203·9			6sd	
	5201·7		5201·7			4sd	
			5197·9				
	5194·3		5194·3			6sc	
5192	*5191·9	(5191·9)	5191·9			8sc	
5190	5190·7	(5190·7)	5190·7			4sc	
			5185·1				
5180			5179·2			1s	
	5171·3	5170·9	5171·3			4sc	
b_3 5168	‡*/5168·5	(5168·5)	5168·5			6sc	r
b_4 5166	\5166·9	(5166·9)	5166·9		(5166·9)	8sc	
			5165·8				
			5164·9				
	5161·8	(5161·6)	5161·8			4sc	
			5158·5				
			5151·2				
			*5150·0				
5148			5147·2			1s	
			5145·6				
			5141·8				
5139	*5138·8	5138·8	5138·8			8sc	
			5136·7				
5133		(5133·0)	5133·0			2s	
			5130·9				
			5126·6				
			5124·3				
			5123·2				
			5121·0				
			5109·9				
	*5107·1		5107·2			6sc	
*5099			5098·3			2n	
			5096·3				
			5082·4				
			5078·8				
			5077·9				
			5075·9				
			*5074·1		(5072)		r
			5071·8				
			5068·1				
			5066·3		(5064·5)		r
	*5064·5		5064·5			4sd	
			5059·8				
	5051·1		5051·0			8sc	

‡ b_3, see Nickel; the solar line b_3 is double b_4, see Magnesium; the solar line b_4 is double.
§ Double. ¶ See Chromium; the solar line here is double.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
	*5049·5		5049·5			8sc	
			5047·6				
			5043·4				
	5041·3		5041·3			6sc	r
	*5040·2		5040·2			6sc	
			5038·2				
			5027·2				
			5026·2				
			5021·5				
5017		(5017·8)	5017·8			3s	
			5014·3				
			5011·6				
			5006·5				
	*5005·3		{5005·3			4sd	
			{5004·9				
			5003·2				
	5002·1		5002·0			2sd	
			4998·8				
	4993·4		4993·4			2sd	
	4990·4		4990·4			4sd	
	4988·4		4988·4			2sd	
			*4984·7				
			4983·4				
			4982·5				
			4981·9				
			4977·8				
			4972·2				
			4969·4				
			4969·0				
			4967·7				
			4967·2				
			4965·2				
			4961·8				
4958	*4956·8	{4956·7	4956·9		(4956·9)	10sc	r
		{4956·5					
			4954·1		(4954·1)		r
			4952·2				
			4949·3				
			4946·8				
			*4941·4				
			4938·8				
			4938·4				
			4932·8				
			4929·3				
4923	*4923·2	4923·3	4923·2			6sc	
4920	4919·9	4920·3	4919·9		(4919·9)	10sc	r
	4918·3	4918·7	4918·3		(4918·3)	8sc	r
			4909·4				
			*4907·0				
			4902·2				
4893		{4891·2	{4891·0		(4891·6)		r
	*4890 5	{(4890·4)	{4890·2		(4890·2)	10sc	r
			4888·0				
			4886·3				
			4885·8				

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			4884·2				
			4880·9				
	4877·5	4878·0	4877·5			6sd	
	*4871·4	(4871·5)	4871·4		(4871·4)	8sc	r
	4870·6	4870·8	4870·6		(4870·6)	8sc	r
			4863·5				
	*4859·2	(4859·4)	4859·2			4sd	
			*4854·6				
			4842·2				
			4839·0				
			4835·0				
			4831·8				
			4802·2				
			4800·0				
			4797·5				
	4788·7		4788·7			2sd	
	4785·9		4785·9			2sd	
			4771·9				
			4767·3				
			4745·2				
			4740·2				
			4736·2				
			4733·3				
			4730·8				
			4726·7				
	4709·5		4709·5			2sd	
	4708·4		4708·4			2sd	
	4706·6		4706·6			2sd	
	4690·9		4690·9			6sc	
			4677·9				
			4672·6				
			4667·2				
			4666·4				
	4653·5		4653·5			6sc	
			4646·3				
			4643·2				
			4637·3				
			4636·9				
	4632·1		4632·1			6sc	
			4624·4				
			4618·8				
	4610·7		4610·8			6sc	
	4602·7		4602·7			4sd	
	4592·0		4592·0			6sc	
4582			4585·2			1s	
			†4580·8				
			4578·1				
			4550·0				
			4546·3				
			4533·3				
	4528·1		4528·1			6sc	
			4524·2				
			*4493·8				
			4489·5				
			4484·8				

† See Calcium and Cobalt.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Kirchhoff	Ångström	Cornu	Liveing and Dewar	I.	II.
			4483·7				
			‖4482·0				
			4479·5				
			4475·2				
			4469·5				
			‖4458·6				
			‖4447·1				
			4442·3				
			4441·7				
			4430·0				
			4426·9				
	‖4414·8	4414·6	4414·8		(4414·8)	10sc	r
		Hartley	4407·8		4407·7		
		and Adeney	4406·9				
4406	‖4404·3	*4403·7	4404·3		(4404·3)	8sc	r
			4402·0				
			4390·4				
			4388·4				
4380	‖4382·9	†4382·6	4382·9		(4382·9)	8sc	r
			4379·2		4379·1		
			4375·4				
			4369·2				
			4367·6				
			4358 2				
			4352·5				
	4343·1		4343·1				
		4338·0				4sd	
4324	‖4325·2	‡4325·0	4325·2		(4325·2)	8sc	r
	4314·6		4314·6		(4314 6)	6sd	r
G 4307	‖4307·2	§4307·1	4307·2		(4307·2)	8sc	r
4303			4304·9			3s	
			4302·0				
4300	4298·5	⎧4298·3	4298·5			3sd	
			4296·8				
4294	4293·9	⎩4293·3	4293·9			3sd	
			4292·9				
			4291·3				
			4287·0				
	4286·0		4286·0			4sd	
			4284·8				
		4281·7	4281·9			2sd	
4272	‖4271 3	4271·0	⎧4271·6		(4271·6)	8sc	
			⎩4270·9		(4270·9)		
			4268·0				
			4267·3				
			4266·9				
			4264·2				
			4263 5				
4259	‖4260·0	4259·9	4260·0			7sc	
			4255·2				
			4253·8				
	‖4250·5		4250·5			10sc	
	4249 8	4249·8	4249·8			8sc	

* 4404·3—Kirchhoff. † 4382·9—Kirchhoff. ‡ 4325·6—Kirchhoff. § 4306·9—Kirchhoff.
‖ Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Ferric Chloride solution.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Ångström	Cornu	Liveing and Dewar	I.	II.
	4247·5		4247·5			4sd	
			4245·2				
			4238·8				
			4238·1				
			4237·4				
	‖4235·5		4235·5			6sd	
	4233·0		4233·0			6sd	
			4229·0				
	*‖4226·8		4226·8			2sd	
	4221·7		4221·7			2sd	
	4218·3		4218·3			2sd	
			4215·4				
			4213·2				
	4209·9		4209·9			2sd	
			4208·3				
			4207·0				
			4206·3				
			4205·3				
			4204·3				
			4203·3				
4201	‖4201·5	4201·4	4201·6			5sc	
			4200·0				
			{4198·1			3sc	
4199	‖4198·0	4198·4	4197·7}			10sc	
			4195·7				
			4195·5				
	4191·2		4191·2			8sc	
	{4187·2		{4187·2			10sc	
	4186·7}		4186·7}			10sc	
			4184·7				
	4181·3		4181·3			4sd	
	4177·0		4177·0			4sd	
			4176·2				
			4175·5				
			4174·8				
			4172·4				
			4171·9				
			4171·1				
			4167·0				
			4166·7				
			4158·5				
			4157·3				
			4155·9				
			4154·0				
	‖4153·8		4153·8			6sd	
			4153·5				
4151	4151·5		4151·5			4sd	
			4150·1				
	4148·6		4148·6			4sd	
			4147·0				
4142	‖4143·1	4143·0	4143·3			6sc	
			4142·9				
	‖4133·9		4133·9			8sc	
			4132·6				
			4131·9				

* See Calcium.
‖ Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Ferric Chloride solution.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Ångström	Cornu	Liveing and Dewar	I.	II.
4131	4131·5		4131·5				
			4127·2			10sc	
			4122·5				
			4121·3				
			4120·4				
	4117·8		4117·8			8sc	
			4084·2				
4074	*4071·0	4071·5	4071·0	4071·1	(4071·0)	8sc	r
4067	*4062·9	4063·0	4062·9	4062·9	(4062·9)	8sc	r
			4054·3				
			4051·8				
4047	*4045·0	4045·4	4045·1	4045·0	(4045·0)	8sc	r
			4040·0				
			4031·5				
			4024·1				
			4020·2				
			4016·7				
	4004·8	4005·0	4004·9	4004·3	Lockyer	4sc	
			3997·8	3996·7	3997·5		
					3996·9		
					3996·5		
					3995·2		
					3993·5		
					3984·6		
					3983·2		
					3980·8		
					3976·8		
					3975·8		
					3975·5		
					3970·3		
					3969·5		
					3968·6		
					3968·3		
H_1		‖3968·7	3968·1	3966·7	3967·0	5sc	
					3965·5		
					3965·1		
					3964·5		
					3963·6		
					3962 1		
					3959·2		
				3955·9	3955·7		
					3955·5		
					3954·2		
					3952·1		
			3951·4		3951·6		
					3950·1		
					3948·8		
					3947·8		
					3947·2		
					3946·7		
					3946·0		
					3944·2		
					3943 8		
					3942·5		
				3941·8	3941·5		

* Observed also in the Spark Spectrum of Ferric Caloride solution by Lecoq de Boisbaudran, who gives also lines at 6095, 6045, 5980, 5936, 5865 and 582).

‖ See Calcium.

IRON—*continued.*

I. Spark Spectrum			II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Ångström	Cornu	Lockyer	I.	II.
					3940·3		
					3939·7		
					3936·3		
					3934·7		
					3934·3		
H_2		*3933·1	3933·0	3932·9	3931·7	3sd	
					3930·2		
		3929·7		3929·8	3929·5	3sc	
		3927·6		3927·3	3927·0	3sc	
					3925·3		
					3924·9		
		3922·5		3922·0	3922·0	3sc	
				3920·0	3919·4		
				3918·4	3918·3		
				3917·8	3917·7		
					3917·5		
					3916·5		
					3916·0		
					3912·9		
					3910·2		
					3907·3		
					3906·2		
				3905·9	3906·0		
					3903·3		
					Liveing and Dewar		
		3902·6		3901·9		3sc	
		3899·3		3898·4	(3898·4)	3sc	
				3897·0			
		3895·1		3894·7		3sc	
				3892·6			
		3888·1		3888·0		3sc	
				3887·4			
				3886·4			
		3885·7		3886·0	(3886·0)	7sc	r
				3884·7			
				3880·3			
		3878·1		3877·4		7sc	
		3872·2		3871·3		3sc	
				3870·6			
		3865·2		3865·5		3sc	
				3865·2			
				3864·8			
				3860·6			
		3859·6		3859·3		7sc	r
		3856·1		3855·7		7sc	r
				3853·7			
				3852·7			
				3851·8			
				3850·0			
		3849·1		3849·7		3sc	
				3845·9			
				3844·6			
				3841·9			

* See Calcium.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Cornu	I.	II.
3810·3	3840·5	7sc	
	3840·1		
	3838·5		
3834·0	3833·6	7sc	r
3827·4	3827·7	7sc	r
3825·5	3825·3	7sc	r
3824·0	3824·1	5sc	r
L 3820·3	*3819·7	7sc	r
	3819·2		
	3816·9		
3815·8	3815·3	7sc	r
	3814·0		
3812·6	3812·6	2sc	
3804·4	3805·0	3nc	
	3802·0		
	3799·4		
3798·4	3798·7	3sc	
	3796·8		
3794·6	3794·9	3sc	
	3793·3		
	3792·7		
	3792·2		
	3790·5		
	3789·8		
3788·0	3787·1	3sc	
	3786·2		
	3785·4		
3767·0	3766·8	7sc	r
3765·3	3765·0	2sc	
3763·3	3763·4	7sc	
3757·9	3757·7	7sc	r
	3753·4		
3749·4	3749·5	9sc	
	3748·2		
3745·4	3745·5	7sc	r
3742·7	3742·9	4sc	
3736·9	3736·5	7sc	r
3734·7	3734·4	9sc	r
	3733·2		
	3732·4		
M 3727·0	†3727·0	7sc	r
	3726·7		
	3724·1		
3722·0	3721·9	4sc	r
3719·7	3719·7	7sc	r
	3716·4		
	3715·5		
3709·0	3709·0	5sc	
	3707·8		r
	3707·5		
3705·5	3705·5	5sc	r
	3703·7		
	3703·2		
3700·0	3700·8	2sc	
3694·2	3693·7	2sc	

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Cornu	I.	II.
3688·5		2nd	
3687·3	3687·2	5sd	
	3685·8		
	3685·0		
3683·0	3683·9	3nc	
	3681·7		
3679·5	3680·3	5sc	
3676·5	3677·6	3nc	
	3669·3	3sc	
	3662·4	1sd	
	3662·0	2sd	
	3656·2	2sd	
	3651·7	3nc	
3649·6	3649·4	3nc	
	3648·6	7sc	r
3647·6	3646·9		
3640·0		3sc	
3637·8	3637·7	3sc	
	3633·8		
3631·0	3630·9	7sc	r
	3623·7		
	3622·7		
	3621·0		
3620·3	3620·6	3sc	
3618·6	3617·8	7sc	
	3616·9		
3609·2	3609·7	7sc	
	3608·3		
3605·6	3606·0	3nc	
	3604·6		
3602·4	3602·1	3nd	
3598·4	3601·8	1sd	
3594·9	3594·0	3nc	
3588·2			
3586·3	3586·2	2sc	
3584·8	3584·9	3nc	
	3584·1	3nc	
N 3581·1	‡3580·6	9sc	
3569·6	3568·9	9sc	
3565·0	3564·1	9sc	
3558·1	3558·1	5nc	
	3556·0		
3554·2	3554·0	5nc	
3540·9	3541·5	5nc	
	3540·1		
	3539·2		
3534·8	3535·4	3nc	
3531·2		3nc	
3528·2	3527·0	1sc	
3525·9	3525·7	5sc	
3520·7	3520·6	5sc	
3513·3	3513·7	5sc	
	3505·8		
	3501·8		r

* 3819·0—Mascart. † 3728·8—Mascart. ‡ 3580·2—Mascart.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Cornu	I.	II.	Hartley and Adeney	Cornu	I.	II.
3496·6	3496·8	5sc			3283·4		
	3495·9				3282·7		
	3494·5			3279·9		2sd	
3492·3	3491·9	5sc	r	3276·2		3sd	
3489·3	3489·8	5sc		3271·6	3272·2	2sd	r
	3488·9			3268·9	3269·3	3sc	
	3488·0			3265·6		3sd	
	3485·4			3263·5	3263·9	3sc	
3475·5	3476·1	3nc	r	3258·2		7sd	
3474·3	3474·9	5sc		3255·1		2sd	
3470·3	3470·4	2sd		3253·2	3252·4	2sd	
3468·8		2sd	r	3249·1	3246·8	1nd	
3465·4	3465·5	5sc		3246·3	3246·1	5sc	r
3460·9	3461·5	2sd		3243·0	3242·8	5sc	
3457·0	3457·8	2sd			3238·9		
3452·3	3453·2	2nc		3237·9	3238·7	2sc	
	3445·7			3236·4	3237·8	2sd	
3443·6	3444·4	3sd		3231·0	3234·3	3sd	
3443·0	3443·0	3sc		3229·9	3232·3	3nd	
	3440·8	7sc		3227·0	3226·5	7sc	
O 3440·2	* 3439·9			3225·0	3224·4	5sc	
	3439·6		r	3221·5	3221·0	3sc	
3436·9		5sc		3218·6	3218·7	3sc	
	3426·7			3212·7	3212·2	7sc	
	3425·4			3210·9	3210·8	2sc	
	3424·8				3210·5		
	3422·8			3209·5	3209·8	3sc	
	3420·9				3209·3		
	3416·0			3204·6	3204·3	2sc	
	3415·5			3199·9	3199·7	2sc	
	3411·8			3198·9	3198·8	2sc	
3406·7	3406·1	5sc	r	3195·7	3196·3	5sc	
3403·7	3403·1	2sc		3195·2		5sc	
3400·2		2sc		3192·7	3192·7	5nd	
3398·2	3397·6	2sc		3192·2	3192·3	5sd	
	3391·0			3186·2		5sd	
3392·0		3sc		3182·3		3sd	
3389·5		3sc		R 3179·1	§3179·8	5nc	
3383·3		2sc		3176·8		5sd	
3370·2		2sc		3174·7		1sc	
3366·1		2sc		3170·4		1sd	
P 3358·7	†3359·3	1nc		3167·0		7sd	
3353·3		3sd		3166·4		2sd	
3305·4		5sc		3162·0	3160·9	3sd	
	3304·7				3157·4		
	3304·1				3156·7		
	3303·7			3153·6		7sd	
3297·3	3296·0	2sd		3150·9		1sc	
3294·6		2sd			3144·4	2sd	
3291·5	3290·8	2sc		3143·9	3144·2		
	3290·0				3143·3		
3288·8	3289·3	2sd			3142·6		
Q 3285·4	‡ 3284·8	3sc		3134·6		3sd	
	3284·6						

* 3440·1—Mascart. † 3360·2—Mascart. ‡ 3285·6—Mascart. § 3177·5—Mascart.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Cornu	I.	II.
3132·9		1sd	
3132·1		1sd	
3126·0		2sc	
3120·7		1nd	
3116·1		3sd	
3113·4		3sd	
3104·8		2sd	
3101·3		3sd	
	3099·8	7sc	
S_2 3099·5	3099·5		r
	3099·2		
3096·7		3sd	
3090·7	3090·4	3sd	
3089·3		2sd	
3082·8	3082**	3sc	r
3078·6	3079·3	5sd	r
3076·7		7sd	
3075·5		5sd	
3070·3	3072**		r
3066·6	3065·5	2nd	
		5sc	
3064·3		2sd	
3061·3		5sd	
3058·5		5sc	
3056·3	3057·3	5sc	r
	3056**		r
3054·8		1sd	
3052·1		1sd	
3048·6		1sd	
s 3046·9	3046·5	5sc	r
3044·2		2sd	
3041·5	3041·5	2nc	r
3040·8	3040·7	2nc	
3040·0	3040·3	2nc	
	3039·2		
3036·4	3036·2	5sc	r
3032·8		1sd	
3030·0	3029·8	3sc	r
3028·8	3028·7	3sc	
	3025·3		
3024·8	3024·6	5sc	r
3022·5	3022·7	3sc	r
T 3020·1	3019·9	7sc	r
3018·1	3019·4	2sc	r
	3017·7		r
3016·9	3016·5	2sc	r
3015·2	3015·0	2sc	
3012·4		3sd	
3010·9		2sd	
	3008·4		r
3007·9	3007·3	3sc	r
3006·8		3sc	
3006·2	3006·3	3nd	r

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Hartley and Adeney	Cornu	I.	II.
3005·7		3sc	
3002·1	3002·7	7sc	
	3002·4		
2999·6	3000·2	5sc	r
2998·1	2999·0	5sc	r
2996·3		3sd	
t 2993·7	2994·4	5sc	r
2989·8		1sd	
2986·2	2987·1	1sc	
2984·6		7sc	
2984·0	2984·1	7sc	r
§§2982·8	2982·0	3sc	2 r
2980·8		3sd	
2979·8	2979·7	3sc	
2977·8	2976·8	3sd	
2974·8	2973·8	2nd	r
2972·1	2970·7	5sc	r
2969·4	2970·0	5nc	
	2967·4		r
2966·0	2965·6	5sc	r
2964·3		3sc	
2963·2		3nd	
2960·2	2960·5	1sd	
2959·0		5sc	
	2957·4		r
2956·5		3sc	
2952·9	2953·8	7sc	r
	2950·5	5sd	
2948·4	2947·8††	7sc	r
U 2946·9			
Liveing and Dewar	Liveing and Dewar		
	2944·6		1
2944·0	2944·0	8	1
	2943·1		1 r
	2940·8		8
	2939·9		1
2938·7	2938·7	1	4 r
	2937·3		2
2936·4	2936·4	2	10 r
2932·4	2932·4	1	2
2931·1		1	
2928·3	2928·3§§	4	10 r
2926·0	2926·0	8	1
	2925·2		1
	2924·7		1
	2923·2		1
2922·8	2922·8	1	1
2921·5		1	
	2920·0		1
2917·4	2917·4	1	2
	2913·6		1
2911·5	2911·5	1	10 r

** Liveing and Dewar. †† 2947·3—Liveing and Dewar. §§ 2982·0—Cornu.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.	Liveing and Dewar	Liveing and Dewar	I.	II.
2910·5		1			2839·6		1
	2908·9		1	2837·7	2837·7	1	2
	2908·2		1	2836·7	?	1	r
2907·1	2907·1	1	1	2835·2		6	
2905·8	2905·8	1	1		2832·8		2
	2903·5		1		2832·4		2
2902·1		1		2831·8	2831·8	1	6r
	2901·3		2	2831·0		8	
	2900·8		2	2828·3	2828·3	2	1
	2898·9		2	2827·3	2827·3	1	1
	2897·8		1	2827·0		1	
2896·7		2		2825·1	2825·1	1	6
2894·5	2894·5	4	2		2823·9		1r
2894·0	2894·0	2	2	2822·9	2822·9	1	6
	2893·2		1		2820·4		1
	2892·0		1	2819·0	2819·0	1	1
	2891·2		1	2817·0	2817·0	1	1
	2889·2		1		2815·1		1
2887·6		1		2813·4		1	
	2887·3		1	2812·8	2812·8	4	8
	2885·8		1	2812·2		1	
2885·5		1			2811·7		1
2883·3	2883·3	4	1	2810·9		1	
2880·4	2880·4	2	1	2809·7	2809·7	1	1
	2878·2		4		2807·9		1
	2876·8		4	2806·7	2806·7	1	6
2876·4		1		2805·4		1	
2874·9	2874·9	2	1	2804·9		1	
	2873·6		6	2804·2	2804·2	2	1
2873·0		4		2803·8		1	
2872·0	2872·0	2	4r	2803·2	2803·2	1	1
2870·7		1			2801·8		1
2869·0	2869·0	1	6		2800·8		6
	2868·0		1		2800·1		1
	2867·1		1		2799·4		1
2866·5		1		2798·8	2798·8	4	1
	2866·2		2r		2797·9		6
2864·7		1		2797·4	2797·4	2	2
	2863·6		4	2796·3		1	
	2863·1		4		2794·5		6
	2862·4		1	2793·3		4	
2862·1		1			2792·2		1
2860·9	?	1	r		2791·5		1
	2858·3		1	2790·3		1	
2857·9		4			2789·5		1
2856·7		1		2788·0	2788·0	6	10
2855·3		1		2785·1		6	
2849·3		1			2784·2		1
2848·2	2848·2	1	1	2783·4		10	
2848·0	2848·0	2	1	2781·6	2781·6	1	2
	2846·5		1	2778·9	2778·9	8	1
2845·3	2845·3	4	2		2778·3		1
2843·6	2843·6	4	8	2777·9	2777·9	2	4
2843·1	2843·1	1	1	2777·7		1	
2840·3	2840·3	6	1	2776·9		1	

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.
2776·1		1	
2774·5	2774·5	2	1
	2773 1		1
2771·9	2771·9	2	8
	2771·1	1	
2770·3	2770·3	1	1
	2769·4		1
2769·1	2769·1	4	1
2768·8	2768·8	4	1
2767·2	2767·2	10	6r
	2766·8		1
2765·3		1	
2764·7		1	
	2764·0		1
2763·6		1	
	2763·0		4
2762·4		1	
	2761·9		4
2761·7	2761·7	6	6
	2759·7		1
	2757·2		4
2756·9		1	
	2756·2		6
2755·5	2755·5	10	10r
	2754·3		1r
	2753·9		1
	2753·5		1
2753·0	2753·0	10	1
2752·1		1	
2750·8		2	
	2750·6		1
2749·8	2749·8	2	8r
2749·0	2749·0	1	1r
2746·6	2746·6	8	8
2746·1	2746·1	6	8
	2744·2		2r
2743·7	2743·7	2	6
	2743·3		1
2742·8	2742·8	8	6r
2742·0	2742·0	2	10r
2741·1		2	
2739·1	2739·1	10	10
2736·9	2736 9	1	6
2736·5	2736·5	10	2r
2735·0	2735·0	2	6
	2733·9		1
	2733·7		1
2733·1	2733·1	4	8
2732·5		1	
2731·5		1	
2730·2	2730·2	6	2
2729·1		1	
2728·3	2728·3	2	1
	2727·5		1
2727·1	2727·1	10	4
2726·0		1	
	2725·5		2
2724·3	2724·3	6	2
2723·1	2723·1	4	10r
2722·3		2	
2721·7		1	
2721·5		1	
2720·3	2720·3	4	10r
	2719·7		2
2718·5	2718·5	6	10r
2718·0	2718·0	1	2
	2717·4		1
2715·7	2715·7	6	1
	2714·9		1
	2714·4		1
2713·8	2713·8	10	10
	2713·5		1
2711·9		1	
2711·5		6	
2711·2	2711·2	4	6
2710·1	2710 1	1	4
2709·7	2709·7	1	1
2708·7		4	
	2708·1		6
2706·7	2706·7	4	1
2706·0	2706·0	6	10
	2705·6		6
2703·6		10	
	2702·6		1
2701·2	2701·2		1
2699·8		1	
2698·6	2698·6	2	4
	2697·7		1
2697·0		4	
	2696·6		1
	2695·9		1
	2695·6		4
	2695·0		2
2694·7		1	
	2694·4		1
	2694·0		2
2693·4		1	
2692·1	2692·1	10	1
	2691·7		1
2691·2		1	
	2690·9		1
	2689·5		2
	2689·3		2
2688·8	2688·8	6	6
	2687·3		1
	2686·8		1
	2686·0		1
2685 7		1	
2684·2	2684·2	10	1
	2683·5		1

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.	Liveing and Dewar	Liveing and Dewar	I.	II.
2682·4		2		2631·0	2631·0	10	10
2682·0		2		2630·7	2630·7	10	10
	2681·5		1	2629·7	2629·7	2	1
	2680·8		1	2629·2	2629·2	2	1
2680·4		2		2627·9	2627·9	10	10
	2679·9		1		2626·8		1
2678·5	2678·5	1	8	2626·2	2626·2	1	1
	2677·2		1	2625·2	2625·2	10	10
2676·1		1			2623·6		1
	2675·1		1	2523·1	2623·1	1	6
	2674·6		1	2622 6		1	
	2672·4		1	2621·2	2621·2	6	6
2671·8	2671·8		1	2620·4		2	
2670·8		1		2619·9	2619·9	2	2
	2669·9		1	2618·6		4	
2669·7		1			2518·3		1
2669·2		1			2617·6		1
	2668·7		1	2617·2	2617·2	10	10
2668·5		1			2615·0		1
	2667·2		1		2614·0		1
2666·7		1		2613·3	2613·3	10	10
2666·1	2666·1	10	10		2612·3		1
	2665·7		2	2611·4	2611·4	10	10
2664·2	2664·2	10	1	2610·7	2610·7	1	1
	2664·0		1		2610·3		1
	2663·5		2	2609·3		1	
2662·2		1			2609·1		1
2661·6	2661·6	1	4	2608·7	2608·7	1	1
	2660·8		2		2608·2		1
2657·8	2657·8	6	1	2606·7	2606·7	6	6
	2656·4		1	2606·5	2606·5	1	1
2655·7	2655·7	2	2	2606·1		2	
2654·4		1		2605·6		1	
2653·3		1			2605·3		6
2652·2		1		2605·1		2	
	2650·9		1	2604·9		2	
2650·4	2650·4	2	1		2604·4		1
2649·2		4		2603·8		1	
2647·3	2647·3	1	4		2603·5		1
2645·8		1			2599·7		1
	2645·2		2	2598·9	2598·9	10	10
2644·9	2644·9	6	1	2597·8	2597·8	10	10
2643·8	2643·8	1	6		2596·0		1
2641·7		1			2595·2		1
2641·4	2641·4	1	4	2594·5		1	
2640·7		1			2593·5		1
2639·2		4		2593·1	2593·1	6	6
2637·3		6		2592·2		6	
	2636·6		1		2591·7		1
2636·1	2636·1	1	1	2591·0	2591·0	6	6
2635·5	2635·5	1	6	2590·0		1	
2635·1		1		2588·2		1	
2632·9		2		2587·5	2587·5	6	6
	2632·3		1	2585·4	2585·4	10	10
2632 0	2632·0	1	2	2584·0	2584·0	1	8

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.	Liveing and Dewar	Liveing and Dewar	I.	II.
2582·0	2582·0	6	4	2549·0		2	
	2581·7		4				
	2580·9		1	2548·4		2	
2580·6		1			2547·8		1
	2580·3		1	2547·0		1	
	2579·9		1	2546·6	2546·6	2	2
	2579·5		1	2545·8	2545·8	1	8r
	2579·3		1	2544·9		2	
2578·9		1			2544·5		4
	2578·7		1	2543·7	2543·7	1	6
	2578·3		1	2543·0	2543·0	6	1
2577·4	2577·4	6	6	2542·4		1	
2576·5		4		2541·7	2541·7	1	6
	2576·2		6	*2541·6		4	
2575·7	2575·7	1	4	2540·8	2540·8	4	8r
	2575·3		2	2540·4		2	
	2574·8		2		2539·1		1
2574·0	2574·0	6	1	2538·6	2538·6	10	2
2572·8		1		2538·0		4	
	2572·5		1		2536·9		6
2571·2		1		2536·6	2536·6	10	2
2570·6		4		2535·2	2535·2	6	8r
	2570·1		2	2534·2	2534·2	8	1r
2569·4	2569·4	1	1	2533·4	2533·4	8	6
2568·6	2568·6	1	1		2532·6		1
2568·1		2			2532·4		1
2566·7	2566·7	6	6	2532·0	2532·0	1	2
2566·0		4			2531·1		1
	2565·1		1	2530·4	2530·4	1	4
	2564·2		1	2529·9		1	
2563·2	2563·2	8	8		2529·6		6r
2562·3	2562·3	8	8	2529·2		8	
	2561·9		1	2528·9	2528·9	1	6r
	2561·5		1		*2528·1		1
	2560·9		1		2527·9		1
	2560·3		1	2527·1	2527·1	2	8r
2560·0	2560·0	4	1	2526·7		2	
2559·6		2		2526·0	2526·0	8	2
2558·9		1		2525·1	2525·1	8	1
	2558·3		1		2524·7		2
2557·2		1		*2523·9	*2523·9	1	8r
	2556·6		1	2523·3	2523·3	1	2r
	2556·0		1	2522·5	2522·5	8	10
2555·2		2		2521·5	2521·5	6	1
	2554·9		1	2520·8	2520·8	6	1
2554·8		2		2519·3	2519·3	1	2
2553·4		1		*2518·8	*2518·8	6	6r
2552·8	2552·8	1	1		2518·5		1r
	2552·3		1	2517·8	2517·8	1	6
2550·8	2550·8	1	1		2517·4		2
2550·3		2		2516·8	2516·8	6	1
2549·7		2			2516·3		1
	2549·2		8r	*2515·8	*2515·8	1	10
2549·1		2		2514·7		4	

* Probably due to Carbon.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.	Liveing and Dewar	Liveing and Dewar	I.	II.
	2514·3		1		2479·2		1
*2514·1	*2514·1	6	6	2479·0		1	
	2513·2		1	2478·3	2478·3	6	10
2512·2	2512·2	4	6	2477·9		1	
	2512·0		6	2477·1		2	
	2511·6		1	2476·5	2476·5	1	2
*2511·4	*2511·4	10	1	2476·0		1	
2510·6	2510·6	2	8r		2475·8		1
*2508·8		2		2475·5		1	
	2508·5		2	2474·9		1	
2507·9		1		2474·5	2474·5	6	6r
2507·6	2507·6	1	6	2472·9		2	
*2506·6	*2506·6				2472·7		1
	2506·2		1	2472·4	2472·4	2	8
2505·8		6		2471·9	2471·9	4	6
	2505·2		1		2470·5		1
2504·9	2504·9	1	1	2470·3		8	
2503·6		6		2469·0		6	
2503·1		6		2468·4	2468·4	1	6
	2503·0		1	2467·8		2	
2502·1	2502·1	8	1r		2467·2		2
	2501·4		2	2466·4	2466·4	8	2
2500·9	2500·9	1	8	2465·4		6	
2500·7		4		2464·7	2464·7	4	6r
2498·7	2498·7	10	1	2464·5		4	
2497·5	2497·5	8	1	2463·7		4	
2496·3	2496·3	1	6		2463·4		2
2495·6	2495·6	4	2	2462 8	2462·8	4	1
	2493·9		1	2462·3	2462·3	4	1
2493·7	2493·7	2	2		2461·9		6
2492·9	2492·9	10	6	2461·4		6	
2492·0	2492·0	1	1	2461·0	2461·0	6	1
2491·1		6			2460·8		1
	2491·0		8r	2460·2	2460·2	4	1
2490·5	2490·5	8	10r	2458·5	2458·5	10	1
2489·5	2489·5	8	10r		2458·2		1
2489·2		4		2457·4	2457·4	2	8
	2488·7		1	2456·4		1	
2487·7	2487·7	6	10		2456·0		1
	2487·1		2	2455·7		1	
	2486·8		2		2455·3		1
	2486·4		2	2454·3		6	
2486·1	2486·1	8	2	2453·8		1	
	2485·7		1r	2453·5		2	
	2884·7		1r		2453·2		6
2483·7	2483·7	6	6	2452·9		1	
2483·3		1			2452·3		1
2482·9	2482·9	1	10		2451·8		1
2482·4		6			2451·3		1
2481·8	2481·8	6	1r	2451·0	2451·0	2	1
2481·3		1			2450·7		1
2480·7		1		2450·0	2450·0	4	1
2480·0	2480·0	8	1r	2449·6		4	
2479·5	2479·5	1	8		2448·5		1

* Probably due to Carbon.

IRON—*continued.*

I. Spark Spectrum	II. Arc Spectrum	Intensity and Character		I. Spark Spectrum	II. Arc Spectrum	Intensity and Character	
Liveing and Dewar	Liveing and Dewar	I.	II.	Liveing and Dewar	Liveing and Dewar	I.	II.
	2448·1		1	2413·0	2413·0	10	10
2447·5	2447·5	6	6		2411·4		1
2447·1		6		2410·7	2410·7	10	10
2446·3	2446·3	6	1	2410·2	2410·2	10	10
2445·9		1		2408·4			1
2445·4	2445·4	6	1	2407·6	2407·6	1	1
2444·9	2444·9	1	1		2407·3		1
2444·3	2444·3	10	2		2406·9		1
2443·7	2443·7	1	6	2406·6		1	
2442·3	2442·3	2	8	2406·3	2406·3	10	10
	2441·5		1	2405·5		1	
2441·0		1		2404·5	2404·5	10	10
2440·1		6		2404·2	2404·2	6	6
	2439·8		6	2402·3	2402·3	2	1
2439·4	2439·4	1	8	2401·9	2401·9	2	1
2439·0		8			2401·4		1
	2437·9		4	2401·0	2401 0	1	1
2437·3		1		2400·0	2400·0	8	1
2436·9		2		2399·0	2399·0	10	10
2436·4		2		2398·5		1	
2436·0	2436·0	1	1		2398·0		1
2435·6	2435·6	1	1	2396·5		2	
2434·7	2434·7	6	2	2395·4	2395·4	10	10
2434·3	2434·3	6	1	2395·2	2395·2	6	6
2433·9	2433·9	1	1	2394·7		1	
2433·2		4			2394·1		1
2432·5		8			2392·8		1
2431·8	2431·8	8	1	2392·4	2392·4	1	1
	2430·7		1	2391·3	2391·3	4	6
2430·5	2430·5	1	1	2390·7		1	
2429·7	2429·7	8	6	2390·1		2	
2429·0	2429·0	1	1		2389·9		6
2428 7		1		2389·2		1	
2428·5	2428·5	1	1	2388·4	2388·4	10	10
2427·9		8		2388·0		1	
2427·0		1		2387·2	2387·2	4	1
2425·4	2425·4	2	1	2386·3		4	
2425·0	2425·0	1	1		2385·8		1
2424·3		1		2384·8	2384·8	2	1
2423·8	2423·8	10	2	2384·2	2384·2	8	8
2422·9	2422·9	4	1	2383·0	2383·0	8	8
2422·4	2422·4	6	1	2382·7	2382·7	6	6
	2421·3		1	2381·7	2381·7	10	10
	2420·7		1	2380·5	2380·5	10	8
	2420·0		1	2379·0	2379 0	10	8
2419·7		1		2378·8		1	
	2419·4		1	2378·2		1	
	2418·9		6		2377·6		1
2418·2	2418·2	2	1		2376·9		1
2417·5	2417·5	8	1	2376·2	2376·2	6	1
	2417·1		1	2374·9	2374·9	10	8
2416·3	2416·3	2	1		2374·1		1
	2415·4		1	2373·4	2373·4	10	8
2414·8	2414·8	1	1	2373·3		4	
2413·8	2413 8	1	1		2372·7		1

IRON—*continued.*

I. Spark Spectrum — Liveing and Dewar	II. Arc Spectrum — Liveing and Dewar	Intensity and Character I.	Intensity and Character II.
2372·3		4	
	2371·1		4
2370·1	2370·1	4	4
2369·6		2	
	2369·1		4
2368·2	2368·2	10	8
2366·2	2366·2	6	6
2365·3		2	
	2365·1		1
2364·4	2364·4	10	8
2363·5		6	
2363·3		6	
2362·9		1	
2361·6	2361·6	6	4
2361·3		1	
	2360·3		1
2359·9	2359·9	10	8
2359·7	2359·7	10	8
2359·2	2359·2	1	1
2358·7	2358·7	10	10
2356·7		4	
	2355·6		1
2355·1	2355·1	2	1
2354·8		2	
2354·6	2354·6	6	6
2354·1	2354·1	6	1
2353·3		2	
2352·1		1	
2351·5	2351·5	1	1
2350·9	2350·9	8	1
2349·9	2349·9	1	1
	2349·5		1
2349·0		1	
2348·0	2348·0	10	10
2347·8	2347·8	10	10
2346·4		1	
2345·9	2345·9	1	1
2344·9		6	
	2344·7		4
2343·9	2343·9	6	4
2343·6	2343·6	2	1
2343·1	2343·1	10	10
2341·8		1	
2341·6		1	
	2341·2		1
2340·0	2340·0	1	2
	2339·3		6
2339·0	2339·0	1	8
2337·7	2337·7	10	8
	2334·8		1
	2334·5		1
	2334·2	1	
	2333·1		1
2332·5	2332·5	10	8
2330·9	2330·9	10	8
	2329·3		1
2326·9	2326·9	10	8
	2319·9		6
	2319·6		1
	2319·2		2
	2317·7		1
	2317·5		2
	2316·7		1
	2313·6		1
	2312·7		8
	2312·0		1
	2311·6		1
	2311·0		2
	2310·6		1
	2309·3		1
	2308·6		8
	2306·0		4
	2305·8		2
	2304·4		2
	2303·4		6
	2303·2		6
	2301·4		6
	2301·0		4
	2300·4		2
	2300·0		6
	2299·2		1
	2299·0		6
	2298·6		4
	2298·0		6
	2297·6		6
	2296·8		6
	2294·2		6
	2293·6		6
	2292·3		6
	2291·4		1
	2290·9		4
	2290·6		1
	2290·3		4
	2289·9		2
	2288·8		6
	2287·9		1
	2287·4		6
	2287·1		6
	2284·0		6
	2283·6		4
	2283·2		2
	2283·0		2
	2282·8		1
	2281·8		1
	2280·0		4
	2279·7		6
	2277·5		4
	2276·9		4
	2275·7		4
	2275·2		1

IRON—*continued.*

Arc Spectrum Liveing and Dewar	Intensity and Character	Arc Spectrum Liveing and Dewar	Intensity and Character	Arc Spectrum Liveing and Dewar	Intensity and Character
2274·9	4	2259·2	4	2214·1	4
2273·8	4	2255·4	4	2211·4	1
2272·5	4	2252·8	4	2210·4	4
2271·8	4	2251·6	1	2207·5	4
2271·5	4	2251·2	1	2200·2	1
2270·5	4	2250·6	1	2200·0	1
2268·8	1	2250·5	4	2199·3	2
2267·2	6	2248·8	4	2195·5	2
2266·8	2	2248·5	4	2191·3	1
2266·6	1	2245·3	2	2186·8	1
2265·7	1	2243·9	1	2186·1	1
2264·7	2	2242·2	1	2183·7	1
2264·2	2	2240·2	1	2181·5	1
2263·2	1	2230·9	1	2178·0	1
2262·8	1	2229·7	6	2177·0	1
2262·4	1	2227·3	6	2173·4	1
2260·7	2	2225·2	4	2171·7	1
2260·4	2	2216·2	6	2167·4	1
2259·8	4				

LANTHANUM.

* Possibly due to Chlorine. † Double. ‡ Observed in the Arc. § See Didymium.
‖ Occurs in Roscoe and Schuster's Terbium Spectrum.

Spark Spectrum Thalén	Spark Spectrum Kirchhoff	Intensity and Character	Spark Spectrum Thalén	Spark Spectrum Kirchhoff	Intensity and Character
6456·0		4	5855·0		2
6410·0		4	5851·0		1
6392·5		8	5847·5		2
6389·0		2	5828·0		1
6325·0		2	5821·5		1
6318·0		2	5820·0		4
6310·0		2	5807·0	5806·2 La. Di.	1
6291·0	6293·7 La. Di.	4	5804·5	5805·1 La. Di.	6
6264·0		2	5794·0	5795·9 La. Di.	6
6261·5		4	5790·5	5790·0 La. Di.	6
6249·0		8	5787·0	5786·1 La. Di.	6
6187·0		2	5769·0	5767·7 La. Di.	8
§6132·0		2	5761·0		4
6128·0		2	5743·0		4
6124·0		4	5740·0		4
6111·0		1	5734·0		2
*6107·0		4	5718·5		2
6099·0		2	5702·5		1
6006 0		4	5673·0		6
5973·0		6	5656·5		4
5929·0		8	5646·5		2
5873·0		1	†5631·0		6
§5867·0		1	5602·0		1
5862·5	5860·6 La. Di.	4	5599·0		1

LANTHANUM—*continued*

Spark Spectrum Thalén	Spark Spectrum Kirchhoff	Intensity and Character	Spark Spectrum Thalén	Spark Spectrum Kirchhoff	Intensity and Character
5587·0		6	4949·0		4
5567·5		4	4945·0		1
5564·5		4	4934·0	4933·9 La. Di.	4
5549·5		4	4920·8	4921·5 La. Di.	10
5534·0		3	4920·0	4920·7 La. Di.	10
5516·0		5	4899·0	4899·1 La. Di.	10
5513·5		1	4878·0		1
5505·0		2	4860·0	4860·2 La. Di.	8
5502·0	5501·9 La. Di.	2	4849·0		6
5500·5	5500·6 La. Di.	8	4842·0		2
5493·0		1	4838·5		2
5491·0		1	4823·5	4822·7 La. Di.	10
5482·0	5484·1 La. Di.	1	4808·0	4809·5	8
5479·5		1	4803·0		8
5475·0		1	4799·5		1
5463·5		1	4796·0		1
5458·0		1	4759·5		1
5454·5	5452·6 La. Di.	8	4757·0		1
5381·0	5380·6	8	4747·5	4746·5 La. Di.	8
5380·3		8	4741·5	4741·0 La. Di.	8
5375·5	5376·1	8	4738·5	4740·0 La. Di.	8
5339·5	5340·1	8	4727·5		6
5302·5		8	4719·0		6
5301·8	5301·3 La. Di.	8	4716·0		2
5301·0		8	‖§4715·0		4
5279·5		2	4702·0		8
§5276·0		2	4699·0		2
5270·5		4	4691·5		8
5259·0		2	4690·0		2
5252·5		4	4687·0		2
5234·0		4	4670·5		8
5225·0		1	4668·0		8
5211·0		4	4662·5		8
§5203·5	5203·6	4	4661·0		8
	5191·8 La. Di.		4654·5		10
	5190·7 La. Di.		4619·0		8
5187·5	5188·0	8	4612·5		8
5182·5	5182·5	10	4605·0		6
5175·5		6	4579·5		8
5166·5		1n	4573·5		8
5162·5		1	4569·5		6
5158·5		1	4567·5		6
5157·0		4	4557·5		10
5156·0		1	4548·5		2
5144·0		2	4541·5		1
5122·0	5122·2 La. Di.	6	4525·5		8
5113·5	5113·8 La. Di.	6	4524·0		6
5096·5		4	4522·0		10
5066·5		1n	4499·5		2
5061·5		1n	§4455·5		4
5055·5		2	4452·0		2
5049·8		2	4430·0		10
4998·5	4999·8 La. Di.	6	4427·0		6
4990·5	4994·2 La. Di.	2	4384·5		6
4985·5		2	4382·5		8
4969·0	4969·6 La. Di.	4	4377·0		4
4951·5		2	4363·0		4

LANTHANUM—*continued.*

Spark Spectrum		Intensity and Character	Spark Spectrum		Intensity and Character
Thalén	Kirchhoff		Thalén	Kirchhoff	
4354·0		8	4142·0		6
4330·0		10	4121·0		10
4322·0		6	4098·5		4
4295·0		10	4086·0		10
4286·0		10	4076·5		10
4280·0		4	4048·0		4
4274·5		4	4042·0		8
4268·0		10	4031·0	‡Lockyer	7
4263·0		8		3995·0	
4248·5		4		3988·0	
4238·0		10	3987·0		4
4235·0		6		3948·1	
4216·5		8	3946·5		6
4202·5		2		3928·3	
4196·0		10		3926·6	
4191·5		6		3920·5	
4184·0		2		3915·5	
4151·5		10			

‡ Arc Spectrum.

LEAD.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum between metallic poles.
† Observed also by Lockyer: the 'indices' denote the 'lengths' of these lines.
§ See Tellurium. || See Silver. ** 4387·3 Kirchhoff.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.
6790				3s	
6655	†6656·3$^{(6)}$	6655·8		10sc	
	†6452·3$^{(5)}$	6453·7		6sc	
	†6059·2$^{(3)}$			2sd	
6034	†6040·2$^{(5)}$	6042·6		6nc	
	†6009·2$^{(2)}$			2nd	
*5997	†6001·7$^{(4)}$	6000·3		6nc	
5895	†5895·1$^{(4)}$			2nd	
5876	†5874·1$^{(2)}$			6nc	
5853	†5856·6$^{(2)}$			4nc	
5823				n	
5776	†5779·1$^{(2)}$			2nd	
*5608	†5607·1$^{(8)}$			10nc	
*5548	†5546·1$^{(6)}$	5544·8		8nc	
	†5523·6$^{(4)}$			4sd	
*5372	†5372·6$^{(6)}$	5373·4		10nc	
5274	†5274·6$^{(2)}$			2sd	
	†5206·7$^{(2)}$			2sd	
*5199	†5201·2$^{(2)}$			6sc	
5190	†5189·2$^{(2)}$			2sd	
5163	†5163·2$^{(3)}$			4sd	
*5044	†5045·1$^{(2)}$	5043·4		8nc	
	†*5004·6$^{(2)}$			6sd	
	†4802·1$^{(1)}$			2nd	
	†4796·6$^{(1)}$			2nd	

LEAD—*continued.*

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
4763	†4760·1(1)			4nd	
	†4573·1			2nd	
	†4401·5(1)			2nd	
		4399·4		2sd	
*4386	†4386·6(4)	4386·4**		9nd	
4271		4271·4		3sd	
	†*4216·0(4)	4245·3		9b'd	
		4180·9		2sd	
	†*4167·5(2)			6sc	
4066	†4062·5(5)	4061·5	(4062·5)	6sc	r
	†*4058·0(8)	4057·6	(4058·5)	3sd	r
		4020·5	4019·0	7sc	r
		3961·5		2sd	
		3951·7		2sd	
		3934·0		3sd	
		3927·5		2sd	
		3910·4		2sd	
		3853·2		3sd	
		3842·9		7sd	
		3832·5		7sd	
		3827·5		7sd	
			3801·0	3sd	
		3785·9		7sd	
		3738·9	3739·3	7sc	
		3734·3		2sd	
		3717·0		3nd	
		3709·0		2nd	
		3688·8		3sd	
			3683·3		8r
		3682·9		7sc	
			3670·7		
		3671·0		7sc	
		3656·1		7sd	
		3639·2	3639·3	7sc	8r
		3591·9		5sd	
		3590·5	3572·0	5sd	
		3572·6		7sc	
		3563·9		3sd	
		3562·2		3sd	
		3484·3		3sd	
		3455·9		3nd	
		3308·9		2sd	
		3296·8		3sd	
		3278·5		5sd	
		3276·9		5sd	
			3260·0		
		3242·4		5sd	
			3238·6		
		3219·9	3219·6	3nc	
		3176·0		9nd	
		3137·3		7nd	
			3118·5		
		3088·5		3sd	
		3086·7		3sd	
		3051·1		3sd	

LEAD—*continued.*

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Hartley and Adeney	Liveing and Dewar	I.	II.
		3043·3		7nd	
		3030·2		2sd	
		3016·5		3nd	
			2981·0		1
		2978·8		2sd	
			2973·5		1
			2967·0		1
		2949·2		3nd	
		2872·2	2872·0	7sc	
		2867·8		2sd	
		2863·2		7sd	
			2850·5		
		2832·2	2832·9	7sc	10n
		2822·1	2822·5	7sc	r
		2801·4	2801·1	10nc	r
			2721·0		
		2716·3		3sd	
			2706·1		
		2697·2	2697·0	3sd	b
		2662·5	2662·7	7sc	
		2650·0	2650·5	5nd	n
		2637·5		2sd	
		2627·4	2627·8	2sd	
		2613·4	2613·7	10nc	8r
		2576·4		7sc	
			2575·7		n
		2567·2		3sd	
		2561·6		7nd	
		{2539·9		2b	
		2523·4}			
		2496·0		2nd	
			2476·5		8r
		2475·7		7sc	
		2462·8		2nd	
		{‖2445·7	2446·1	3sd	8r
		2443·6}	2443·7	3sc	8r
		{2432·3		2sd	
		2427·8}	2428·5	2sd	8r
		§2411·2	2411·5	2sd	8r
		2402·1	2401·8	3sd	8r
			2399·4		8r
		2393·7	2393·7	7sc	10r
		2390·8		2sd	
		2389·0	2388·8	2sd	
		2333·3		2sd	
			2332·0		
		2297·7		2sd	
		‖2247·9		7sc	
		2238·2		2sc	
		2204·3		7nc	
		2170·0		3sd	

Becquerel has observed the following infra-red lines in the Arc Spectrum of Lead :—10598, 10870, and 11330 (strong) ; 12210 and 12290 (weak).

Lithium.

* Observed also by Lecoq de Boisbaudran in the Flame Spectrum of Lithium Salts.
† Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Lithium Chloride solution.
‡ See Cæsium. Observed also in the Lithium Arc Spectrum by Lockyer.
§ Double. ‖ 6706·2 Ketteler; 6763·0 Müller; 6708 Rühlmann; 6703 Fizeau.

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character.	
Huggins	Thalén	Kirchhoff	Mascart	Liveing and Dewar	I.	II.
†*6705	6705·5	6704·4	6705·7‖	(6705·5)	10sc	r
†*6098	6012·2	6012·1	6101·5	(6012·2)	6sc	r
†4972	‡4971·7			(4971·7)	4sc	r
†4602	4602·8		4602·0	§4603·0	10nc	nr
				4273·0		
				†4131·7		nr
				3984·5		r
				3913·5		nr
				3862·3		
				3799·0		
				3232 0		
				2741·0		r
				2561·5		r
				2475·0		r
				2425·5		r
				2394·5		n
				2373·5		n
				2359·0		n

Magnesium.

* Observed, together with the Bands of the Oxide, by Lecoq de Boisbaudran in the Spark Spectrum of solution of Magnesium Chloride.
† 4480·1, Hartley and Adeney.
§ Observed also by Lockyer in the Spectrum of the Spark between metallic poles; the 'indices' attached to these numbers denote the comparative 'lengths' of the lines.

I. Flame Spectrum	II. Spark Spectrum			III. Arc Spectrum	Intensity and Character		
Liveing and Dewar	Kirchhoff	Thalén	Liveing and Dewar	Liveing and Dewar	I.	II.	III.
			5710·7	5710·7		8sc	8sc
		§*5527·4(3)	(5527·4)	(5527·4)		8sc	6sc
(5183)	b_1 5183·0	§*5183·1(4)	5183·1	5183	10sc	10sc r	10sc r
(5172)	b_2 5172·0	§*5172·1(4)	5172·2	5172	9sc	9sc r	9sc r
(5167)	b_4 5166·9	§*5166·9(4)	5166·6	5167	1sc	8sc r	8sc r
Bands of Oxide			4808			2sc	
		§*4703·6(2)	4703·5	4703·5		8nc	8sc
		4586·6	(4586·6)			4nc	
4570·5			4570·5	4570·5	10sc	2sc	10sc r
	4480·9	§*†4481·0	(4481)			8nd	
	Hartley and Adeney	Cornu		4351·2		4s	8sc
				4166·0		4s	8sc
			4057·3	4057·3		4s	4sc
	3896·0		3895·0			4sd	
	3892·0		3893·0			4sd	
3865					4b		
3860					4b		

b_4 See Iron; the Fraunhofer line b_4 is double.

MAGNESIUM—*continued.*

I. Flame Spectrum	II. Spark Spectrum			III. Arc Spectrum	Intensity and Character		
Liveing and Dewar	Hartley and Adeney	Cornu	Liveing and Dewar	Liveing and Dewar	I.	II.	III.
3858					4b		
3855	3855·5		3852		4b	4sd	
3848	3849·5		3847		4b	4sd	
3845					4b		
3841					4b		
(3838)	3837·9	3837·6	(3837·6)	(3837·6)	10s	10sc r	10sc r
(3831)	3832·1	3831·5	(3831·5)	(3831·5)	10s	10sc r	10sc r
(3829)	3829·2	3829·0	(3829·0)	(3829·0)	10s	10sc r	8sc r
3824					4b		
3815					4b		
3810					4b		
3806					4b		
3799					4b		
3790					4b		
3782					4b		
3777					4b		
3772					4b		
3765	3765·2				4b	2nd	
3756					4b		
3750					4b		
3730					10n		
3724					10n		
3720					10n		
	3336·2	3334·2	(3334·2)	(3334·2)		6sc	8sc
	3331·8	3330·0	(3330·0)	(3330·0)		6sc	8sc
	3329·1	3327·0	(3327·0)	(3327·0)		6sc	7sc
		3278·4		?		5sc	?
	3139·3					2sd	
	3134·2					2sd	
	3107·0					4nd	
	3096·2	3095·6	(3095·6)	(3095·6)		10sc	10sc r
	3091·9	3091·9	(3091·9)	(3091·9)		8sc	10sc r
	3089·9	3090·0	(3090·0)	(3090·0)		8sc	8sc r
	3071·6					5sd	
	3046·0					2sd	
	2941·6			2942		2sd	6sc
			2940·3			2sd	
				2938·5			6sc
				2937·5			6sc
	2935·8	2934·9	(2934·9)	(2934·9)		10nc	1sc
	2928·1	2926·7	(2926·7)	(2926·7)		10nc	1sc
	2913·8		2913·2	2913·2		8sd	1sc
	2884·3					3nd	
(2850·3)	2851·2	2850·3	2851·8	2851·8	10sc r	10nc r	10nc r
	2847·9					1sc	
	2845·9					1sc	
	2815·3					2nd	
	2810·0					2nd	
	2801·6	2801·3	2802·4	2802·4		10sc r	10sc r
	2796·9	(2797·1)	(2797·1)			9sc	
	2794·1	2794·5	2795·2	2795·2		10sc r	10sc r
	2789·6	2789·9	(2789·9)			9sc	
	2781·8		2782·2	2782·2		6sc	5sc r
	2780·2		2780·7	2780·7		6sc	5sc r
	2778·7		2779·4	2779·4		8sc	6sc r
	2776·9		2778·2	2778·2		6sc	5sc r
	2775·5		2776·9	2776·9		6sc	5sc r

MAGNESIUM—*continued.*

I. Flame Spectrum	II. Spark Spectrum			III. Arc Spectrum	Intensity and Character		
Liveing and Dewar	Hartley and Adeney	Cornu	Liveing and Dewar	Liveing and Dewar	I.	II.	III.
				2767·5			5sc
				2764·5			5sc
	2736·0			2736		2sd	6ncr
	2734·3			2732·5		2sd	6ncr
				2731			4ncr
				2698			6sc
				2695			6sc
				2693·5			4sc
				2672·5			5ncr
				2670			5ncr
				2668·5			3nc
	2658·4					4nd	
				2649			4sc
				2646			4sc
				2633			3nc
				2630			3nc
				2605			2nc

Becquerel has observed the following infra-red lines in the Arc Spectrum of Magnesium: 8990, 10470 ?, 12000 (probably double) and 12120—the last three presenting the aspect of the group b.

MANGANESE.

* Observed, together with the Bands of Manganese Oxide, by Lecoq de Boisbaudran in the Spark Spectrum of Manganese Chloride solution.

† Observed also by Lockyer; the 'indices' attached to these numbers denote the comparative 'lengths' of the lines.

‖ 'Could not be identified,' Lockyer.

I. Spark Spectrum		II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Ångström	Cornu	Liveing and Dewar	I.	II.
6344						
6122					b	
*6021	†6020·9(4)	6020·9	6020·9		10sc	
*6014	†6015·8(4)	6015·8	6015·7		10sc	
6012	†6012·7(4)	6012·6	6012·5		10sc	
5556					1s	
*5513	†5515·7(4)				2sd	
*5467					1s	
5432	†5443·1(3)				2sd	
*5419	†5419·6(4)				6sc	
	†5412·5(4)				6sd	
*5407	†5406·6(1)				2sd	
5404					1	
5396	†5399·7(4)				4sd	
*5392	†5393·6(4)				4sd	
*5377	†5376·7(4)				6sc	
	*‖5359·1				4sd	
5348					1s	
*5338	†5340·3(4)				6sc	
5295					b	

MANGANESE—*continued.*

I. Spark Spectrum		II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Ångström	Liveing and Dewar	Cornu	I.	II.
*5254	†5254·2$^{(4)}$	5254·2			4sd	
	*†5233·8$^{(4)}$	5233·4			4sd	
	*†5195·4$^{(4)}$	5195·0			4sd	
*4824	†4822·9$^{(4)}$	4822·5	(4822·9)		10sc	r
*4785	†4782·7$^{(4)}$	4782·6	(4782·7)		10sc	r
*4765	†4765·9$^{(4)}$	4765·9			2sc	
	†4764·8$^{(4)}$	4764·8			10sc	
4762	†4761·6$^{(4)}$	4761·4			10sc	
	†4760·8$^{(4)}$	4760·8			2sc	
*4754	†4753·5$^{(4)}$	4753·3	(4753·5)		10sc	r
*4738	†4738·1$^{(1)}$	4738·1			6sd	
*4728	†4729·1$^{(3)}$	4729·1			6sd	
	†4726·1	4726·1			6sd	
*4710	†4708·8$^{(4)}$	4708·8			6sd	
*4503	†4503·6$^{(3)}$	4503·3			2sd	
	†4501·3$^{(3)}$	4501·1			8sd	
4499	†4498·3$^{(3)}$	4498·2			8sc	
	†4495·3$^{(3)}$				2sd	
4490	†4491·1$^{(3)}$	4491·0			2sd	
	†4489·6$^{(3)}$	4489·4			6sc	
	†4479·0$^{(2)}$	4479·0			2sd	
4477	†4472·5$^{(2)}$	4472·2			8sc	
	†4470·6$^{(2)}$	4470·5			8sc	
*4464	†4464·1$^{(2)}$	4464·0			6sc	
4461	†4461·6$^{(3)}$	4461·4			6sc	
	†4461·1$^{(3)}$	4461·0			6sc	
	†4459·9$^{(3)}$	4460·0			2sd	
4457	†4457·8$^{(3)}$	4457·4			6sd	
	†4457·4$^{(3)}$				4sd	
	†4457·1$^{(3)}$	4456·8			2sd	
	†4456·3$^{(3)}$				4sd	
4455	†4455·6$^{(3)}$	4455·7			2sd	
	†4455·3$^{(3)}$	4455·1			6sc	
		4454·5				
4451	†4452·1	4452·1			2sd	
4449	†4450·5$^{(3)}$	4450·5			6sc	
*4436	†4436·5$^{(3)}$	4436·4			6sc	
	†4435·4$^{(3)}$	4435·5			2sd	
*4415	†4414·8$^{(3)}$	4414·8			8sc	
*4281	†4280·5$^{(3)}$	4280·4			6sc	
*4267	†4265·0$^{(3)}$	4264·9			6sc	
*4259	†4258·2$^{(3)}$	4258·1			6sc	
*4237	†4234·8$^{(3)}$	4234·6			10sc	
	†4227·0$^{(4)}$	4227·0			10sc	
	*†4083·5$^{(3)}$	4083·3			6sc	
	†4083·0$^{(3)}$	4082·7			2sc	
	†4079·6$^{(3)}$	4079·6			6sc	
	*†4062·9$^{(2)}$	4062·9			2sd	
	*†4054·4$^{(2)}$	4054·3			6sc	
	*†4048·2$^{(2)}$	4048·0		4048·7	6sc	
	*†4040·6$^{(3)}$	4040·6		4040·6	6sc	
	†4034·0$^{(3)}$	4034·9		4034·9	2sd	
	†4032·9$^{(3)}$	4032·9	(4032·9)	4033·8	2sd	r
	†4031·8$^{(3)}$	4031·8	(4031·8)	4032·7	6sc	r
	†4029·5$^{(3)}$	4029·4	(4029·5)	4029·9	6sc	r

MANGANESE—*continued.*

I. Spark Spectrum		II. Arc Spectrum			Intensity and Character	
Huggins	Thalén	Ångström	Lockyer	Cornu	I.	II.
			3991·7			
			3989·2			
	†3983·2(3)	3988·0			2sd	
		3986·3				
		3986·0				
		3984·6				
			3976·2			
			3974·8			
			3953·4			
				3952·0		
			3951·9			
			3950·9			
			3942·2			
			3928·8			
			3925·7			
			3923·4			
			3922·5			
			3921·8			
			3920·8			
			3917·5			
			3910·7			
			3910·4			
				3881·8		
				3824·0		
				3806·4		

MERCURY.

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of Mercuric Chloride solution, together with the following additional lines :—5647, 5620, 5561, 5529, 5498, 5314, 5292, 5269, 5246, 5222.

† Possibly due to an impurity.

Spark Spectrum				Intensity and Character
Huggins	Thalén	Kirchhoff	Hartley and Adeney	
6383				1
6360				1
6144	6151·2	6151·0		10sc
6088				1
5885	5888·1			8nc
5871	5871·1			4sd
5817				1
5800				.
5788	*5789·6	5790·3		10nc
5768	*5768·1	5768·1		10nc
5678	*5678·1	5678·2		8nc
5594	*5595·1			6nd
5460	*5460·6	5459·8		10nc
5425	5426·1	5425·8		8nc
5364	5364·6			4nd
5281	5278·6			2nd
5218	5217·2			2nd
	5206·2			4nd
5132	5131·2			4nd

MERCURY—*continued.*

Spark Spectrum				Intensity and Character
Huggins	Thalén	Kirchhoff	Hartley and Adeney	
4959	4958·1			6nd
4918	*4916·1			4nd
4826				1
4357	*4358·1	4350·6	4358·0	10sc
			4348·0	2sc
			4341·0	2sc
			4077·5	3nc
	*4078·5		4046·5	10nc
4055	*4047·0		3984·0	8sc
3990	3982·2		3859·0	3nc
			3820·0	3nc
			3807·0	2sc
			3800·0	2sc
			3790·0	8sc
			3770·0	3sc
			3754·7	2sc
			3751·0	8sc
			3681·9	3nc
			3662·9	5nc
			3654·4	6nc
			3632·9	7nc
			3560·1	8sc
			3542·3	8sc
			3492·6	1sd
			3473·4	1sd
			3451·4	1sd
			3389·5	8nc
			3365·5	2sd
			3351·2	3nc
			3341·2	8sc
			3326·4	2sc
			3207·1	3sc
			3130·4	10nc
			3124·5	10nc
			†3094·0	2sc
			3021·0	8nc
			2966·4	10nc
			2946·6	8sc
			2935·5	3sd
			2925·2	3sc
			2915·3	3sc
			2892·9	8sc
			2846·8	10nc
			2832·1	2sc
			2819·7	8nc
			2810·0	2nd
			2804·5	6sc
			2798·5	3nc
			2790·0	3sc
			2773·2	2nd
			2760·8	3sd
			2751·5	6sc
			2702·0	2nd
			2657·6	3nd
			2652·2	8nc
			2644·6	2nd
			2640·6	2nd

MERCURY—*continued.*

Spark Spectrum — Hartley and Adeney	Intensity and Character	Spark Spectrum — Hartley and Adeney	Intensity and Character
2602·3	6sd	2390·0	1nc
2584·2	2sd	2355·2	3nc
2575·3	2nd	2342·2	1nc
2535·8	10sc	2340·0	1nd
2533·8	8nc	2315·2	1nc
2522·7	1nd	2296·5	1sc
2514·3	1nd	2292·6	1nc
2491·4	8sc	2264·2	6sc
2484·2	2nc	2263·3	6sc
2477·7	1nd	2261·4	8nc
2468·0	2nd	2254·0	8sc
2467·0	2nd	2231·0	1sc
2463·7	2nd	2225·7	8nc
2459·3	1nd	2190·9	1sc
2414·3	8sc	2148·0	1sc
2407·3	8sc		

MOLYBDENUM.

I. Spark Spectrum — Thalén	II. Arc Spectrum — Lockyer	Intensity and Character I.	Intensity and Character II.	I. Spark Spectrum — Thalén	II. Arc Spectrum — Lockyer	Intensity and Character I.	Intensity and Character II.
6029·2		10sc			3991·0		
5887·6		10nc			3990·6		
5856·6		8sc			3985·5		
5791·1		6sd			3982·1		
5750·1		6sd			3981·5		
5687·6		6sd			3981·0		
5649·1		4sd			3980·6		
5631·1		4sd			3979·7		
5569·1		10sc			3979·1		
5540·1		2sd			3978·3		
5531·6		10sc			3976·8		
5505·1		10sc			3974·8		
5360·1		4nd			3967·6		
4979·1		2sd			3957·6		
4867·6		4nd			3954·2		
4829·6		4sd			3952·9		
4818·1		4sd			3946·0		
4757·6		4sd			3944·2		
4730·6		4sd			3942·5		
4706·6		4sd			3942·2		
	4576·0				3934·0		
4536·1		4sd			3929·5		
4475·1		4sd			3928·0		
4433·6		4sd			3922·9		
4411·6		4sd			3921·2		
4380·5		4sd			3917·0		
4326·0		4sd			3916·7		
4277·5		6nc			3916·0		
	3999·8				3914·8		
	3997·5				3902·4		
	3993·2				3901·3		
	3992·4						

NICKEL.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Nickel Chloride solution, as also the following lines: —6315, 6261, 5827, 5801, 5756, 5716, 5695, 5665, 5641 (double), 5621, 5609, 5588, 5129, 5048, 4998, 4950, 4808, 4762, 4732, 4606, 4594, 4571, 4550, 4471, 4461, 4327, 4288.

† Observed also by Lockyer; the 'indices' attached to these numbers denote the comparative 'lengths' of the lines.

‡ 5891·9 Thollon.

I. Spark Spectrum		II. Arc Spectrum		Intensity and Character	
Thalén	Kirchhoff	Ångström	Cornu	I.	II.
*†6175·9$^{(3)}$	6175·5	6175·9		6nc	
†6115·5$^{(2)}$	6115·7	6115·2		4sd	
*†6107·7$^{(2)}$	6108·2	6107·1		4sd	
			6011·2		
			6006·3		
			5996·8		
			5995·7		
			5899·8		
†5892·1$^{(2)}$	5892·2	5892·1	‡5891·9	10sc	
			5883·7		
*†5856·6$^{(2)}$	5857·3			4sd	
*†5476·0$^{(4)}$	5475·8	5476·0		6sc	
*†5175·8$^{(2)}$	5176·2	5175·8		2sd	
b_3*†5168·5$^{(2)}$	5168·3	5168·5		2sd	
*†5155·3$^{(2)}$	5154·6	5155·2		2sd	
*†5145·9$^{(2)}$	5145·9	5145·9		2sd	
†5142·2$^{(2)}$	5141·6	5141·8		2sd	
*†5137·5$^{(2)}$	5136·5	5136·8		2sd	
*†5115·0$^{(2)}$	5114·7	5115·0		2sd	
*†5099·8$^{(3)}$	5099·3	5099·3		2sd	
†5098·6$^{(3)}$	5098·8	5098·4		2sd	
*†5080·7$^{(3)}$	5080·5	5080·7		2sd	
†5079·8$^{(3)}$	5080·0	5079·6		2sd	
*†5034·7$^{(2)}$	5034·7	5034·8		6sc	
*†5016·6$^{(2)}$	5017·1	5016·7		6sc	
*†4983·4$^{(2)}$	4982·7	4983·4		2sd	
†4979·7$^{(2)}$	4979·7	4979·4		2sd	
*†4935·2$^{(3)}$	4935·0	4935·2		6sc	
*†4917·7$^{(1)}$	4917·9	4917·7		6sc	
*†4904·0$^{(3)}$	4903·5	4903·9		6sc	
*†4873·0$^{(1)}$	4872·8	4873·0		10sc	
*†4865·4$^{(2)}$	4866·0	4865·5		10sc	
*†4854·8$^{(3)}$	4855·6	4854·6		10sc	
*†4830·3$^{(2)}$	4830·8	4830·2		2sd	
†4828·5$^{(2)}$	4828·7	4828·3		2sd	
*†4785·9$^{(2)}$	4785·3	4785·8		8sc	
*†4755·1$^{(3)}$	4755·3	4754·9		2sd	
*†4713·8$^{(4)}$	4713·6	4713·8		10sc	
*†4647·1$^{(3)}$	4646·7	4647·0		2sd	
*†4401·8$^{(1)}$		4401·9		2sd	
		Lockyer			
		3972·7			
		3971·2			
		3969·2			
			3641·0		
			3618·3		
			3572·9		
			3570·8		
			3565·0		
			3523·9		
			3514·7		

b_3 See Iron; the Fraunhofer line b_3 is double.

NICKEL—*continued.*

Arc Spectrum — Cornu	Intensity and Character	Arc Spectrum — Cornu	Intensity and Character	Arc Spectrum — Cornu	Intensity and Character
3510·2		3372·9		3231·3	
3491·9		3372·4		3212·7	
3470·4		3370·6		3134·4	
3461·5		3367·8		3131·0	
3457·8		3365·3		S₁ { 3100·7	
3445·7		3364·5		3100·5	
3436·0		3363·9		3056·3	
3431·8		3360·3		3053·3	
3422·1		3359·8		3049·6	
3419·5		3320·8		3036·7	
3418·8		3320·3		3030·3	
3413·2		3313·4		3011·2	
3391·4		3310·0		3003·1	
3389·8		3248·6		3002·0	
3378·7		3242·3		2992·0	

NITROGEN.

* Observed also by Plücker, who gives also Nitrogen lines at 6376, 6358, 6341, 6288, 6249, 6165/6152, 5754, 5560, 5330, 5309, 5164, 5160/5152, 5120, 5098, 4743, 4732, 4644 and 4151/4147, of which 5309, 5164 and 4644 have also been noted by Salet.

† Observed also by Salet. § Observed also by Lecoq de Boisbaudran.

Spark Spectrum or Elementary Line Spectrum — Huggins	Thalén	Kirchhoff	Hartley and Adeney	Intensity and Character
6602*†	6602·3§	6603·1		4s
6482*†	6479·8§	6479·9		5s
5950*†	5949·2	5949·6		4s
5942*†	5941·7	5940·2		10n
5930*†	5932·1§	5931·9		10n
5925*†	5929·6	5929·2		4s
5768*†	5767·1			4s
5746†	5745·1			4s
5726				1s
5709*†	5711·1§	5710·8		4s
5686*†	5685·6	5685·6		4s
5680*†	5678·1§	5678·1		10n
5675*†	5674·6	5674·6		6s
5668*†	5666·1	5666·6		10n
5550*†	5549·1			4s
5541*†	5541·1			6s
5534†	5534·1§			8n
5530*†	5530·1			6s
5524*				1s
5495*†	5495·1§			7n
5479*†	5479·1			6s
5462*†	5461·6			4s
5453*†	5453·1§			3s
5350	5351·1			2s

NITROGEN—*continued.*

Spark Spectrum or Elementary Line Spectrum				Intensity and Character
Huggins	Thalén	Kirchhoff	Hartley and Adeney	
5338*	5339·6			2s
5319	5320·1			2s
5179	5184·7			5n
5176	5178·2			4s
5172	5172·2			2s
5071*				2s
5045†§	5045·1	5043·3		8s
5024*†	5025·1			8s
5016*†	5016·1			6s
5010*†	5010·1			6s
5007	5006·6			4s
5003*†§	5005·1	5004·6		10n
4999*†§	5002·1	5000·6		10n
4993*†	4993·6			6s
4986*†	4987·1			6s
4931				1s
4895*†	4895·6			4s
4880*				1s
4866				1s
4858*†				4s
4849*†				4s
4804*†§	4803·1			8s
4788†§	4788·1			8s
4781†	4779·1			10s
4640	4640·2			6s
4629*†§	4630·6	4629·8	4628·9	8s
4621*†	4621·1	4620·7	4619·9	5s
4613*†	4613·1	4612·8	4612·3	5s
4608*†§	4606·6	4606·6	4605·6	6s
4600*†§	4601·1	4601·0	4600·1	6s
4553*†			4553·2	2b
4533*†			4530·1	3n
4506*			4506·6	3s
4496				1s
4490				1s
4477			4476·6	3s
4448*†§	4446·6	4446·3	4446·1	7s
4430*†§	4432·1		4432·6 4425·9	3b 3n
4398†				4s
4347†	4347·5		4348·2	6s
4238*†	4230·0		4236·4 4228·9	6n
4206*			4206·3	2n
4170*†			4176·8 4169·2	4n
4142* 4130*	4137·0		4145·4 4132·8	5s 5s
4101†			4102·6	5s
4094*			4096·5	5s
4038†	4040·1		4041·7	5n
4000†	3995·1		3994·5	8s

Nitrogen.

Band Spectrum			Intensity and Character	
I. Negative	II. Positive			
Ångström and Thalén	Lecoq de Boisbaudran	Ångström and Thalén	I.	II.
		6870·0		$4b^r$
		6785·7		$6b^r$
	6752	6778·6		$4b^r$
		6760·0		$3b^r$
		6701·0		$6b^r$
	6682	6693·4		$4b^r$
		6673·5		$3b^r$
		6621·8		$6b^r$
	6604	6614·2		$4b^r$
		6594·7		$3b^r$
		6542·3		$6b^r$
	6524	6533·8		$4b^r$
		6516·3		$3b^r$
		6465·5		$6b^r$
	6448	6458·6		$4b^r$
		6440·6		$3b^r$
		6392·5		$6b^r$
	6375	6384·8		$4b^r$
		6366·8		$3b^r$
		6321·0		$9b^r$
	6306	6313·8		$7b^r$
		6294·9		$5b^r$
		6249·2		$9b^r$
	6233	6242·6		$7b^r$
		6225·5		$5b^r$
		6183·2		$5b^r$
	6171	6175·1		$4b^r$
		6158·2		$3b^r$
		6125·4		$4b^r$
	6108	6118·8		$3b^r$
		6102·1		$2b^r$
		6066·3		$6b^r$
	6048	6060·6		$4b^r$
		6043·3		$3b^r$
		6011·8		$6b^r$
	5994	6004·6		$4b^r$
		5987·8		$3b^r$
		5957·3		$6b^r$
	5943	5950·5		$4b^r$
		5933·3		$3b^r$
		5904·6		$6b^r$
	5891	5897·5		$4b^r$
		5882·5		$3b^r$
		5853·0		$9b^r$
	5839	5846·1		$7b^r$
		5830·5		$5b^r$
		5801·8		$9b^r$
	5790	5795·3		$7b^r$
		5780·6		$5b^r$

Band Spectrum			Intensity and Character	
I. Negative	II. Positive			
Ångström and Thalén	Lecoq de Boisbaudran	Ångström and Thalén	I.	II.
		5752·0		$9b^r$
	5737	5745·6		$7b^r$
		5730·7		$5b^r$
	5695	5703·8		$4b^r$
	5680	5682·5		$2b^r$
	5650	5657·9		$4b^r$
		5637·2		$2b^r$
	5600	5612·6		$4b^r$
		5594·2		$2b^r$
		5567·9		$6b^r$
	5557	5563·0		$4b^r$
		5551·8		$3b^r$
		5525·2		$6b^r$
		5518·7		$4b^r$
		5506·0		$3b^r$
		5513·4		$6b^r$
		5493·7		$3b^r$
		5482·8		$6b^r$
		5476·9		$6b^r$
		5472·6		$4b^r$
	5457			2n
		5441·9		$9b^r$
		5437·0		$7b^r$
		5422·1		$5b^r$
		5406·4		$9b^r$
		5401·7		$7b^r$
		5387·4		$5b^r$
		5371·7		$9b^r$
		5366·7		$7b^r$
		5353·2		$5b^r$
	5330	5339·7		$3b^r$
	5302	5306·3		$3b^r$
		5273·8		$6b^r$
		5256·3		$3b^r$
		5244·6		$6b^r$
		5239·3		$4b^r$
5227·5			$6b^r$	
	5222	5226·5		$3b^r$
		5213·1		$9b^r$
		5207·7		$7b^r$
		5196·1		$5b^r$
		5183·4		$9b^r$
	5177	5179·3		$7b^r$
		5165·8		$5b^r$
		5153·7		$6b^r$
5150·0			$3b^r$	
		5149·0		$4b^r$
		5138·7		$3b^r$
		5126·5		$6b^r$

NITROGEN—*continued.*

Band Spectrum			Intensity and Character		Band Spectrum			Intensity and Character	
I. Negative	II. Positive				I. Negative	II. Positive			
Ångström and Thalén	Lecoq de Boisbaudran	Ångström and Thalén	I.	II.	Ångström and Thalén	Lecoq de Boisbaudran	Ångström and Thalén	I.	II.
		5097·7		6b^{r}		4492	4489·0		6b^{r}
	5064	5065·6		6b^{r}		4414	4417·0		6b^{r}
		5032·0		6b^{r}		4345	4346 0		6b^{r}
	4973	4972·0		6b^{r}	4281·0			5b^{r}	
	4916	4919·0		6b^{r}		4269	4271·0		6b^{r}
	4814	4813·0		6b^{r}	4239·0			4b^{r}	
	4724	4722·0		6b^{r}	4203·0	4200	4203·0	3b^{r}	6b^{r}
4709·3			7b^{r}		4175·0			2b^{r}	
	4663	4666·0		6b^{r}			4144·0		5b^{r}
4653·5			6b^{r}			4139			
	4644	4649·0		6b^{r}		4093	4098·0		2b^{r}
4601·2			5b^{r}			4062	4063·0		5b^{r}
	4576	4574·0		6b^{r}		4000	4002·0		3b^{r}
4555·2			4b^{r}				3952·0		1b^{r}
4516·5			3b^{r}						

OSMIUM.

Spark Spectrum		Intensity and Character	Spark Spectrum		Intensity and Character
Huggins	Thalén		Huggins	Thalén	
6460		2s	5414		3s
6280		1s	5201		1s
5991		1s	5073		1s
5858		2s	4550		1s
5777		1s	4419	4422·1	8sd
5719		2s	4357		2s
5582		2s	4311		2s
5521		4s	4294		2s
5440		1s	4260		6s

Lockyer has observed the following lines in the Arc Spectrum of Osmium between wave-lengths 3900 and 4000 :—3990·4, 3975·5, 3962·7, 3918·3.

Oxygen.

* Observed also by Plücker. † 4648·9 and 4641·4 Kirchhoff.
‡ Observed also by Salet, who gives also lines at 6450, 6120, 4475.
§ Observed also by Ångström. ‖ Observed also by Lecoq de Boisbaudran.
¶ This band is made up of lines at 5205·0, 5213·3, 5216·9, 5225·3, 5231·2, 5239·0, 5247·7, 5255·0, 5262·7, 5269·5, 5276·9, 5284·4, 5292·5.
** 6171·1 Kirchhoff; 6170 Ångström.
†† This band is made up of lines at 5552·8, 5558·4, 5564·5, 5570·1, 5575·8, 5581·2, 5591·4, 5601·2, 5611·2, 5618·8, 5629·6.

I. Compound Line Spectrum	II. Elementary Line Spectrum				III. Negative Glow Spectrum	Intensity and Character		
Schuster	Huggins	Hartley and Adeney	Thalén	Schuster	Schuster	I.	II.	III.
	6171*‖		6170·7**‡				5s	
6156·9						6s		
					6010 to 5960			b
					5900 to 5840			b
					5630 to 5553 ††			b
5435·6						6s		
5329·4						6s		
					5292 to 5205 ¶			b
	5205			5205·4§‡			6s	
	5190*		5189·7	5189·6§‡			4s	
			5178·2*	5175·4‖§‡			3s	
	5163*§‡						2s	
				5159·3§			5s	
	4953*			4954·4§			3s	
	4943*		4941·1‖	4942·2 ‡§			8n	
				4940·2			5n	
	4925*		4924·1	4923·7‡§			6s	
	4907*		4906·1	4906·1‡§			5s	
	4892*			4890·1‡§			3s	
	4872*			4871·0‡§			4s	
				4864·0*§			3s	
				4860·2‡§			3s	
				4856·2*§			4n	
	4853*			4850·0 to 4841·6 ‡			1b	
				4750·1*			1s	
				4740·9*			1s	
			4712·1*	4709·0‡§			6s	
	4705*‖		4706·6	4704·6‡§			10s	
	4699*		4698·1	4698·5‡§			8s	
				4695·5*‡			1s	
	4677*	4674·2	4675·1	4675·4‡§			3s	
				4673·1			1s	
	4662*	4660·2	4661·6	4660·7‡§			3s	

OXYGEN—*continued.*

I. Compound Line Spectrum	II. Elementary Line Spectrum				III. Negative Glow Spectrum	Intensity and Character		
Schuster	Huggins	Hartley and Adeney	Thalén	Schuster	Schuster	I.	II.	III.
	4648*‖	4647·2	4649·1†	4649·3§‡			3s	
				4648·0			9s	
		4641·2	4642·1†	4640·6§‡			7s	
	4640*		4640·1	4637·4§‡			6s	
				4608·0			2n	
				4605·7			1s	
	4596*	4595·0	4596·1	4595·1§‡			5s	
	4588*	4589·3	4590·6	4589·9§‡			5s	
	4467*	4466·1		4469·2‡			4n	
				4465·3			3n	
		4458·7*‡					3s	
				4452·7‡*			2s	
				4448·3			2s	
				4443·0*‡			1s	
	4416*‖	4415·5	4418·1	4416·8§‡			7s	
	4414*	4413·6	4414·1	4414·5§‡			8s	
				4395·6*			1s	
4367·6						6s		
	4364*	4365·8	4368·1	4366·2§‡			4s	
		4350·5	4350·5	4353·5			4s	
	4347*‖	4348·2	4347·5	4349·0§‡			6s	
			4346·0	4346·9*§			5s	
		4343·9		4345·0§			1s	
				4341·4*			1s	
		4335·9	4333·0	4336·6*§‡			2s	
	4318*‖‡	4318·7	4319·0	4319·2 *§			3s	
		4316·2	4316·5	4316·5 §			3s	
	4278							
	4190*‡	4189·3§	4189·5				5s	
	4183‡	4185·1§	4184·5				5s	
			4155·0*‡§				1n	
	4149*		4149·0‡§				3s	
		4123·7§	4123·0*‡				4s	
	4117*	4119·0§					5s	
		4075·1	4075·5‡				6s	
	4073*		4074·0 ‡§					
		4071·4§	4071·5				6s	
	4069*	4069·2§	4069·5				6s	

For ultra-violet lines, possibly due to oxygen, see 'Air.'

Plücker gives also oxygen lines at 6452, 6118, 5340, 5315, 5144, 4848, 4327, 4262, 4243, 4171, 4136, 4101, and 4094, of which 4243 has also been noted by Lecoq de Boisbaudran.

PALLADIUM.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Palladium Chloride solution, together with the following lines :—6778, 6177, 5495, 4917, 4170, 4088.
† Double.

Spark Spectrum			Intensity and Character	Spark Spectrum			Intensity and Character
Huggins	Thalén	Kirchhoff		Huggins	Thalén	Kirchhoff	
6381			1sc	5512			2nd
6248			1sc	5465			2s
*6125	6129·2	6129·4	2sc	*5436			1n
5895			b	*5394	5394·1	5394·0	8sc
5866			3sc	*5359	5361·6	5361·9	4sd
5854			1n	*5342	5345·1	5344·1	4sd
5823			1s	*5310	5312·1	5312·8	4sd
5805			n	*5292	5295·1	5293·7	10sc
5787			n	*5254	5257·1	5255·7	4sd
*5737		5736·4	5sc	5249			2sc
5733			1sc	*5233	5233·7	5234·3	8sc
	*5694·1	5693·9	6sd	*5209	5208·2	5207·8	4sd
*5669	5668·1	5668·8	6sd	*5163	5163·2	5163·4	10sc
*5653	5651·1		4sd	*5116	5116·6		8sd
*5638	5640·1	5642·5	4sd	*5110	5110·1	5110·7	8sd
*5622	5618·1		6sd	*5062		5062·6	3n
5607			1sc	*4876	4874·6	4874·9	6sd
*5599			4sc	*4818	4817·1	4821·0	6sd
5587			4sc		*4787·1	4787·1	6sd
5564			1sc	*4474	4473·6	4473·5	6sd
*5546	5546·1	5545·4	6sd		4278·0		2nd
5540	5542·1	5540·3	6sd	*4212	4212·5		8sc
		*5528·7					

Lockyer has observed the following lines in the Arc Spectrum of Palladium between the wave-lengths 3900 and 4000 :—3991·5, 3984·8, 3957·7.

PHOSPHORUS.

I. Band Spectrum		II. Line Spectrum		Intensity and Character	
Lecoq de Boisbaudran	Salet	Plücker	Salet	I.	II.
		6505	6510		6
		6457	6460		4
		6433			1
		6370			2
		6200			1
		6173			4
		6100			4
	6090				
		6071			4
		6057			10

PHOSPHORUS—*continued.*

I. Band Spectrum		II. Line Spectrum		Intensity and Character	
Lecoq de Boisbaudran	Salet	Plücker	Salet	I.	II.
		6043 ⎫	6038		⎧ 4
		6032 ⎭			⎩ 10
			6017		
δ5994	5990	5990		5b^r	2
		5964			2
	5900				
	5840				
		5601			2
γ5605	5590	5589	5590	8b	2
		5552 ⎫	5545	3n	2
5538		5540 ⎭			
	5520				
		5500	5505		4
		5486			2
		5480			
	5470			b^r	
		5462	5463		4
		5452			4
5136				3n	
		5420	5420		10
		5402			8
		5381			8
		5358	5365		1
		5337	5330		8
		5306			8
		5284	5283		10
c.5263	5250			9b^v	
		5243	5245		10
		5178			
β5106	5110			8b	
5024	5030	4972		3n	4
			4935		4
4890	4910			2n	
	4780				
	4700				
		4600	4600		10
		4588	4590		10
		4557			b
		4529			b
		4501			b
		4477			4
		4472			b
		4423			4
		4232			2
		4222			2
		4180			2

Platinum.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Platinum Chloride solution, together with the following lines;—6757, 6319, 6219, 5758. 4999, 4659, 4415, 4191, 4165, 4118.
† Double.

Spark Spectrum Huggins	Thalén	Kirchhoff	Intensity and Character
	*6522·3	6522·3	6sc
6374			1n
*6015			4s
		5988·1	
		*5982·3	1s
5979		5975·4	n
5964	5963·7	5961·7	6sc
5952		5951·7	4s
*5840	5845·1		4s
5835	5837·1		4s
†5800	5806·1		4
*5477	5478·1		4sd
	5475·6	5474·7	4sd
*5389	5389·6		6sc
*5367	5367·6		8sc
*5299	5301·6	5300·4	10sc
*5226	5226·2	5226·3	8sc
5196	5198·2		4sd
*5059	5059·6	5059·6	8sc
	*4879·1	4878·8	4sd
	4851·6		4sd
	4803·1		4sd
*4553	4551·9		8nc
*4521			5s
*4499	4498·3	4498·2	8sc
*4444	4442·1	4442·3	4sd
	*4389·5		4sd
*4327	4327·0		4sd

Lockyer has observed the following lines in the Arc Spectrum of Platinum between the wave lengths 3900 and 4000:—3995·9, 3979·7, 3965·1, 3952·5, 3947·3, 3924·4, 3922·0, 3910·2, 3905·8, 3903·7, 3903·0, 3900·2.

Potassium.

* Observed also by Salet.

I. Flame Spectrum	II. Spark Spectrum				III. Arc Spectrum	Intensity and Character		
Lecoq de Boisbaudran	Lecoq de Boisbaudran	Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.	III.
α { 7697	δ { 7698			7700·2	(7698)	8s	8s	r
α { 7663	δ { 7661			7680·5	(7661)	8s	8s	r
	γ { 6946	6953		6940·5	(6946)		8s	r
	γ { 6913	6932		6915·7	(6913)		7s	r
		6305						
		6246						
	6116	6120					2s	

POTASSIUM—*continued.*

I. Flame Spectrum	II. Spark Spectrum				III. Arc Spectrum	Intensity and Character		
Lecoq de Boisbaudran	Lecoq de Boisbaudran	Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.	III.
β 5831	α *5831	5831	5829·1		(5831)	3s	10sc	r
	*5812	5811			(5812)		6s	
5803	5801	5800	5802·1		(5801)	4s	10sc	r
5783	*5783		5782·6		(5783)	3s	10sc	r
	5638						2sc	
		5516						
	β *5355		5353·6		(5355)		8nd	r
δ5342	*5336		5338·6		(5338)	3n	8nd	r
					5334·5			
	*5319		5322·6		(5319)		8nd	r
	η *5112				(5112)		5n	r
5104					(5098)	2b		
	*5095				(5095)		5n	
	5081				(5081)		1n	
	5050						2s	
	5025						1n	
	5002						6s	
	4963				(4964)		1n	
					4956			
4948					4950	2b		
	4936				4942		2n	
					4870			n
					4863			n
					4856			n
					4850			n
	ζ4828	4827	4827·1				6sd	
					4808			n
					4803			n
					4796			n
					4788			n
					4759			
	4607						3s	
	4505						2s	
	4387	4386					3n	
	4307	4309	4309·5				4sd	
	4262	4263					2s	
	4185	4184					4s	
γ4045	*4044	4044			4045	3b	8n	r
					4042			r
					3445·0			8r
					3443·6			8r
					3216·5			7r
					3101·0			6r
					3033·0			5r
					2992·0			4r
					2963·4			3r
					2942·0			2r

Becquerel has observed infra-red lines at 7700, 10980, 11020, and 12330.

Rubidium.

* Double.

I. Flame Spectrum	II. Spark Spectrum		III. Arc Spectrum	Intensity and Character		
Lecoq de Boisbaudran	Thalén	Kirchhoff	Liveing and Dewar	I.	II.	III.
7951			(7951)	4s		
δ7800			(7800)	8s		r
γ6297	6296·7	6297·7		8s	10sc	
ε6203	6204·2	6204·2		6s	8sc	
6159	6160·2	6159·2		4s	6sd	
	6070·2				6sd	
6059				2s		
ζ {5724				6s		
ζ {5650				5s		
5429				5s		
5359				3s		
5259				3s		
5194				1s		
*5161				3n		
5085				1b		
5021				1n		
	4776·1				4sd	
	4569·6				2sd	
	4551·1				2sd	
β4216			(4216)	9sr		
α4202	4202·0		(4202)	10sr	8nc	

Samarium.

* Possibly due to Chlorine.
† These lines occur in Roscoe's 'Terbium' Spectrum, *Journ. Chem. Soc.* xli. p. 283.

Spark Spectrum — Thalén	Intensity and Character	Spark Spectrum — Thalén	Intensity and Character	Spark Spectrum — Thalén	Intensity and Character
5830·0	2	5511·0	1n	†5271·0	6
5802·0	2n	5497·5	2	†5251·0	4
5787·0	2	5493·5	5	*5221·0	1
5777·0	1	5485·0	2	5200·0	6
5773·0	1	5465·5	4	†5174·5	4
5763·0	1	5452·0	5	†5172·5	4
5757·0	1	5421·0	1	5166·5	1
5732·0	1	5415·5	1	5161·0	1
5705·5	2	5410·5	1	5157·0	1
5695·0	2	5404·5	3	†5155·0	2n
5659·0	2	5403·0	1	5143·0	1
5643·0	1n	†5367·5	4	†5121·5	4n
5640·0	2	5348·5	1n	†5117·0	6
5625·0	2	†5340·5	4	†5104·0	1
5621·0	1	†5320·0	4	5103·5	1
5551·0	4n	†5302·0	1	†5103·0	1
5515·0	5	†5282·0	4	†5100·0	1

SAMARIUM—*continued.*

Spark Spectrum	Intensity and Character	Spark Spectrum	Intensity and Character	Spark Spectrum	Intensity and Character
Thalén		Thalén		Thalén	
5088·5	1n	4661·0	3	†4427·0	1
5080·0	2	4655·0	1	4424·5	8
†5071·0	4	4648·5	4	†4420·5	4n
†5069·0	2	4647·3	2	†4418·5	1
†5052·5	4	†4646·5	2	4416·5	1
5044·0	6	4645·0	2	4411·0	1
†5028·0	3	†4642·0	4	†4408·5	1
4975·5	2	4629·5	2n	4402·0	2
4971·5	1	4626·5	4	4400·5	1
4961·5	2	†4615·0	4	4396·5	1
4952·5	2	4610·5	1	4393·0	1
4949·0	2	4605·5	2	†4390·0	6
4946·0	1	†4594·5	1	4384·0	1n
4923·0	2	†4593·0	4n	4379·5	2
4919·0	4	†4584·5	3	4378·0	2
4913·0	1	†4581·0	4	4374·5	1
4910·5	4	†4577·0	3	†4373·0	2
4904·0	2	4567·0	4	4370·0	1
4883·5	6	†4560·5	2	4367·0	1
4868·0	1	4556·5	1	†4361·5	2
†4847·0	4n	4554·0	2	†4351·5	2
4843·0	2	†4552·5	3	†4350·0	2
†4841·0	6n	†4544·0	4	†4347·0	4
4829·0	1	4542·0	1	4345·5	2
†4815·0	6	4540·5	1	4336·0	1
4792·0	1	†4537·5	4	4334·0	2
†4790·0	1n	4534·0	1	4329·0	2
4785·0	4	†4524·0	4	4323·0	1
4782·5	4	†4522·5	4	†4318·5	4
†4777·0	2	†4519·5	4	†4313·0	1n
†4773·5	2	4514·5	2	†4309·0	2
4770·0	1	†4511·0	4	4304·5	1
4759·5	6	4504·0	1	4296·5	4n
4750·0	1	4502·0	2	4291·5	1
†4745·0	4	†4498·0	4	4286·5	1n
4728·0	6	4479·5	1	4282·0	1
†4725·0	1	4477·5	4	4280·0	4n
†4720·0	1	†4473·0	1n	4275·0	2
4715·5	2n	†4470·5	2	4271·5	1
4712·5	1	†4466·5	8	4262·5	3
†4703·5	6	4457·5	4	4256·5	4
4688·0	2	†4454·0	6	4244·5	1n
4687·0	2	†4452·5	6	4237·0	1n
4680·5	1	†4444·0	2n	4234·5	1n
†4676·5	2	4443·5	2	4229·5	1n
†4673·5	4	4441·0	2	4224·5	2n
4670·0	2	†4435·0	1	4219·5	1n
†4668·5	4	†4433·5	8n	4204·5	2
4663·0	1	4429·0	2	4130·0	1n

SCANDIUM.

* Possibly double. † Probably due to the Oxide.

Spark Spectrum Thalén	Intensity and Character	Spark Spectrum Thalén	Intensity and Character	Spark Spectrum Thalén	Intensity and Character	Spark Spectrum Thalén	Intensity and Character
6304·0	10	5723·5	4	5340·0	1	4921·5	1
6279 0	2	5716·0	4	5339·0	1	4908·5	1
6258·0	2	5710·5	4	5317·5	2	4838·0	1
6246·0	6	5707·5	4	5284·5	4	4833·0	1
6238·0	6	5699·5	8	5257·5	4	4827·0	1
6210·0	8	5686·0	8	5239·0	8	4753·0	1
6192·5	$2b^r$	5683·2	4	5218·5	2	4743·0	6
6153·0	$6b^r$	5671·0	8	5210·0	2	4739·5	6
6145·0	$2b^r$	5667·5	4	5117·0	2	4737·0	4
6140·0	$4b^r$	5665·7	4	5100·5	1	4733·2	4
6115·0	$8b^r$	5656·5	8	5098·5	4	4728·5	4
6100·5	$6b^r$	5640·0	6	5096·4	1	4669·5	8
6079·0	$10b^r$	5590·5	2	5089·5	1	4572·5	1
6071·5	$8b^r$	5564·0	2	5086·5	5	4556·0	1
6064·0	$8b^r$	5526·0	12	5085·0	4	4415·0	10
† 6037·0	$10b^r$	5519·5	6	5083·0	5	4400·0	10
6016·0	$4b^r$	5513·5	6	5081·0	6	4385·0	1
5918·0	$2b^r$	5484·0	6	5075·5	1	4374·0	10
5886·5	b^r	5481·0	6	5070·0	4	*4354·5	1
5877·0	b^r	5451·0	1	5063·5	2	4324·5	10
5848·5	b^r	5445·5	4	5030·5	10	4320·0	10
5842·0	b^r	5391·3	6	4991·0	1	4314·0	10
5809·0	b^r	5374·5	4	4979·5	1	4306·0	1
5801·5	b^r	5355·0	6	4973·0	1	4295·0	1
5772·0	b^r	5348·5	6	4953·5	2	4248·5	10
5736·5	b^r	5341·5	1				

SELENIUM.

* Double.

I. Band Spectrum	II. Spark Spectrum		Intensity and Character		I. Band Spectrum	II. Spark Spectrum		Intensity and Character	
Salet	Salet	Plücker and Hittorf	I.	II.	Salet	Salet	Plücker and Hittorf	I.	II.
		6503		6		5630	5628		6
		6480		6		5600	5596		6
		6431		6		5570	5566		6
		6308		6		5530	5524		6
		6166		b	5500				
		6135		b			5461		b
	6070	6070		6			5448		b
		6035		2			5391		2
		5952		2			5374		8
5870									
					5370				
		5856		6		α5307	5293		10
		5845		2		β 5270	5259		8
5790					5270				
						5250	5243		8
		5746		2			5232		4
		5700		2			5220		4
		5683		4		γ5223	5215		10
		5668		2	5160	δ5177	5162		10
5650							5153		2

SELENIUM—*continued.*

I. Band Spectrum	II. Spark Spectrum		Intensity and Character		I. Band Spectrum	II. Spark Spectrum		Intensity and Character	
Salet	Salet	Plücker and Hittorf	I.	II.	Salet	Salet	Plücker and Hittorf	I.	II.
	ε5142	5124		10			4700		b
		5115		4			4675		b
		5103		4	4670				
		5099		4			4663		b
	ζ 5095	5091		10		ν4658	4654		10
		5089		4		4640	4638		8
	ζ 5070	5066		6		4620	4619		8
					4610				
		5048		2		π4607	4606		10
		5029		6			4596		4
		5014		2			4567		2
5050		5003		2			4516		b
		5000		2			4469		b
	η 4995	4994		10			4447		b
	η 4970	4975		10			4414		b
4950				b			4402		b
4840	θ4840*	4845		10			4383		b
		4840		10			4349		b
	μ4760	4776		10			4318		b
4750						4270	4269		b
	4745	4744		b		4215	4219		b
	4735	4734		4		4170	4179		b
		4707		4			4138		b

SILICON.

* Double.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Salet	Plücker	Kirchhoff	Liveing and Dewar	I.	II.
α6360	6329			b	
β5981	5978			b	
		5058·1			
γ5049	*5043	5043·4		b	
δ4420				b	
	4205?			b	
ε4130	4160?			b	
ζ3890		Hartley and Adeney			
		2881·0	2881·1		
		2631·4			
		2541·0			
		2528·1	2528·1		
		2523·5	2523·9		
		2518·5	2518·8		
		2515·5	2515·8		
		2513·7	2514·1		
		2506·3	2506·6		
		2435·5	2434·8		

SILVER.

* Observed by Lecoq de Boisbaudran in the Spark Spectrum of Silver Nitrate solution, together with the following:—5022, 4997, 4968, 4669, 4622, 4570, 4518, 4434, 4396, 4208.
† 5463·5 and 5207·1, Mascart. ‡ See Tin. § Observed also by Lockyer.
|| See Lead. ** See Copper.

I. Spark Spectrum			II. Arc Spectrum	Intensity and Character	
Huggins	Thalén	Kirchhoff	Liveing and Dewar	I.	II.
6371				1sc	
6249				1sc	
6034	6036·2			2nd	
5973				1sc	
5854				1sc	
	5656·1			4nd	
5644	5645·1			4nd	
5626	5625·6			4nd	
5622	5622·6			8nd	
5607	5610·6			4nd	
5590	5590·1			4nd	
5570	5568·1			4nd	
	5556·6			2sd	
5558	5551·6			8sc	
	5522·1			4nd	
	5486·6			2nd	
5471	5470·1	†5469·9		8sc	
5463	*5464·1	5464·0	(5464·1)	10sc	r
5426	5423·6			6nd	
5412	5411·1			2nd	
5401	5401·6			8nc	
	5299·1			6nd	
5207	*5208·9	†5208·7	(5208·9)	10sc	r
	4874·1			8sc	
	4666·6			4sd	
	*4475·1			4sd	
		Hartley and Adeney	§4211·3		
			4208		
			§4053·0		r
		3541·3		2sd	
		3404·2		2sd	
		3389·7		2sd	
		3382·3		10sc	
		‡3351·8		2nd	
		3311·6		2sd	
		3306·1		2sd	
		{3300·6		2sd	
		{3299·0		2sd	
		3292·3		2nd	
		3288·6		2nd	
		3280·1		10sc	
		3272·8		2nd	
		3265·2		2nd	
		3260·2		2nd	
		3251·8		2nd	
		3243·8		4sd	
		{3231·8		2nd	
		{3228·6		2nd	
		3222·3		2nd	

SILVER—*continued.*

Spark Spectrum Hartley and Adeney	Intensity and Character	Spark Spectrum Hartley and Adeney	Intensity and Character	Spark Spectrum Hartley and Adeney	Intensity and Character
3216·0	2nd	2552·0	1sd	2365·8	4sd
3208·1	2nd	2534·5	7sd	2364·3	5sd
3198·8	2nd	**2506·0	7sd	2362·3	5sd
3190·6	2nd	2503·6	4sd	2359·2	5sd
3183·7	2nd	2486·4	2sd	2358·1	7sd
3179·2	2nd	**2485·4	2sd	2343·7	1sd
3174·3	2nd	2479·9	5sd	2342·1	1sd
3134·9	1nd	2476·8	6sd	2339·2	1sd
3129·2	1nd	**2473·3	7b^{r}d	2332·5	1sd
2937·4	2sd	2469·0	2sd	2331·7	9b^{r}d
2933·5	5sd	2462·2	5sd	2325·8	7b^{r}d
2928·2	5sd	2459·8	5sd	2325·3	9b^{r}d
2919·1	4sd	2453·0	7sd	2322·3	4nd
2901·6	5sd	2447·4	9sd	2320·6	9b^{r}d
2895·6	5sd	‖2445·7	4sd	2319·5	2sd
2872·7	5sd	2443·9	5sd	2317·4	9b^{r}d
2814·5	5sd	2437·3	9nd	2310·1	4sd
2798·9	5sd	2429·8	9sd	2296·8	2sd
2766·4	7sd	2428·8	4sd	2286·7	1sd
2755·5	7sd	2422·8	2sd	2280·7	9b^{r}d
2742·9	2sd	2419·9	7sd	2277·8	2sd
2720·6	1sd	2414·5	1sd	2275·3	2sd
2711·3	7nd	2413·3	9b^{r}d	2254·1	4sd
2680·5	6sd	2411·3	8b^{r}d	2249·9	7b^{r}d
2659·6	7sd	2409·3	1sd	‖2247·6	7b^{r}d
2656·2	4sd	2406·4	2sd	2230·6	5b^{r}d
2627·3	4sd	2404·5	2sd	2206·0	1sd
2625·2	4sd	2395·7	2sd	2202·0	1sd
2613·7	4sd	2393·3	1sd	2186·0	4b^{r}d
2605·4	4sd	2390·8	5sd	2165·8	2sd
2598·2	1sd	2386·7	2sd	2161·3	1sd
2594·7	2sd	2386·2	2sd	2145·4	4b^{r}d
2579·9	7sd	2383·6	2sd	2119·0	1nd
2565·8	2nd	2375·5	6nd	2112·0	1nd
2563·2	2nd				
‖2561·5	3sd				

SODIUM.

* Observed also by Lecoq de Boisbaudran in the Spark Spectrum of Sodium Sulphate.
† Observed by Lockyer. The 'indices' attached to these numbers denote the comparative 'lengths' of the lines.

I. Spark Spectrum		II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Cornu	Liveing and Dewar	I.	II.
†6155$^{(3)}$	*6160·2		(6160·2)	8sc	
†6149$^{(3)}$	6154·4		(6154·4)	8sc	
D_1 †5895$^{(4)}$	*5895·1		(5895·1)	10sc	r
D_2 †5889$^{(4)}$	5889·1		(5889·1)	10sc	r
†5687$^{(3)}$	*5687·3		(5687·3)	6sd	r
†5681$^{(3)}$	5681·5		(5681·5)	6sd	r

SODIUM—*continued.*

I. Spark Spectrum		II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Cornu	Liveing and Dewar	I.	II.
			* 5673·6		r
			5668·6		r
†5154[1]	* 5155·0		(5155·0)	6sd	s
†5159[1]	5152·7		(5152·7)	6sd	s
†4985[1]	* 4983·3		4983	4nc	nr
	4982·0		4982		nr
			4980·5		n
			* 4751·4		s
			4747·5		s
			* 4667·5		nr
			4663·7		nr
			4543·6		s
			4540·7		s
			4496·4		n
			4494·5		n
			4423·0		s
			4419 5		s
			4393		b
			4390		b
			4343		b
			4325		b
		3301·2			
		3300·8			

Becquerel has observed infra-red lines at 8190 and 11420 in the Arc Spectrum of Sodium.

STRONTIUM.

* Observed by Lecoq de Boisbaudran, together with the bands of Strontium Oxide, in the Spark Spectrum of solution of Strontium Chloride.

† Observed also by Lockyer: the 'indices' attached to these numbers denote the comparative 'lengths' of the lines.

‡ See Barium. § See Calcium. ‖ See Iron. ¶ See Manganese.

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Lockyer	Liveing and Dewar	I.	II.
7108					4s	
6885					4s	
6790					4s	
6641					1s	
6606					2s	
*6548	†6550·3[2]				4sd	
6502	†6501·8[2]	6502·7			8sd	
6435					b	
6410	†6407·3[1]	6407·4			10sc	
6388	†6387·3[2]				6sd	
6383	†6380·3[2]				4sd	
6369					1s	
6347					1s	
6343					1s	
6311					b	
6274					1s	
6251					b	
6220					b	

STRONTIUM—*continued.*

I. Spark Spectrum			II. Arc Spectrum		Intensity and Character	
Huggins	Thalén	Kirchhoff	Lockyer	Liveing and Dewar	I.	II.
6172					1s	
6098					2s	
5998					b	
5977					b	
5971	†5970·7(2)				2sd	
	†5850·1(2)				2sd	
5816					1s	
5766					1n	
5647					2n	
5623					3s	
5579					1s	
5543					4s	
*5540	†5540·1(2)	5539·4			6sd	
5531	†5533·0(2)	5533·6			8sc	
*5519	†5522·6(2)	5520·6		(5522·6)	8sc	r
*5500	†5503·6(2)	5503·0		(5503·6)	8sc	r
5496					b	
5487	†5485·1(1)	5484·8			6sd	
*5480	†5480·1(2)	5180·8		(5480·1)	10sc	r
*5450					5s	
5423					2s	
5383					3b	
*5254	†5256·1(1)	5256·6		(5256·1)	8sc	r
*5238	†5238·7(1)	5238·1		(5238·1)	10sc	r
*5228	†5228·7(1)	5228·3		(5228·7)	6sd	r
5224	†5225·7(1)	5225·4		(5225·7)	6sd	r
5221	†5223·7(1)	5222·8		(5223·7)	6sd	r
5217					2s	
*5155				(5155·0)	2s	r
5102					1	
*4967	†4967·6(1)				4sd	
4962	†4961·6(1)			(4961·6)	8sc	r
4943					1b	
*4893				(4893·0)	1s	r
*4875	†4876·1(1)			(4876·1)	6sd	r
4872	†4872·1(1)			(4872·1)	6sd	r
4865				(4865·0)	2	r
4853					2	
*4830	†4831·6(1)			(4831·6)	6sd	r
*4811	†4812·1(1)			(4812·1)	6sd	r
*4784	†4783·6(1)			(4784)	6sd	
4750					1s	
4742	†4740·6(1)			(4741)	6sd	
*4721	†4721·1(1)			(4721)	6sd	
*4604	†4607·6(4)	4607·4		(4607·6)	10nc	r
4438			4437·0(1)		2n	
4367			4365·0(2)		1s	
4361					1n	
4337			4336·0(3)		2n	
4319			‡‖4325·0(3)		2n	
*4305	†4305·3(2)	4304·9	4305·3(4)	(4305·3)	10nc	r
	§†4226·3(3)				6nd	
*4215	†4215·3(3)		4215·3(5)	(4215·3)	10nc	r
*4161	†4161·0(2)		4161·0(3)		6nc	
*4078	†4078·5(4)		4077·0(5)	(4078·5)	10nc	r
			¶4031·7(2)			
			‖4031·5(2)			

STRONTIUM—*continued.*

Arc Spectrum		Intensity and Character
Lockyer	Liveing and Dewar	
4029·4 $^{(4)}$		
3969·1		
3939·5 $^{(1)}$		
	§3705·0	
	3653·0	
	3547·0	
	3527·0	
	3498·0	
	3464·0	
	3458·0	n
	3379·5	
	3364·5	
	3305·2	
	2931·1	

Becquerel has observed infra-red lines at 8700, 9610, 10030, 10310, and 10980 in the Arc Spectrum of Strontium.

On the Connection between Sunspots and Terrestrial Phenomena.[1] *By* Professor SCHUSTER, *F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATES I.—III.]

THE very remarkable connection between the state of the solar surface and magnetic phenomena on the earth has naturally suggested the question whether other meteorological phenomena show a similar relationship. The older speculations which date back almost to the discovery of sunspots were revived, and an opportunity was once more given to the meteorologists to prove the often questioned utility of their long-continued series of thermometer and barometer readings. They have made use of this opportunity, and we shall see what the result of their labours has been.

It may be well to state at once what, in my opinion, we are and what we are not to discuss to-day. We have not come here to discuss the *à priori* probability of a connection between sunspots and the weather, or, as it is often erroneously expressed, an influence of sunspots on the weather. The only question before us is the proof or disproof of such a

[1] This paper was read in order to initiate a special discussion on the Connection of Sunspots with Terrestrial Phenomena, on the morning of Monday, September 1. The following paper by Professor O. J. Lodge initiated a similar discussion on Friday, August 29, on the Seat of the Electromotive Force in the Voltaic Cell.

connection by a strictly statistical inquiry. We are, further, not to discuss whether the connection, if it exists, is sufficiently large to affect materially the character of our summers or of our winters. The scientific interest is the same whether the influence be large or small; and though the difference in temperature between years of maximum and years of minimum sunspots may only be the hundredth part of a degree, we must be satisfied with the result as soon as it has been sufficiently well established.

Few people only are aware of the many careful and unprejudiced investigations that have been made on the subject; and there is a great deal of misconception, even among those who take a special interest in it, as to the uniform drift of these investigations. There can no longer be a doubt that during about four sunspot periods (1810–1860) a most remarkable similarity exists between the curves representing sunspot frequency and the curves of nearly every meteorological phenomenon which is related to temperature. This is not, in my opinion, a matter open to discussion; it is a fact. But it is equally certain that during the thirty or forty years previously to that time no such relationship exists, and that since 1860 the connection has again, in some cases, become less distinct. The question which arises now is this: Does the absence of any apparent connection at the beginning of this, and especially at the end of last century, which, as far as we can judge, may be partially repeated at the present time, render it probable that the relationship which held good for nearly, if not quite, half a century, is only accidental; or is it more reasonable to suppose that there is a true connection, but that other causes are at work sufficiently strong altogether to hide the regularity for a succession of years at a time? This is a point on which everybody will follow the dictates of his own common sense, and on which, therefore, we must not expect any unanimity of opinion. In giving an account of the work which has been done, and of the questions which are pending, I shall not attempt to mention, much less to summarise, every paper that has been written on the subject. There is hardly one on which we possess more exhaustive summaries, and to them I must refer the reader who wishes a more detailed account.[1]

Reduction of Sunspot Measurements.

In order to compare terrestrial phenomena with sunspot activity, we must first obtain a numerical measure of that activity. Messrs. De La Rue, Stewart, and Loewy have in their researches measured the spotted area of the sun; and recently the 'Solar Physics Committee' has deduced, as far as possible, this area from the measurements of Schwabe and Carrington. The spotted area of the sun, no doubt, is at present the most scientific measure of solar activity; but we do not possess the necessary data for its determination except for a very limited period. For the older observations, then, at any rate, we must be satisfied with a simpler measure, and it has become customary to adopt Wolf's so-called sunspot numbers. The sunspot number for a certain day, according to Wolf, is $\kappa\,(f+10g)$,

[1] F. G. Hahn: *Ueber die Beziehungen der Sonnenfleckenperiode zu meteorologischen Erscheinungen.* (Leipzig, 1877.) Hermann Fritz: *Die Beziehungen der Sonnenflecken zu den magnetischen und meteorologischen Erscheinungen der Erde* (*Naturk. Verh. d. holl. Maatsch. Wiss.* Haarlem, 1878.) Siegmund Günther: *Der Einfluss der Himmelskörper auf Witterungsverhältnisse*, Nürnberg, 1884.

where f is the number of groups of sunspots seen on the day, a solitary spot counting as a group; g is the total number of spots, and K is coefficient, depending on the instrument used. Putting K equal to one, for instance, a group of two spots would give a number 12, while two single spots would count as 22. The applicability of Wolf's equation is shown by the fact that all the results deduced from it agree well with those deduced from the direct measure of spotted area, and that especially the parallel behaviour of the sunspot curve with that of the daily variation of the magnetic needle becomes very apparent by using Wolf's number. Even for the later observations, for which we possess the sunspot areas, it is a matter open to discussion whether an empirical formula like that of Wolf may not give a more correct representation of solar activity than the actual measure of the area. Thus it is very plausible, as shown in the above example, that two spots, though covering the same area, should represent a greater total solar activity if they are situated at the different parts of the solar surface than if they are close together, forming one group. But, at the same time, there is something arbitrary in Wolf's number, each spot counting alike, whether it is large or small. We are forced at present to use Wolf's numbers, as giving us the most complete and homogeneous series; but we ought not to remain satisfied in future observations with the mere counting of groups and spots without estimation of their areas. Wolf has, in order to equalise the irregular variations, taken as a sunspot number for a given month the mean of the number deduced from that month, the six preceding months and the six following months, giving half the weight to the most distant month on either side. The numbers thus obtained he calls compensated sunspot numbers. He has calculated the numbers for each month from July 1749 to June 1876.[1] I shall adopt these numbers here as the measure for solar activity.

Connection between Sunspots and Terrestrial Magnetism.

It is a well-known fact that the magnetical needle, in addition to its more irregular displacements, shows each day a periodical movement. Towards seven or eight o'clock in the morning the needle begins to travel west; at about one in the afternoon it has reached its greatest deflection; it then begins to travel east until about eleven at night. During the night it is pretty stationary, moving, however, more quickly again in the early hours of the morning.

The hour at which the needle turns, as well as the extent of its daily period, depends on the season. The range of this diurnal variation is greater in summer than in winter. At Kew, for instance, the greatest western deflection during the winter months averages nearly seven minutes and a half, while the average deflection between October and March is only about five minutes of arc. In the Southern Hemisphere the motion of the needle is reversed, and in the equatorial regions there is consequently a belt, shifting with the seasons, at which the variation vanishes.

Rudolf Wolf, General Sabine, and Alfred Gautier pointed out almost simultaneously, in the year 1852, that this daily variation of the mag-

[1] *Memoirs R. Astr. Soc.*, vol. xliii. p. 200 (1875–1877).

netic declination was coincident with that of sunspot frequency, and that its daily range increased and decreased with that of the spots. The increase of the amplitude is approximately proportional to the variation at different places of the earth's surface, so that on the average the daily oscillation is from 1·5 to 1·7 times as large at times of sunspot maxima as at times of sunspot minima. If we compare together the curves of sunspot frequency and those of the daily range, we find that not only do the maxima and minima correspond with each other, but that the shape of the curves is throughout very similar, the irregularities of one being generally repeated in the other. The connection seems so close that Wolf has attempted to represent it by means of a mathematical formula. Denoting by M the daily range of declination, and by W Wolf's number for sunspot frequency, the following equation is found to hold very nearly: $\mathrm{M} = a + b\mathrm{W}$. a and b are two constants, which depend on the place of observation. Wolf has determined them for thirty places, but the question of the constancy of these factors can only be settled by further observations. According to Ellis and Balfour Stewart, the curves of daily declination range lag rather behind those of sunspot frequency; even sudden outbursts of solar disturbance seem to be represented in the magnetic curves by an increase in the daily range, which takes place nearly simultaneously.

The intensity of the horizontal component of the earth's magnetism has a daily range, showing an oscillation which is larger at times of sunspot maxima than at times of sunspot minima.

Hansteen [1] has investigated the changes in the daily average of magnetic declination and of dip, and has found that they present a period corresponding to that of sunspot frequency; the horizontal intensity is larger, and the dip less at times of fewer sunspots; and these two elements vary together in such a way as to suggest the probability that the vertical force remains comparatively unaltered, so that the change in the dip seems produced by a change in the horizontal force only. At Kew,[2] however, the change in the horizontal force seems inappreciable, while the dip is increased at times of numerous sunspots, which latter result agrees with that of the Munich observers, and seems to point to a change in the vertical force. At Toronto,[2] on the other hand, both the dip and the horizontal force seem to increase simultaneously with increase of sunspots, so that here the vertical force seems to alter more rapidly than the horizontal component. But it must be remembered that changes in the dip and in the horizontal force cannot be determined to the same degree of accuracy as change of declination, and these last-mentioned results are therefore not established with certainty. Fritz has investigated the question whether the state of the sun's surface affects the rate at which the secular change of declination takes place, and has found that at Paris, Brussels, and Munich the secular change takes place most quickly when there are many spots on the sun. The Kew results show, however, an increase in declination at times of many spots, which denotes a retardation in the secular change. The increase which is given by the Toronto measurements, on the other hand, supports the view expressed by Fritz, as the declination at Toronto at the present time increases.

[1] *Ast. Nachr.* No. 1069 (1857).

[2] See the article 'Terrestrial Magnetism' in the *Encycl. Brit.* (Balfour Stewart), p. 24.

In addition to the more regular changes in the magnetic needle we observe occasionally greater magnetic disturbances, which have been called magnetic storms by Humboldt. These magnetic storms are both more violent and more frequent at times of maxima than of minima of sunspot frequency. Loomis [1] has tried to determine whether particular magnetic storms are coincident in time with increased solar activity. He took over a hundred magnetic disturbances, and determined the spotted area on the sun on the days of the storms as well as on the preceding and succeeding days, and found an increased area on the same, and the four or five preceding days. It would thus seem that a greater number of spots was accompanied or shortly followed by magnetic disturbances.

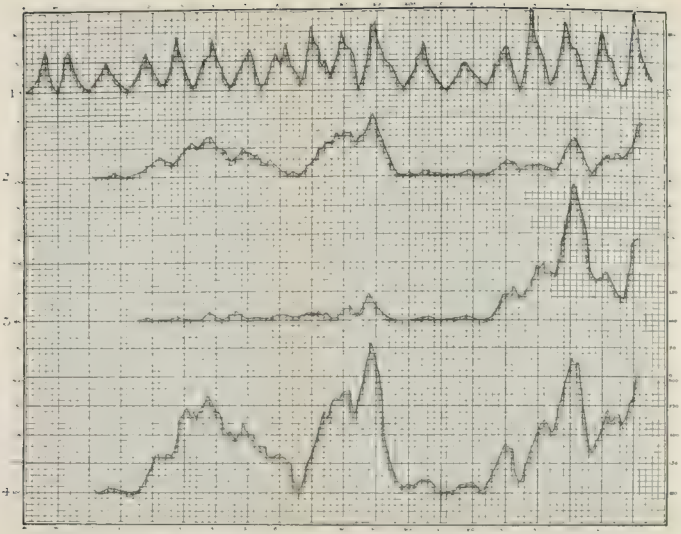
One or two occurrences, though not directly connected with our subject, deserve mentioning. On September 1, 1859, Mr. Carrington at Redhill, and Mr. Hodgson at Redhill, both observed two brilliant patches of intense white light in the neighbourhood of a great spot. The phenomenon was an altogether exceptional one, and was accompanied by a magnetic disturbance, which was repeated with greater energy the same evening, and brillant auroræ were seen over a large part of the terrestrial globe.

Professor Young [2] has also on one occasion noticed an exceptionally strong outbreak of protuberances on the sun to be accompanied by a magnetic disturbance.

Connection between Sunspots and the Aurora Borealis.

It was suspected in the first half of last century already that the aurora appeared more frequently in years in which the number of spots on the sun was peculiarly great. After the discovery of the periodicity of sunspots the connection was placed beyond doubt by Wolf,[3] Fritz,[4] and Loomis.[5] We owe to Fritz [6] the most detailed investigation of the subject, and we shall here give a short summary of his results. In the first place, the eleven-yearly period of sunspots can be distinctly traced in the frequency of auroræ observed in our atmosphere. This holds for the auroræ seen in Europe as well as in America. It is true for those observed in the arctic circle as well as those observed in the temperate zone, and, as far as the scarcity of the material allows us to judge, the same connection exists for the aurora australis. The sunspot curve presents the appearance of a phenomenon similar to, if not identical with, that of beats, which at certain intervals raises the maxima values high above their means. This phenomenon appears in an exaggerated form in the curve of frequency of the aurora borealis. It is, indeed, much more marked than the eleven years period itself, a fact which it is important to bear in mind in any attempt to speculate on the nature of the connection, for it shows that the number of auroræ is not proportional to the number of sunspots, like the increase in amplitude of the daily variation, but that while a small number of sunspots hardly shows any effect, a slight increase in them is often accompanied by a very large increase in the number of auroræ. The inequalities in the sunspot curve show thus a tendency to be exaggerated in the curve of auroræ, and the exaggeration is the greater, the greater the number of sunspots. Plate I., which is copied

[1] *American Journal of Science*, vol. l.
[2] *The Sun.*
[3] Wolf's *Mittheilungen*, No. X. (1859).
[4] *Ibid.* No. XV. (1863).
[5] *Amer. Rep.* (1865).
[6] *Ueber die Beziehungen*, &c.



Curve 1 represents the Sun-spot Frequency.
Curve 2 represents the Frequency of Aurora Borealis seen in Europe between [illegible]
Curve 3 represents [illegible] Aurora Borealis [illegible]
Curve 4 represents [illegible] Aurora Borealis [illegible] Arctic Circle.

Illustrating Prof. Schuster's Paper on the Connection between Sun Spots and Terrestrial Phenomena.

from a memoir by Fritz, will repay a careful study. While especially in curve 4, which takes in the largest number of observations, we can trace the rise at each spot maximum, it will be seen that the amplitude of the oscillation is very irregular, but suggests the existence of a secular period. The length of that secular period can be approximately estimated by taking account of some older observations. In this way Fritz has fixed its period at fifty-five years, but this is a point on which it is safe to speak with caution.

Curve 1 of the plate represents the sunspot frequency. In curve 2 the European observations of auroræ between latitudes 46° and 55° were taken into account. Curve 3 represents the frequency of auroræ observed in America between latitudes 0° and 60°. Finally, curve 4 takes in all European observations extending to the arctic circle.

General Discussion.

A very remarkable connection between sunspots and terrestrial phenomena is thus established, and the question naturally arises whether we can form any idea as to the nature of the connection. Though this may seem hopeless at present, we can at least form an opinion as to how the connection cannot be explained. In the first place, we must not think of a direct magnetic effect between sun and earth. The sun is too hot to be bodily magnetised; and even were it made of hard steel magnetised to saturation, it would not sensibly affect the magnetic needles of the earth. It has been suggested that the sun may be electrified to a high potential, and by its induction affect the magnetic elements of the earth. It has also been maintained that the space between the sun and earth is a good conductor of electricity, and must thus bring their electric states into connection. I reserve for another opportunity the discussion of the possibility or probability of either of these hypotheses; at present it will be sufficient to say that I am unable to conceive how, even granting their truth, they can possibly explain the increase in the diurnal variation at times of many spots.

We do not at present know what the daily variation of the magnetic needle is due to, and therefore it seems premature to consider what causes may modify the effect. The solar influence bears on it the stamp of a temperature effect, while the lunar influence seems tidal. It is difficult to say, without very careful consideration, what the thermo-electric effects in the earth's crust might be. The electro-motive force no doubt is very small, but then the resistance is small also, and the current might be quite appreciable. Tides in the earth's interior, like those assumed by Professor W. G. Adams,[1] do not apparently exist to any appreciable degree, but there must be a tidal stress, and though very small the consequent strain might produce a difference of resistance in different directions, and thus alter the channels of the electric currents. The superposition of such a thermal and tidal effect seems to me to be the most hopeful hypothesis at present, but I have not followed it out sufficiently to be able to do more than to throw it out as a suggestion. These and other considerations, however, lead us on to inquire whether these magnetic and electric effects are not perhaps only secondary, and that the sun acts

[1] Royal Institution, June 3, 1881.

primarily only by its radiation. This is the idea which forms the foundation of Professor Balfour Stewart's work on the subject. He has also thrown out the idea that connection currents in the outer parts of our atmosphere may, by their motion across the lines of magnetic force, induce sensible currents. I do not believe that our present knowledge of the passage of electricity through gases quite warrants the assumption of such a possibility, for though we may make the electric resistance in some parts of the vacuum almost as small as we please, the total electro-motive force which is capable of setting up a discharge at all must always be considerable. At any rate, it is absolutely necessary, before going further, to decide whether we can trace a connection between the number of sunspots and those terrestrial phenomena which depend on his temperature. It is only when we are in possession of all the facts that we may hope for a solution of the mystery.

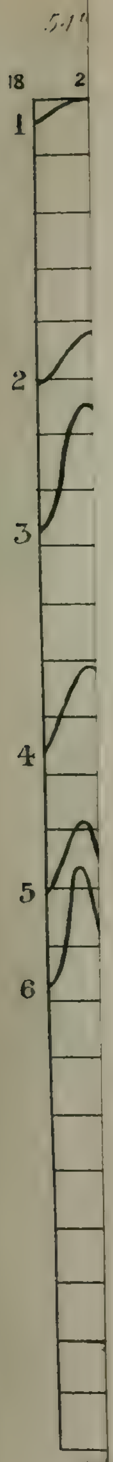
Connection of Sunspots and Temperature.

We owe to Gautier[1] the first detailed examination of this question, which led him to the result that the years of many sunspots are probably rather colder, those with few sunspots rather warmer, than the average. Other investigations led generally to a similar, occasionally, however, to a contradictory result, until Koeppen, by means of a very exhaustive investigation, has given us some decisive results. Koeppen[2] has brought together the temperature records of nearly 250 stations from different parts of the earth.

These were divided into five groups, according to their geographical position—namely, tropics, sub-tropics, the warmer parts of the temperate zone, the colder parts of the temperate zone, and the cold zone. Each of these groups was examined separately. The curves are plotted down in Plate II., and will show a very remarkable relationship to the sunspot curve. The connection is most marked for the tropics, then gradually as we move away from the equator it becomes less and less distinct. The following table, which compares together the years in which the maxima and minima took place, will also render the connection very clear. The table in which the ectropical regions have been united is taken out of Hahn's monograph. It is well known that sunspot periods differ in length, and that the time between a maximum and a minimum is shorter than that between a minimum and a maximum. This peculiarity is exactly reproduced in the temperature curve, as the comparison (Table II.) made by Koeppen will show. The numbers express the years intervening between two successive turning-points of the curve.

The difference between the average temperature in a year of maximum and one of minimum sunspots is by no means small; it reaches 0°·73 C. in the tropical regions, and a little over half a degree in the ectropical groups. The maxima and minima of temperature in the tropics seem to take place a little before the corresponding phases of the sunspot curve, while the ectropical regions show a retardation of the phase. The curve shows some irregularities about the year 1860, but especially towards the beginning of the century it is very much disturbed; and, worse still, between 1780 and 1790 the effect seems exactly reversed. This latter

[1] *Ann. Chim. Phys.*, III., XII. (1844).
[2] *Zeitschrift der oest. Ges. Met.*, vol. viii. pp. 241 and 257.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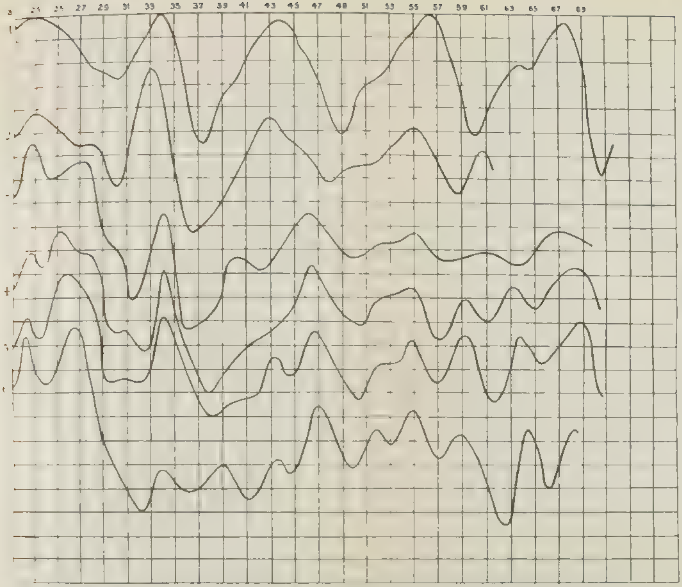

Curve 1 is the inverted Sunspot Curve
Curve 2 represents the Mean Temperature in the Tropical Zone
Curve 3 represents the Mean Temperature in the Subtropical Zone.
... of Temperate Zone
... of Temperate Zone.

Illustrating Professor Schuster's Paper on the Connection between Sun Spots and Terrestrial Phenomena fact would throw grave doubts on the reality of the connection, had it not been pointed out that just at that time the sunspot curve was very irregular. It has been shown by Koeppen that the maximum of temperature in 1779 and the minimum in 1785 occurred when it ought to have done under the supposition of a regular course of sunspot activity. It is useless to speculate how such a state of things could have been brought about, we can only wait the further development of events.

TABLE I.

	Minimum of Temperature		Maximum of Sunspots	Maximum of Temperature		Minimum of Sunspots	
	Tropics	Ectropical Regions		Tropics	Ectropical Regions		
1		1815·5	1816·4	1822·5	1825·8	1823·3	2
3	1830·1	1831·9	1829·9	1833·1	1834·2	1833·9	4
5	1836·4	1837·8	1837·2	1842·8	1846·4	1843·5	6
7	1847·6	1850·3	1848 1	1854·7		1856	8
9		(1861,6)	1860·1		(1868,7)	1867·2	10

TABLE II.

Sunspots		6·9	6·6	4·0	3·3	6·3	4·6	7·9
Temperature	Tropics		7·6	3·0	3·3	6·4	4·2	7·1
	Ectropical Regions	10·3	6·1	2·3	3·6	8·6	3·9	

Hahn has paid special attention to the summers and winters which are remarkable either by an exceptionally high or an exceptionally low temperature, and he has shown that, on the whole, both hot summers and warm winters occur near times of minimum sunspot frequency, while cold winters and summers both occur most frequently directly after a time of great solar activity. But the facts do not show themselves sufficiently regular as to warrant at present any prediction on the general nature of any particular summer or winter.

The results obtained by Koeppen have been confirmed in many ways. Stone[1] has shown that the mean temperature at the Cape of Good Hope shows a decided tendency to imitate the curve of sunspot frequency, and in such a way that to a great number of spots corresponds a minimum of temperature. Piazzi Smyth[2] tells us in the same way that the thermometers sunk into the rocks of Calton Hill show a decided period of eleven years. The maxima of temperature occurred in 1846, 5; 1858, 6; and 1868, 7. These times fall shortly after the minima of spots, which took place in 1843, 5; 1856, 0; and 1867, 2. It is to be observed that thermometers introduced into the ground are specially fitted for the examination of long period oscillations. The rate at which the amplitude of an oscillation decreases with the depth, increases quickly with the length of the period, and the deeper thermometers are introduced into the ground, the more will all short period inequalities be sifted out, and only the longer ones will remain. The amplitude of long oscillations will of course be reduced also, and there are limits, therefore, depending on the sensitive-

[1] *Proc. Royal Soc.* xix., 389. [2] *Astr. Obs. Ed.* xiv.

ness of the thermometers at which the best results will be obtained. This is the place to mention a very interesting and important investigation, lately published by Professor W. Foerster,[1] the Director of the Berlin Observatory. He has found that the position of one of the pillars of the observatory is subject to periodical angular displacements, and that these can be represented by means of two periods, an annual one and one of eleven years' duration. This latter has agreed for three sunspot periods with the sunspot curve. Its amplitude is as much as fourteen seconds of arc. Professor Foerster seems to believe that the effect is due to an accumulation of heat within the pillar. His explanation seems to me to be contrary to the laws of thermo-dynamics, and I think it is much more likely that the change in inclination is due to general disturbance in the level of the surrounding district, which itself would be a consequence of the eleven years period of underground temperature. Comparing together the effects of winter and summer with those of the sunspot period, it is found that a sunspot maximum brings with it a maximum of temperature. The phases show a retardation, as was to be expected. The contradiction of two so well-ascertained effects as those of Koeppen and Foerster is very curious. Its further investigation will no doubt lead to interesting results.

Professor Balfour Stewart has taken a different line from that of previous workers. He takes as his variable quantity, not the temperature of the place, but the daily range—that is to say, the difference between the maximum and the minimum temperature of the day. He also confines his attention to the shorter periods of sunspot and magnetic inequalities. The duration of these shorter periods has been previously determined. Whether these periods are real or apparent only is not material, as long as we confine our attention to the same period of time. His latest reductions, undertaken jointly with Mr. Laut Carpenter,[2] have led him to the following results:—

1. Sunspot inequalities around 24 and 26 days, whether apparent or real, seem to have periods very nearly the same as those of terrestrial inequalities as exhibited by the daily temperature ranges at Toronto and at Kew.

2. While the sunspot and the Kew temperature range inequalities present evidence of a single oscillation, the corresponding Toronto temperature range presents evidence of a double oscillation.

3. Setting the celestial and terrestrial members of each individual inequality so as to start together from the same absolute time, it is found that the solar maximim occurs about eight or nine days after one of the Toronto maxima, and the Kew temperature range maximum about seven days after the same Toronto maximum.

Solar Radiation.

The most direct method to settle the question of variability of the solar radiation would be to measure directly that radiation. The peculiar difficulties which have hitherto stood in the way of continuous records of solar radiation are now gradually being overcome, and we may hope before long to have some decisive evidence either for or against the variability. Our knowledge at present is very vague. Professors Roscoe

[1] *Ast. Nach.*, No. 2545, p. 1. [2] *Proc. Royal Soc.* xxxvii. p. 314.

and Balfour Stewart have reduced some observations made by Mr. Campbell.[1] There is a slight preponderance of strong radiation at times of the maxima of spots. Mr. Blanford has come to the same conclusion from the results of some Indian observations. But in both cases the effects of atmospheric absorption could not be eliminated, and for this reason we must not attach any very great importance to the result. Professor Balfour Stewart has constructed an apparatus which it is hoped will allow any observer to take continuous records of solar radiation. A committee of this Association has been formed to test the instrument, which after some alterations introduced by Professor Stokes will very likely prove both efficient and easy to handle. Dr. Froelich [2] has in the meantime made some very praiseworthy efforts in the same direction, and has come to the conclusion that the solar radiation differs at different times by as much as eight or ten per cent. The range of observations has hitherto only extended over the space of a few months. The radiation seemed the stronger the weaker the daily range of magnetic declination; that is to say, the sun seemed hotter when it showed smaller signs of sunspot activity. Dr. Froelich's experiments have been criticised by Dr. H. Vogel as well as by Professor Langley, and indeed there is much to be said against the certainty of his result. Professor Langley objects that the logarithmic law of increasing absorption with increasing thickness of absorbing layer is only true for a ray of monochromatic light, and may not necessarily be true for a mixture of such rays. This is undoubtedly correct, but Dr. Froelich answers that he has by observation proved the law to be correct. Looking over the curves as given by Dr. Froelich, it seems, however, that, although the law holds very nearly, a very slight deviation from it might account for the differences observed by him. We have, in fact, to use the formula to extrapolate by, and a very slight error would produce considerable differences in the final result. But although the question of variability of the sun has in this way by no means been proved as yet, I believe that Dr. Froelich's method well deserves further development, and that he would obtain most valuable results by taking up again his original intention of observing at high altitudes. It is only by reducing the atmospheric effects as much as possible that we can hope to eliminate it altogether. There are places in the Western Himalayas, not very difficult to get at, where it would be possible to camp out at an altitude of eighteen thousand feet. An expedition fitted out to take regular observations on solar radiation for a succession of several months would bring home most valuable results. While we are looking for changes in the total radiation of the sun, we ought not to forget the instruments devised by Sir Henry Roscoe to measure and register the actinic effects. For it is quite possible that the increase and decrease in radiation will make itself principally apparent in the more refrangible rays.

Atmospheric Pressure.

The relation between solar radiation and the atmospheric pressure at any given place on the earth's surface must necessarily be a very complicated one, and must vary greatly with the meteorological conditions of

[1] *Proc. Royal Soc.* xxiii. p. 578 (1875).
[2] *Electrotechnische Zeitschrift*, v. p. 3 (1884).

the country. We shall therefore only give a short summary of the results which have been obtained. In 1878, Mr. Fred. Chambers [1] pointed out that between the years 1848 and 1876 the curve of mean pressure both in summer and in winter showed a similarity to the sunspot curve. The greatest barometric pressure occurs a short time after the minimum of sunspots. Allan Broun [2] showed that the results for the Bombay observatory are confirmed by the records of other Indian observatories. Mr. Archibald [3] soon afterwards gave evidence of a periodical variation of atmospheric pressure at St. Petersburg, where, however, the maximum pressure occurred two years after the sunspot maximum. The matter was fully entered into by Mr. Blanford,[4] who has confirmed the previous results. At the Indian stations, especially at those situated near the equator, the maximum of atmospheric pressure seems to occur at or a little after the sunspot minimum, while the reverse is the case for all stations in Western Siberia and Russia. The range of time for which these relations have held good is, however, so restricted, that we cannot do more than simply record them, and wait for further confirmation.

It seems curious that some barometric observations show more relationship to the longer sunspot period, which is so well marked in the aurora borealis. Wolf has first pointed out that the excess of the atmospheric pressure in July over that in June decreased from 1770 until about 1805, then increased again till shortly after 1833, decreasing from that time to 1860.

The daily variation of the barometer has been investigated by Hornstein, and also seems to show a long period, having its maxima and minima in good agreement with the corresponding phase of the long period of the aurora borealis. It would not be wise to attach too great a value at present to these coincidences.

A very interesting point has been brought to light by Mr. Joseph Baxendell,[5] of Manchester. He finds, in the first place, that, as was to be expected, the barometer stood on the average higher when the wind came from the north, east, or south-east, than when it blew from the south-west, west, or north-west.

He next compared together these differences in different years. In the second horizontal row of the following table we give the difference in pressure during easterly winds (north-east, east, and south-east) on the one hand, and westerly winds on the other. It is seen that this difference was greatest in 1860, then gradually decreased till 1867, and then was again greater in 1868. This agrees well with the variation in the number of sunspots which took place during the same time, as is seen by comparison with the numbers given in the fourth horizontal row, which indicate Wolf's sunspot numbers.

1858	1859	1860	1861	1862	1863
+0·199	+0·141	+0·226	+0·061	+0·073	+0·012
+0·221	+0·238	+0·231	+0·229	+0·109	0·103
56·2	90·3	94·8	77·7	61·0	45·4

1864	1865	1866	1867	1868
−0·044	−0·077	−0·053	−0·150	+0·09
0·122	0·083	0·038	0·066	0·074
45·2	31·4	14·7	8·8	36·8

[1] *Nature*, vol. xviii. p. 567 (1878).
[2] *Ibid.* vol. xix. p. 6 (1878).
[3] *Ibid.* vol. xx. p. 29 (1879).
[4] *Ibid.* vol. xxi. p. 477 (1880).
[5] *Proc. Manchester Phil. Soc.* xi. 1872, p. 122.

The numbers show that during the year of few sunspots the barometer stood higher with westerly than with easterly winds. The third row gives the difference in the height of the barometer with north-westerly as compared with south-westerly winds. The observations used were those taken at the Radcliffe observatory. It would be interesting to see how matters have been going on since 1868.

General Remarks on the Reduction of Observations.

The task of proving a periodicity in meteorological phenomena coincident with that of the sunspots is by no means an easy one. For such a periodicity, if it exists, is clearly mixed up with other and larger variations, which may hide the period in question. It becomes, then, necessary to inquire what are the processes of reduction that are most suitable for the purpose. In the first place, wherever it is necessary to hide short-period inequalities, we may do so by taking means over suitable periods. For instance, in investigating the effect of the sunspot period, it is quite justifiable to take mean values of the quantities we are investigating over three or five years. We shall thereby reduce the amplitude of the longer inequalities, but they will be more clearly defined, as we have destroyed completely all inequalities of less than three or five years. No exception whatever can be taken to such a process as this; and if the curve thus smoothed down shows evidence of similarity to the sunspot curve for a sufficiently long period of time, we may take the connection to be a real one.

In some of the investigations, however, it seemed advisable to take a slightly different plan. Thus, for instance, Professor Balfour Stewart, in his consideration of temperature ranges, has compared certain daily values with the average of the same values over twenty-four days. Now, in this process the different periods are very unequally affected. Professor Stokes[1] has given us the formula which enables us to see the way in which such a reduction influences the amplitude of different periods. If the amplitude of the original period is taken as one, then the amplitude of the reduced period is given by—

$$\frac{\sin\frac{n\pi}{N}}{n\sin\frac{\pi}{N}} - \frac{\sin\frac{m\pi}{N}}{m\sin\frac{\pi}{N}}$$

where n and m represent the periods over which the averages have been taken.

Applying this formula to the case under consideration, I find that, while a period of twenty-four days approximately would have its amplitude reduced in the proportion of 1 to 0·96, a period of eighteen days would be increased in the ratio of 1 to 1·13. For Dr. Stewart's purpose it would have been better, therefore, to have taken his means over about thirty days instead of twenty-four, as it was the inequalities of twenty-four days that he was specially investigating, and wishing to increase relatively.

[1] In a paper by J. H. Poynting, *Proc. Stat. Soc.*, London, 1884.

It happens occasionally that any one single sunspot period does not give a clear periodical variation of some meteorological quantity; this does not prove that no connection exists, but only that, if it does, it is hidden under some larger irregularity. To show a connection we should have to take a longer series of observations into account, and see whether the average at sunspot maxima shows a different value from the average of sunspot minima. It is in investigations such as these that we must be specially careful not to be misled by accidental coincidences. Fourier has taught us that any variable quantity, however irregular, can be represented by a series of harmonic variations, and there need be no physical reality at all attached to such a periodicity. Let us suppose, for instance, that we want to see whether some quantity shows a periodicity of ten years. The simplest way to proceed would be to break up our series of observations into parts of ten years' duration; each part would contain ten terms if yearly means are employed, and we could now take the average of corresponding years; that is to say, the average between the years 1, 11, 21, and so on; then the average between the years 2, 12, 22, and so on. We should then get ten values, and if these values were to show a regular increase or decrease, we might conclude that a ten years periodicity really existed. But that is by no means necessarily the case. Any quantity, however irregular, will, according to Fourier, be decomposed into periods. A marked increase and decrease would only prove that the quantity when so decomposed has the amplitudes of all submultiples of ten years smaller than the amplitude of the ten years period. But the amplitudes of periods less than ten years have often, in the investigations to which I am referring, been already reduced or destroyed by the peculiar way of taking means. So that nothing at all is really proved. It is even difficult to see, considering that we have such a small number of sunspot periods at our disposal, how any satisfactory plan of reduction can be devised. It will be better, therefore, at present to attach only very secondary value to coincidences which do not make themselves perceptible in each period. Should it ever be proved that there is really a change in the sun's radiating power in different years according to the number of sunspots, the case would be altogether changed. We might then take it for granted that all meteorological phenomena present the same period, and the process of averaging between different periods would justly help us to fix the amplitude and the phase of the oscillation.

I therefore in what follows, for the reasons just given, pass very quickly over, or altogether omit those coincidences which seem to be subject to the above criticism.

Intensity of Wind.

The most important investigation under this head is no doubt Meldrum's comparison of the number of gales in the Indian Ocean in different years. The following table speaks for itself. The greater number of cyclones during times of many sunspots appears very clearly.

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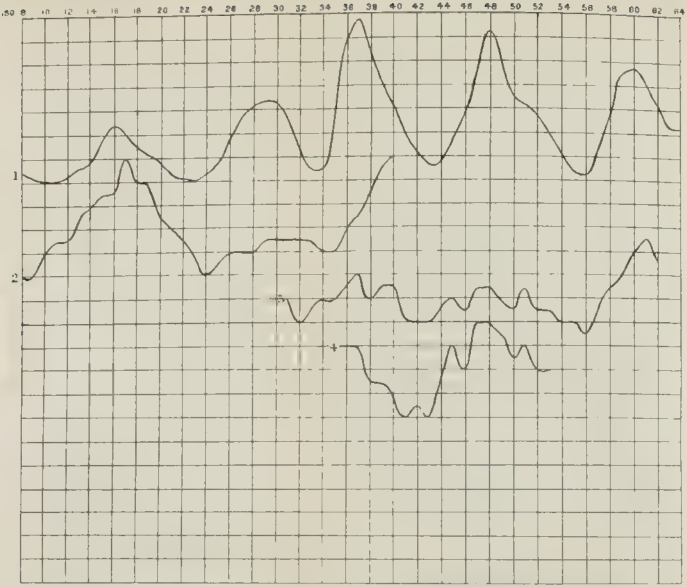

Curve 1 represents Sunspot Frequency
Curve 2 represents Hailfall Frequency a M [illegible] Udine, Vienna, and Prague.
Curve 3 represents Hailfall Frequency at Stuttgart Bremen, and Basle.
Curve 4 represents Hailfall Frequency at Stuttgart, Bremen, London, Boston, &

Illustrating Professor Schusters Paper on the Connection between Sun Spots and Terrestrial Phenomena

Year	Number of Cyclones	Wolf's Sunspot Numbers		Year	Number of Cyclones	Wolf's Sunspot Numbers	
1847	5	97·4		1861	11	77·7	
1848	8	124·9	Maximum	1862	10	61·0	
1849	10	95·4		1863	9	45·4	
1850	8	69·8		1864	5	45·2	
1851	7	63·2		1865	7	31·4	
1852	8	52·7		1866	8	14·7	
1853	8	38·5		1867	6	8·8	Minimum
1854	4	21·0		1868	7	36·8	
1855	5	7·7	Minimum	1869	9	78·6	
1856	4	5·1		1870	11	131·8	Maximum
1857	4	22·9		1871	11	113·8	
1858	9	56·2		1872	13	99·7	
1859	15	90·3		1873	12	67·7	
1860	13	94·8	Maximum				

Poey has investigated in a similar manner the cyclones in the West Indies, and his results are favourable to Meldrum's conclusion.

We also possess a large number of reductions of strength and direction of wind on land. These, on the whole, seem to show that intensity is stronger at times of maxima sunspots, but the connection is by no means certain.

Rainfall.

The investigations of the amount of rainfall are very numerous. They have generally but not uniformly led to the result that the fall is greater in years of many spots, but the reductions are often subject to the criticisms which we have discussed, and I must therefore refer those who take an interest in the subject to the original papers.

Hail.

It is remarkable that the hailfall statistics have led to a much more decided result than the investigations on rainfall. We owe to Fritz some extensive investigations on the subject; instead of giving his tables, it will be better to plot down his results so as to obtain curves of hailstone frequency. Curve 1 (Plate III.) gives the sunspot curve; curves 2, 3, and 4 give that of hailstone frequency. In curve 2, five yearly means of observations taken at Milan, Udine, Vienna, and Prague are combined. Curve 3 represents similar means of observations taken at Stuttgart, Bremen, Basle. In curve 4 the observations of Cuba, Stuttgart, Bremen, Chiswick and London, Boston, Providence, are taken into account. A few series of observations which we possess from last century are decidedly favourable to the same conclusion. The connection between sunspots and hailfall is fairly well established.

Clouds.

Humboldt supposed that there exists a curious connection between the aurora borealis and the clouds which are known under the name of cirrus or cirro-stratus. Though Humboldt's view has not been proved, there is yet a greal deal to be said in its support. It becomes interesting, then, to inquire whether the frequency of these cirri or cirro-stratus changes with the sunspots. The connection has, indeed, been fairly well established; and the greatest number of cirri are nearly always observed when many auroræ are observed—that is, generally, when there are many spots on the sun. Now, the cirri are clouds in which the water is, in all probability, in a frozen condition; and we are thus brought directly from the sunspots through the aurora to temperature effects. The meteorological quantities hang, indeed, so closely together that, as soon as we admit a connection between sunspots and auroræ, we admit their connection with other meteorological phenomena. We ought not then to ask, 'Is there a relationship between sunspots and the weather?' but rather, 'Is the relationship sufficiently large to be observable by means of our ordinary instruments?'

If cirri occur most frequently at times of frequent auroræ, and if cirri are due to clouds of ice needles, we ought to see most solar halos at times of many auroræ. This has been shown to be the case by Sophus Tromholdt. Between the years 1857 and 1873 the number of solar halos varied exactly in the same manner as the number of auroræ; they also showed the maximum in each year at the time of the equinoxes.

Investigations have also been made with regard to other clouds, and it has generally been found that the greatest number of clear days in Central Europe occurred at times of few spots on the sun.

Thunderstorms.

Professor von Bezold[1] has recently published a most interesting memoir on the distribution of lightning flashes which have done damage to dwellings in the kingdom of Bavaria. As the insurance is altogether in the hands of the Government, the kingdom is peculiarly fitted for such an investigation, there being a fairly complete set of statistical data available for the last fifty years.

The following table will show that the numbers of fires caused by lightning is quite sufficient to base an inquiry on them. It will also plainly show the very remarkable fact that the flashes of lightning which have done damage have enormously increased in the last fifty years:—

Period	Fires by lightning	Yearly average
1833–1843	355	32·3
1844–1865	1,142	51·9
1866–1879	1,550	103·3
1880–1882	401	133·6

This astonishing fact, which seems to hold true not only for the kingdom of Bavaria, had already previously been commented upon, and formed the subject of a separate investigation by Holtz. It is by no means due to the greater number of houses insured in recent times, for in the last fifty years that number has increased only thirty-five per cent., while the number of houses struck has increased over three hundred per cent. Professor von Bezold thinks that there is evidence to show that during the second half of last century the number of houses damaged was also larger than in the first half of the present one. But,

[1] *Abh. der Kais. Akad. München*, vol. xv. (1884 .

in addition to this continued increase of damage done by lightning since 1833, there seems a clear connection with the sunspot variation. The years of maximum sunspots were 1837, 1848, 1860, and 1870; but we find minima in the per-centage of houses damaged in 1836, 1849, 1860, and 1870. These are, however, not the only minima, but between each two of them there is another, so that we generally have a comparatively small number of houses damaged in the years of sunspot minima as well. In other words, the curve of houses damaged shows with perfect regularity a double oscillation for each sunspot period, the maxima of sunspots corresponding more closely to the better defined minima of lightning flashes. It is curious that Fritz had come previously exactly to the same conclusion in reducing the number of thunderstorms observed in the Indian Ocean. He had then taken the result to be unfavourable to a connection with sunspots; but now that the same law is found to hold so accurately in Bavaria, it certainly deserves very close attention. Professor von Bezold has pointed out that the annual curve of thunderstorm frequency shows a similar double period. There is a very decided maximum in summer, but secondary maxima exist in January. It ought also not to be forgotten that the auroræ show evidence of a similar double period. During the years of minima of spots there is often a small increase in their number.

Harvests, Famines, and Commercial Crises.

The question of harvests is principally of historical interest, for before the relationship of solar phenomena to terrestrial magnetism was suspected, Sir William Herschel tried to find a connection between sunspots and the price of wheat. He came to the conclusion that the price of wheat was generally higher at times of few sunspots. When Herschel obtained these results, the periodicity of sunspots had not been discovered, and he had therefore to take the years during which, as shown by the records, sunspots had been looked for but not discovered, and to compare them with the years which followed and preceded. The investigations which have been made since Herschel's time have not led to any decisive results, and do not therefore deserve any more detailed account. The wine harvests give, however, very curious results. I have pointed out that the best years of Rhine wine in this century are all very close to years of minima of sunspots.[1] The years 1783, 1811, 1822, 1834, 1846, 1857, and 1865 are known for the quality of their wines; and we have sunspot minima in 1785, 1811, 1823, 1834, 1844, 1856, and 1867.

Fritz has subjected the quantity of wine yielded by the vineyards in Prussia to a careful analysis. The result proved a very decided period during this century. The quantity was always larger in the period between a sunspot minimum and the following maximum than at times of decreasing sunspots. The numbers obtained for other countries give the same result, the years of largest quantity generally falling near, but a few years previously to the sunspot maximum. If the quality is taken into account, we find the best qualities preceding the years of greatest quantity, and falling, therefore, as already pointed out, near the years of sunspot minima. It is certainly a suggestive fact that the vine, which depends so much on solar radiation for the proper ripening of its fruit, should show

[1] *Nature*, v., p. 501, 1871.

such a decided sunspot period, both in the quality and in the quantity of its produce.

Dr. Hunter has endeavoured to connect together the years of famine in Southern India with the sunspot minima. The question of famines is, of course, intimately connected with that of rainfall, which latter, as I have pointed out, has not hitherto yielded any very decided results. The difficulty consists in the local circumstances which at different places complicate the result very much; and while it is therefore impossible to deny a certain value to Dr. Hunter's conclusions, we shall do well to suspend our judgment until another sunspot cycle will have given us more ample material.

Stanley Jevons[1] has pointed out a periodicity in commercial crises, and has endeavoured to connect it with the sunspot period.

The regular recurrence of crises at an interval of a little over ten years is very striking, but the disagreement of the period itself with that of the sunspots is fatal to the hypothesis of any true connection. Jevons was misled, by a paper of Allan Broun, to adopt a wrong average period for the sunspot activity. Sunspots were very irregular at the end of last century, and there seemed at one time a doubt whether we ought to count two long or three short periods between the years 1885 and 1804. Wolf adopted the former, and Allan Broun the latter view. Accordingly they obtained different values for the average sunspot period. There seems at present to be no doubt that 11·1 years is the true average period, as this is the length we obtain by leaving out of account altogether the period of irregularity. The very regularity indeed of the series of commercial crises is an argument against its connection with the sunspot period, which itself is rather irregular in length. We find, indeed, that those terrestrial phenomena, which are proved to depend on the presence or absence of sunspots, partake of the same irregularities which are shown by the sunspot curves.

An important contribution to the discussion of the general question was made by Professor J. H. Poynting.[2] His primary object was to determine whether there was a general meteorological cause operating, which, during certain years, influenced the yield of certain crops in the same way all over the world. If this is so, the curves representing these yields ought to have approximately the same shape in every country. We need not here enter into the method which Professor Poynting has used to smooth down his curves. The result of his investigation seems to show that the price of wheat has varied approximately in the same manner in England and in Delhi. The curves representing the cotton crops in different countries show a still more striking resemblance to each other, and the yield of cotton seems to vary inversely as that of the wheat crop. All this is distinctly in favour of a common meteorological cause affecting widely different parts of the earth in the same way. There seems, however, no striking similarity between the crops and the variation of sunspots, except in the case of the silk crop in China, as shown by the curve of imports from that place.

Cosmical Phenomena.

Although we are here directly only concerned with terrestrial matters, it seems yet of importance to point out that the causes which are operating will very likely be found to operate all through the solar system. The

[1] *Nature,* xix. p. 588 (1879). [2] *Proc. Stat. Soc.* vol. xlvii. p. 240.

evidence of periodical changes in the appearance of the surface of Jupiter is very strong. Wolf was the first to draw attention to these periodical changes. More lately, Ranyard tried to show that the distinctness of the belts, as well as the appearance of certain spots in the atmosphere of Jupiter, pointed to a connection with sunspots. Dr. Lohse has further investigated the matter, and has found a strong evidence of periodical variability in the belts coincident with sunspot changes.

The celebrated astronomer Bruhns has made a remark which, if confirmed, would throw a great deal of light on the whole matter. According to him, there were fewer comets visible during this present century at times of minimum than at times of maximum sunspots. As we know comets to be connected with swarms of meteorites, we might perhaps ultimately find the sunspot period itself to be due to the periodicity of such swarms, having their perihelion close to the sun. This was first suggested by Johnstone Stoney,[1] and I[2] have brought forward arguments in favour of this view. The remark of Bruhns has, however, been much weakened by the subsequent inquiries of Wolf. Fritz, on the other hand, has pointed out that the centuries in which we know that many large comets have appeared have also been remarkable for the display of auroræ and of sunspots, while the seventeenth century was poor alike in comets and in auroræ.

Conclusion.

Having thus given a rapid survey of those meteorological phenomena which possibly or probably may be connected with occurrences on the solar surface, I must leave every one to draw his own conclusions. But few, I think, will not re-echo the following eloquent remarks of Professor Stanley Jevons:—

'But why do we beat about the bush, when all that is needed is half a dozen of Pouillet's heliometers with skilled observers, who will seize every day to determine directly the heating power of the sun. Why do we not go to the great luminary himself, and ask him plainly whether he varies or not? If he answers No, then some of us must reconsider our theories, and perhaps endure a little ridicule. But if, as is much more likely, he should answer Yes, then the time will come when the most important news in the "Times" will be the usual cablegram of the solar power. Solar observatories ought to be established on the table-land of Quito or Cusco, in Cashmere, in Piazzi Smyth's observatory on the Peak of Teneriffe, in Central Australia, or wherever else the sun can be observed most free of atmospheric opacity. An empire on which the sun never sets, and whose commerce pervades every port and creek of the sunny South, cannot wisely neglect to keep a watch on the great fountain of energy. From that sun, which is truly "of this great world both eye and soul," we derive our strength and our weakness, our success and our failure, our elation in commercial success, and our despondency in commercial collapse.'

[1] *Proc. Roy. Soc.* xvii. p. 1, 1868. [2] *Observatory* II. p. 262.

On the Seat of the Electromotive Forces in the Voltaic Cell. *By* Professor OLIVER J. LODGE, *D.Sc.*

(A communication ordered by the General Committee to be printed *in extenso* among the Reports.)

As this is the first formal discussion ever held in Section A, I may be permitted in starting to say with what hope I look forward to these discussions in the future, and how anxious I am that they should succeed. I have attended the meetings of the British Association consecutively for twelve years, and have been gradually more and more impressed with the small result the Sectional meetings have, as compared with what might be expected considering the magnitude of the men who frequently take part in them. In this Section room physicists from all parts of the British Isles, as well as from Europe and America, are more frequently to be met with than at the meetings of the Royal Society itself, and the whole atmosphere ought to be favourable to a free and informal interchange of opinions, most beneficial, instructive, and stimulating to the younger men like myself. And to a great extent this is the case, especially when our present sectional President is at the meeting, whether in the chair or out of it. But still as a rule, mitigated it is true by a few brilliant exceptions, there is a long list of somewhat dreary papers to be worked through every day, the discussion on each being nipped in the bud in order to get on to the next and clear off the list.

In favour of this practice of encouraging papers rather than discussion, it may be truly urged that useful discussion on abstract papers such as we are likely to have in this Section is almost impossible: only in case he has been recently working at a similar subject, does an ordinary physicist feel competent even to ask a pertinent question. But if papers on fundamental or controversial topics were encouraged and definitely asked for in good time beforehand, workers might be encouraged to look up that particular subject specially, to read its literature, to make experiments on it perhaps, and generally to give it that careful thought without which discussions can neither be lively nor fruitful. Abstract papers can at any time be communicated to one of the learned societies whose business is with papers and their publication, and where the general public are not admitted. It was with these ideas that the Secretaries of the Section last year agitated for the inauguration of such discussions, and, thanks to the energy of Dr. MacAlister, the first of them now begins at this unique and most interesting meeting.

The subject chosen for the present discussion illustrates in a remarkable way the need for such conversations. It is scarcely credible at the present rate of progress that, eighty-four years after the discovery of the voltaic pile, opinion should still be utterly divided as to the seat of the main E.M.F. in it. I venture to hope that it may now be decided, and a substantial agreement arrived at with respect to it. My business is to open the discussion, but it so happens that for some seven or eight years I have believed myself to see more or less clearly to the root of this particular matter, and a laborious review of the literature of the subject has only strengthened my conviction. Having therefore strong and definite views I can hardly help letting them appear, and without assuming prematurely that these views are agreed with, they may yet serve as links with which to connect the facts and the multifarious observations thereon.

1. In the course of my reading on the subject, I have found only two great and epoch-making papers, that of Volta in 1801, and that of Sir William Thomson in 1851. Other contributions are some of them keen, like those of Faraday and Clerk Maxwell; some of them laborious, like those of Hankel and Ayrton and Perry; but none contain anything essentially and powerfully new except those two: unless indeed we include in the subject the immensely important phenomena of Seebeck and of Peltier, and Faraday's fundamental law of electro-chemical decomposition.

Volta[1] showed that when two metals were put into contact and separated, the insulated one was charged with electricity sufficient to make gold leaves diverge. He also stated that the contact force between any two metals was independent of intermediate metals, so that the metals could be arranged in a definite numerical series; and he gave the first series of the kind—

$$\underset{5}{Zn \smile Pb} \underset{1}{\smile Sn} \underset{1}{\smile Fe} \underset{2}{\smile Cu} \underset{3}{\smile Ag.}$$

Moreover he started a hypothesis to account for the action, a sort of impulsion or attraction of electricity by matter—an idea subsequently elaborated by Helmholtz. Fabroni[2] objected to Volta's explanation of his experiment. He denied contact force and considered that the electricity was developed by chemical action.

Then the fight began, and lasted on and off some half-century. On the one side were Volta, Davy, Pfaff, Péclet, Marianini, Buff, Fechner, Zamboni, Matteucci, and Kohlrausch. On the other were Fabroni, Wollaston, Parrot, Œrsted, Ritchie, Pouillet, Schönbein, Becquerel, De la Rive, and Faraday.

It was not all fighting; part of it resulted in a more thorough investigation of voltaic phenomena, and very often the original point of dispute was lost sight of, and Volta's fact itself was doubted in the eagerness to disprove Volta's explanation. The experiments of Pfaff and Péclet,[3] however, fairly well established the correctness of his observation, and Kohlrausch showed how, by means of a Daniell's cell combined with a condenser, to measure Volta forces absolutely, thus inventing a method which has been employed with modifications by Hankel, by Gerland, by

[1] Volta: *Gehler's Wörterbuch*, iv. 616. See also a carefully edited version *Annales de Chim.* xl. 1 ser., p. 225, 1801.

[2] Fabroni: *Journal de Physique de l'abbé Rozier*, xlix. 348.

[3] Péclet on the contact of good conductors.—*Comptes Rendus*, 1838, p. 930.—*Pogg. Ann.* xlvi. 1839, p. 346. *Ann. de Chim.* 1842 and 1841, 3 ser. ii. 233.

Pfaff, letter to Gay Lussac.—*Ann. de Chim.* 2 ser. xli. 236, 1829. Pfaff.—'For and against the production of E. by chemical processes, as a consequence of some experiments on the E.M.F. of liquids and metals.'—*Pogg. Ann.* xli. 1840, pp. 110 and 197. Pfaff—'Experimentum crucis in favour of the contact theory.'—*Pogg.* liii. 1841, p. 303. This crux is on p. 306, and consists in substituting $ZnSO_4$ for H_2SO_4 in a Grove cell, and showing that the current through a thin wire galvanometer is stronger than before. This, he says, leaves no further shift or evasion (Ausflucht) for the chemical theory. It is a fact we have grown accustomed to, but it *is* rather surprising that the E.M.F. given by $ZnSO_4$ should be even higher than that given by H_2SO_4. A convenient 'Ausflucht' could nevertheless be provided for the chemical theory by pointing out that the combustion heat $Zn,2NO_3$ is greater than $Zn,SO_4 - H_2,SO_4 + 2(H,NO_3)$, if indeed the fact be so. Another shift is to talk about basic sulphate and the sourness of $ZnSO_4$: another is to use the word 'dissociation.'

Clifton, by Ayrton and Perry, by von Zahn, and by most other experimenters on the subject.[1]

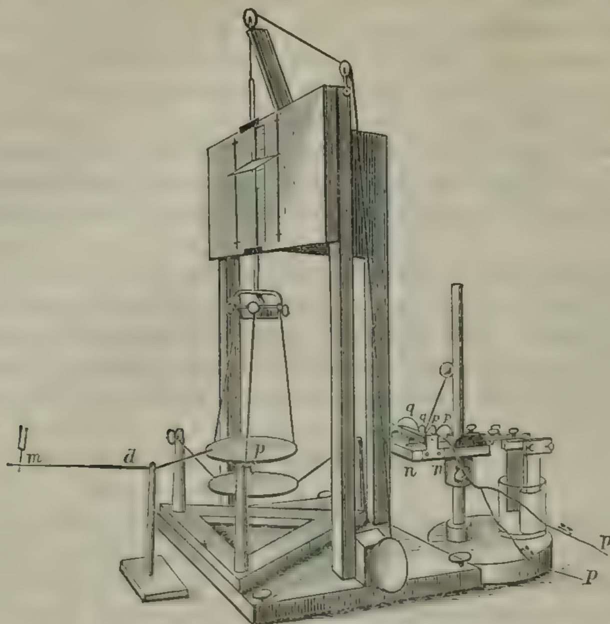

FIG. 1.—Kohlrausch's Early Form of Condenser.

Both the plates are insulated by silk threads. The fixed wire *d*, with which the raised plate comes into contact, leads to a Dellman electrometer. The connections are arranged for determining the 'electroscopic tension' on the poles of an open battery, to see if it is the same as the E.M.F. See *Pogg. Ann.* 1848, vol. 75, pp. 88 and 220.

This apparatus he also used to measure the Volta effect between two metals, his classical memoir on the subject being in *Pogg. Ann.* 1851, vol. 82, p. 1. Later he improved the condenser, bringing it into the form shown in the following figure.

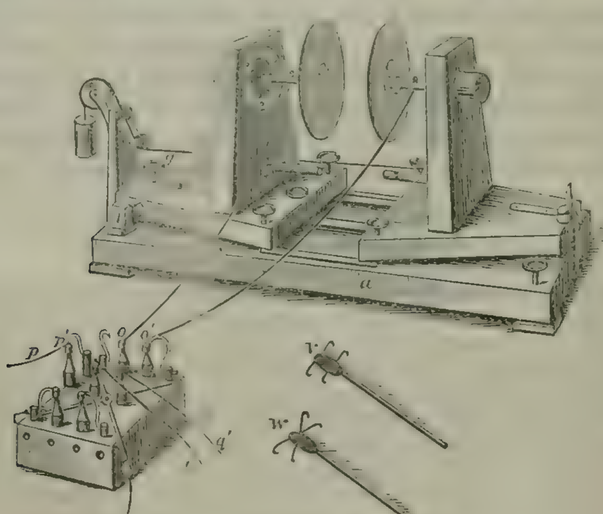

FIG. 2.—Kohlrausch's Later Form of Condenser. See *Pogg. Ann.* 1853, vol. 88, p. 464.

[1] Kohlrausch's method consisted in bringing the plates of the two metals close together, connecting them by a wire for an instant, separating them, and putting one

Wherever electrostatic methods were employed, and where the electroscope was the instrument of research, contact theorists had it all their own way, and it was only by apparent effort and twisting of experiments that the chemical theorists could maintain their ground. But when electric currents were dealt with and the galvanometer used, then the chemists had their turn, and they showed most conclusively that no mere contact could maintain a current unless heat disappeared or chemical action occurred: a fact obvious enough to us to-day on the principles so laboriously and finally established by Joule. By means of the galvanometer the contact theory was so belaboured by Faraday that it ultimately seemed to give up the ghost, and the chemical doctrines triumphed. So much so that Volta's original fact, in spite of the evidence which had been accumulated, was again doubted; and one finds in text books culled from this period statements that Volta must have had wet fingers, or that he rubbed the plates together, or that there was moisture in the air. Also hints are given that films existed on the plates, that squeezed coats of varnish or lacquer might produce some electricity, and so on. It was pointed out moreover by De la Rive[1] how minute a trace of chemical action could produce how much electricity, and how little electricity could affect an electroscope. But it is to be noted that any chemical action caused by damp on the plates or moisture in the air would be of the nature of local action, and local action is not a satisfactory producer of manageable electricity. Sir Humphry Davy is very clear on this head. He shows that chemical action need produce no electricity, instancing the burning of iron, nitre on charcoal, potash and acid in a crucible or an electroscope, &c.; a plate of zinc placed on mercury and separated is found positive, but if left long enough to amalgamate, the compound shows no signs of electricity. Davy's views are singularly advanced, and are worth quoting.[2]

into connection with a Dellman electrometer, the other with the earth. The observation is repeated with a Daniell in the connecting wire, first one way then the other. Thus three equations are obtained, $M/M' = k\alpha$, $D + M/M' = k\beta$, $D - M/M' = k\gamma$; whence $M/M' = \frac{B-\gamma}{B+\gamma} D$, or $\frac{\alpha}{\beta - \alpha} D$. —*Pogg. Ann.* vols. lxxv. p. 88; lxxxii. pp. 1. and 45, and lxxxviii. p. 465, 1851 and 1853. He gets his results much lower than later experimenters; only ½ a volt for Zn/Cu, and ·58 for Zn/Pt.

[1] De la Rive.—*Traité d'électricité*, ii. p. 776.—*Ann. de Chimie*, xxxix. p. 311, 1828.

[2] Davy: Bakerian Lecture, 1806. See *Phil. Trans.* 1807, p. 39: 'As the chemical attraction between two bodies seems to be destroyed by giving one of them an electrical state different from that which it naturally possesses . . . so it may be increased by exalting its natural energy. Thus while zinc is incapable of combining with oxygen when negatively electrified in the circuit even by a feeble power, silver easily unites to it when positively electrified . . . Among the substances that combine chemically, all those, the electrical energies of which are well known, exhibit opposite electrical states . . . In the present state of our knowledge it would be useless to attempt to speculate on the remote cause of the electrical energy, or the reason why different bodies after being brought into contact should be found differently electrified; its relation to chemical affinity is, however, sufficiently evident. May it not be identical with it, and an essential property of matter?' Page 44: 'The great tendency of the attraction of the different chemical agents by the positive and negative surfaces in the voltaic apparatus seems to be to restore the electrical equilibrium . . . The electrical energies of the metals with regard to each other, or the substance dissolved in the water, seems to be the cause that disturbs the equilibrium, and the chemical changes the cause that tends to restore the equilibrium; and the phenomena most probably depend on their joint agency.' He then gives a very voltaic account of the action of the pile—much in agreement with Sir Wm. Thomson—and endeavours to reconcile chemical and contact theorists by pointing out how essential a part chemical action

Quite detached from any connection with the controversy, because at that time quite unintelligible to all but one or two here and there, two papers appeared in 1851 by the President of this Section, which were the triumph and apotheosis of the chemical theory of the source of the current in the voltaic cell.[1] In one of these papers (that on 'Electrolysis') it is irrefutably established on the basis of the conservation of energy, that, making exception of such irreversible effects as are not readily brought into calculation, and allowing for certain possible reversible effects to be investigated thermo-electrically, the E.M.F. of a cell is not only dependent on the chemical action going on, but is calculable numerically in absolute measure on purely chemical data supplied provisionally by Dr. Andrews. It is proper to say, however, that this brilliant theory is avowedly based on the laborious and acute experimental work of Joule on the conservation of energy in the voltaic circuit.[2]

In the other of the two papers (that on 'Thermo-electricity') it was shown that, from the fact that a current absorbed or generated heat at a metallic junction, an E.M.F. was necessarily situated there—in other words, that the Peltier effect necessitated the previously discovered Seebeck one.

The establishment of the conservation of energy, by Joule, for ever placed beyond doubt the fact that the energy of the electric current produced by a battery was due to, and was the equivalent of, the chemical

plays in the production of a *current*, a most clear-sighted thing to do at that date. One more sentence may be quoted from this remarkable paper, though it is not quite so striking as the preceding. Page 49: 'These ideas are evidently directly in contradiction to the opinion advanced by Fabroni, and which in the early stage of the investigation appeared extremely probable, viz., that chemical changes are the *primary* cause of the phenomena of Galvanism. Before the experiments of M. Volta on the electricity excited by mere contact of metals were published, I had to a certain extent adopted this opinion; but the new fact immediately proved that another power must necessarily be concerned, for it was not possible to refer the electricity exhibited by the opposition of metallic surfaces to any chemical alterations, particularly as the effect is more distinct in a dry atmosphere, in which even the most oxidisable metals do not change, than in a moist one, in which many metals undergo oxidation.'

[1] Sir W. Thomson: 1. 'On the Mechanical Theory of Electrolysis and the applications of the Principle of Mechanical Effect to the Measurement of Electromotive Forces in Absolute Units.'—*Phil. Mag.* December, 1851. *Reprint of Mathematical and Physical Papers*, vol. i. pp. 472 and 490. 2. 'On the Dynamical Theory of Heat, part vi. Thermo-electric Currents.'—*Proc. R.S., Edin., Dec.* 1851; *Trans. R.S. Edin.*, 1854; *Math. and Phys. Papers*, vol. i. p. 232 and p. 316.

Helmholtz also clearly applied the conservation of energy to voltaic circuits in his memoir, *Die Erhaltung der Kraft*, read before the Physical Society of Berlin, July 23, 1847. In this powerful memoir Prof. Helmholtz sails placidly through a great part of Physics, applying to various phenomena the then new principle of the conservation of energy. He regards all action as occurring at a distance, and shows, as is well known, that on this hypothesis central forces are the necessary and sufficient condition of conserved energy. This part may now be regarded as superseded; but in the more special portions, among other things, he develops the mechanical theory of the E.M.F. of voltaic cells, of thermo-electric piles, and of magneto-machines; anticipating in many respects the somewhat later though independent work of Sir W. Thomson on these subjects. Prof. Helmholtz's memoir is easily accessible through a translation, by J[ohn] T[yndall], which appeared in May, 1853, in the 'new series' of Scientific Memoirs issued by Taylor & Francis.

[2] Joule: 'On the heat evolved by metallic conductors of electricity, and in the cells of a battery during electrolysis,' *Phil. Mag.* [3] xix. 260, 1841; 'On the electric origin of the heat of combustion,' *ibid.*, xx. 98, and xxii. 204; 'On the heat disengaged in chemical combinations, *Phil. Mag.* [4] iii. 481. See also *Reprint of Joule's Papers by the Physical Society of London* (Taylor & Francis).

actions going on there; but it was supposed, and is still supposed (though, as I venture to think, quite erroneously) to leave untouched the question as to the precise seat of the E.M.F. in a battery.

However that may be, the success of the chemical theory of the electric current naturally caused it to be still more certainly assumed that the apparent contact force of Volta could also be accounted for by accidental chemical action, and that without some chemical action somewhere no Volta effect could be produced. This also I believe to be quite false; provided always that the phrase 'chemical action' be used in its ordinary sense as meaning combination, and that the word 'action' be not explained away as meaning anything whatever.

2. The triumph of the chemical theorists with regard to the Volta effect was, however, shortlived, for, from 1860, the invention of the quadrant electrometer put into the hands of electrostatic experimenters a far more refined and delicate instrument than could have been thought possible a few years before; and the illustrious inventor of that instrument himself for ever put the truth of Volta's phenomenon beyond doubt, by the most simple and beautiful device of suspending a charged torsion arm over a zinc-copper junction. By comparing the deflection so produced with that caused by a Daniell cell, an absolute measure of the so-called contact force was made; and it was shown that on uniting the copper and zinc by a drop of water, instead of by a metal, no deflection was produced. It was also shown that the deflection was greatest when the zinc was clean and the copper oxidised.[1]

But Sir William Thomson went further than this; he sounded a theoretic note, and in a sentence revived the whole controversy about the seat of power in the pile. The sentence is this: 'For nearly two years I have felt quite sure that the proper explanation of voltaic action in the common voltaic arrangement is something very near Volta's, which fell into discredit because Volta or his followers neglected the principle of the conservation of force. I now think it quite certain that two metals dipped into one electrolytic liquid will (when polarisation is done away with) be at the same potential.' And then he goes on to one of those brilliant and extraordinary speculations characteristic of no one else, and applies this apparent contact force to determine a lower limit to the size of atoms—an application obviously of transcendent interest, and of more importance than all the previous outcome of contact discussions put together.[2]

The whole subject now acquired a fresh interest, and the new series of experimental determinations of contact force began.

3. Hankel's and Gerland's measurements belong to this period in point of date (1861–1869), though in method and motive they probably are the outcome of the earlier period.[3] Hankel uses a modified Kohlrausch method

[1] *Proc. Lit. and Phil. Soc.*, Manchester. Letter from Prof. W. Thomson to the president, Dr. Joule, Jan. 21, 1862. 'New proof of contact electricity.' See reprint of papers on Electrostatics and Magnetism, p. 317.

[2] 'There cannot be a doubt that the whole theory is simply chemical action at a distance. Zinc and copper connected by a metal wire attract each other from any distance, so do platinum plates coated with oxygen and hydrogen respectively. I can now tell the amount of the force, and calculate how great a proportion of chemical affinity is used up electrolytically before two such disks come within any specified small distance down to a limit within which molecular heterogeneousness becomes sensible. This of course gives a definite limit for the size of atoms.'—Letter to Dr. Joule, 1862, cited above. See also Thomson and Tait, *Nat. Phil.*, Part II., Appendix F.

[3] Hankel: *Electr. Untersuchungen: Abh. der Königl. Sächs. Gesellschaft. Math.-Phy*

and a Bohnenberger or Hankel electroscope; he makes measurements of Volta force for numerous metals, but his special merit is the determination of metal-liquid contact forces without introducing blotting paper, glass, or fingers, as the earlier experimenters had done.

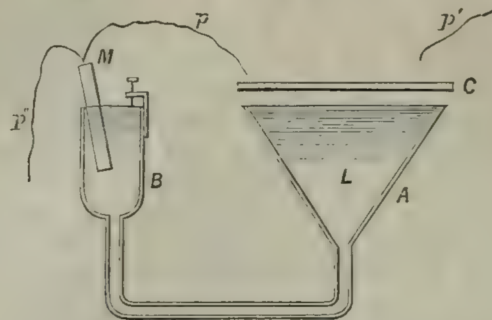

FIG. 3.—Hankel's Arrangement for observing the Volta Effect between a Metal and a Liquid.

The liquid L is in a funnel tube A B, C is a copper plate, and M the metal under observation. First P touches C for an instant, then C is raised and made to touch P′, which leads to a Hankel electrometer.

This gives $\text{Cu}/\text{M} + \text{M}/\text{L} = k\alpha$.

Then the liquid is run out of the funnel, a plate of the metal M is placed on its mouth, and the experiment repeated.

This gives $\text{Cu}/\text{M} = k\beta$

To eliminate k substitute a plate of zinc for M, and get

$$\text{Cu}/\text{Zn} = k\gamma. \quad \text{Then finally } \text{M}/\text{L} = \frac{\alpha-\beta}{\gamma}\,\text{Cu}/\text{Zn}.$$

In all these expressions air contact forces are as usual neglected. But it is very tempting to try if by increasing the number of such equations one cannot calculate some metal air contact forces. Thus the special case when M is copper gives one more equation. We can then take zinc instead of M, and can also make the condenser plate of zinc instead of copper, and so on; but we get no forwarder, fresh unknowns appear as fast as additional equations, and some of the equations are liable to degenerate into identities.

So far back as 1824 Becquerel[1] attempted the investigation of metal-liquid contacts, and Buff[2] made some measurements in 1842, but his results are scarcely likely to be reliable considering the poor experimental resources of that date.

Professor Clifton employed Kohlrausch's method in 1877, using a Thomson electrometer and a Clark cell as standard of E.M.F. He has only published a preliminary paper,[3] in which he overlooks minutiæ such as change of contact force by time and adventitious circumstances.

Klasse—1861 and 1865. See also *Pogg. Ann.* cxv. p. 57, and cxxvi. pp. 286 and 440; cxxxi. p. 607.

Gerland: 'On the E.M.F. between Water and some Metals,' *Pogg. Ann.* cxxxiii. 1868, p. 513; cxxxvii. 1869, p. 552. In his second paper, to get over the air effect, Gerland joins two metals through a galvanometer, and then dipping them into a liquid observes the first swing of the needle. He also compensates the E.M.F. by Poggendorff's method. He thus determines the value of—

$$\text{M}/\text{M}' + \text{M}'/\text{Liquid} + \text{Liquid}/\text{M}.$$

[1] Becquerel: *Ann. de Chimie*, 1824. He put the liquid in a copper capsule on the plate of an electroscope, and connected it with the condenser plate by his fingers.

[2] Buff: *Liebig, Ann. Chem. u. Pharm.* 1842. He made the lower plate of his condenser the metal to be examined; on it he placed glass, and then filter paper soaked in the liquid, which he connected with the metal plate by a wire of the s metal.

[3] Clifton: *Proc. Royal Soc.* xxvi. p. 299, 1877.

When he touches on theory he agrees with Thomson. Professor Clifton has examined the Volta effects for the substances ordinarily used in batteries with great care, and has probably elicited the maximum of accuracy possible to his method. He gives the E.M.F. of numerous virgin cells in which no current has circulated.

Ayrton and Perry in 1876 devised in Japan a very ingenious but somewhat unwieldy modification of Kohlrausch's method, and with the help of students carried out a most extensive and laborious series of determinations of metal/metal, metal/liquid, and liquid/liquid contacts.[1]

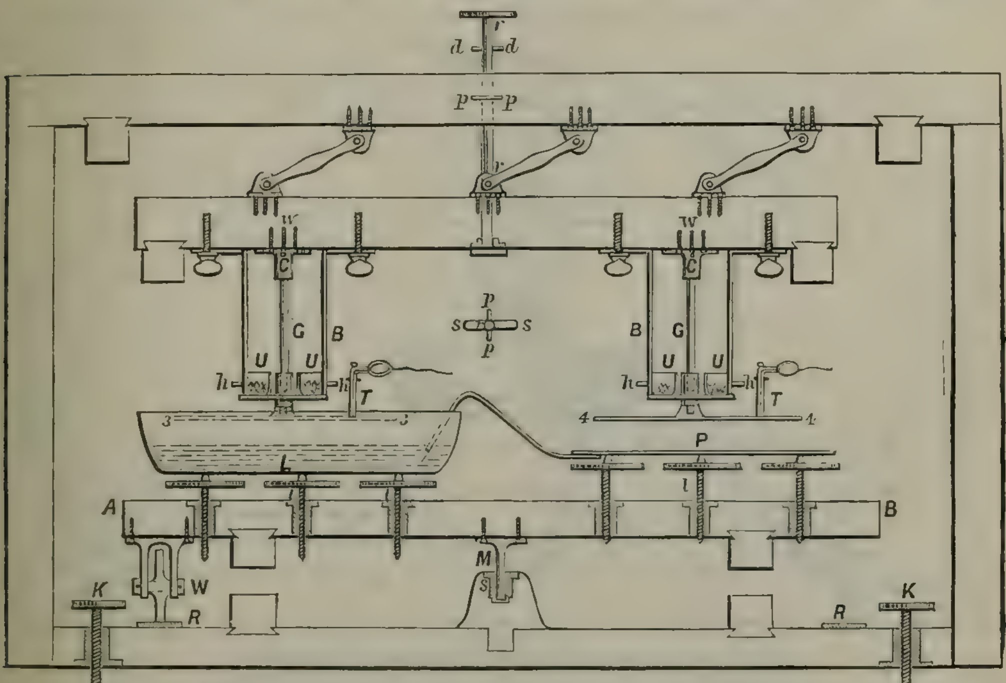

FIG. 1.—Ayrton and Perry's Apparatus for measuring the Volta effect with all sorts of substances.

The substances are arranged on the lower platform, as, for instance, the metal and liquid shown in the figure at P and L. The platform A B is capable of rotation through 180° on its railway R. 3 and 4 are carefully insulated gilt plates fixed to a bar which can be raised and lowered. The experiment consists in lowering these plates close to the surfaces to be tested, and connecting them with each other for a short time; then raise them, rotate the platform through 180°, lower again, and connect them with a quadrant electrometer.

On the appearance of Clifton's paper the year after, they issued a strongly-worded claim[2] in respect both of priority and completeness, a claim which seems to me well established, for their results are the most comprehensive yet obtained, and the energy needed to devise, construct, and use such an apparatus as the one they depict must have been immense. A convenient summary of their numbers is to be found in Everett's 'Units,' second edition. The main result achieved by them is the experimental establishment of the summation law for all substances

[1] Ayrton and Perry: Brit. Assoc. Glasgow, 1876. No abstract printed. Part I. *Proc. Roy. Soc.* 1877 or 1878 is a preliminary account. Part II. describes a metallic voltaic cell of magnesium and platinum and mercury, also some experiments on electrolytes of high resistance. Part III. *Phil. Trans.* 1880, is the complete account of their published electroscopic experiments.

[2] Ayrton and Perry: Letter published in 1877 by Meiklejohn, Yokohama.

(this is not to be confused with Volta's summation or series law, which is only applicable to metals), viz., that the total E.M.F. of a closed circuit of any number of substances may be reckoned by adding up the Volta forces observed electrostatically for every pair of substances in contact. This law is, it seems to me, for reasons given later (7), very probable theoretically, but still it was quite essential to have it experimentally established, especially as they point out that it is often called in question

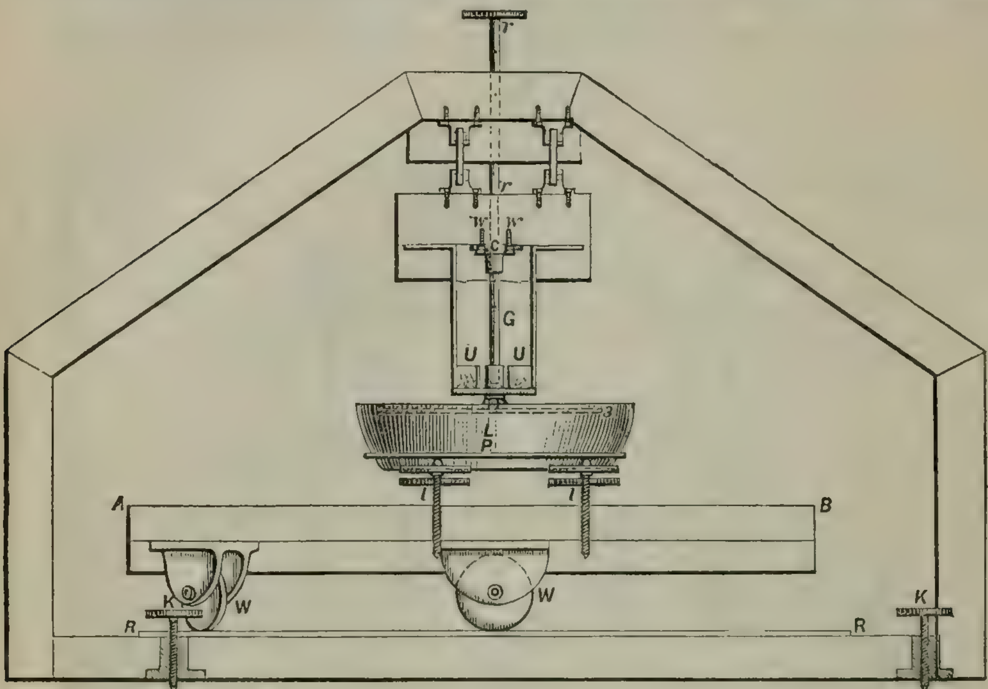

FIG. 5.—End view of Ayrton and Perry's Apparatus.

without good ground. The establishment of this law is, I say, perhaps their main work in this matter, besides the observation of the Volta effect for various difficult substances, especially liquids and liquids.

Clifton arrives at the same conclusion with regard to summation, and gives handy diagrams, reproduced in 'Jenkin's Electricity,' of the contact force at the different junctions. My own opinion is that the intended and obvious significance of these diagrams is theoretically wrong, but they embody certain experimental results conveniently, and they can be interpreted properly.

Both Clifton and Ayrton and Perry appear to believe in the great constancy of the value Zn/Cu. Clifton gives it as ·8516 Volt. ('Quelle précision ! ' somewhat sarcastically ejaculates Pellat, who himself finds it to vary between ·63 and ·92). Ayrton and Perry assert that it is more constant than a Daniell. I believe that both Professor Clifton and Professors Ayrton and Perry have made several experiments besides those recorded in their communications to the Royal Society, but as they have not been published I can give no account of them.

Among the Thèses presented to the Faculty of Science in Paris in 1881, we find an important memoir by Pellat,[1] which reviews the whole

[1] Thèses présentèes à la Faculté des Sciences de Paris, pour obtenir le Grade de Docteur-ès-Sciences Physiques, par M. H. Pellat, Professeur de Physique au Lycée

position very clearly, and records a series of determinations of Volta force among metals, determinations which are evidently the most accurate and satisfactory yet made. He adopts the capital experimental method of

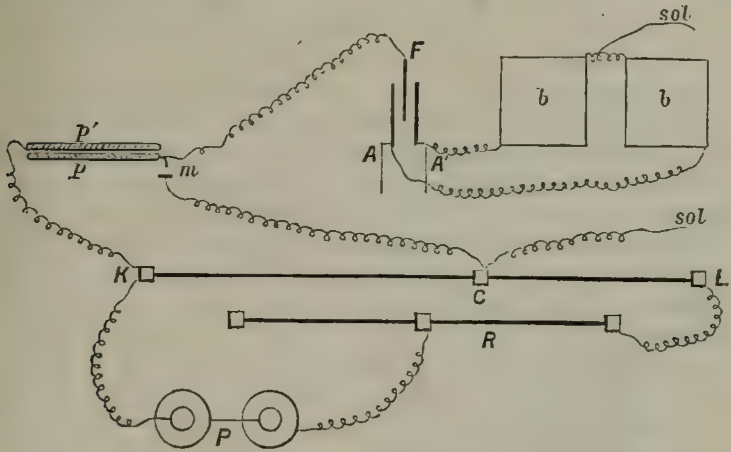

FIG. 6.—Diagram of Pellat's Method.

LÉGENDE.

KL compensateur.
C curseur.
R rhéostat.
P piles Daniell fournissant le courant du compensateur.
$p'p$ plateaux du condensateur (p fixe, p' mobile).

m interrupteur.
F feuille d'or.
A et A′ plateaux attractifs de l'électroscope.
b b batteries de 100 volts chacune pour charger les plateaux A A′.

The diagram Fig. 6 pretty well explains itself. The contact at m is broken the instant before p' is raised.

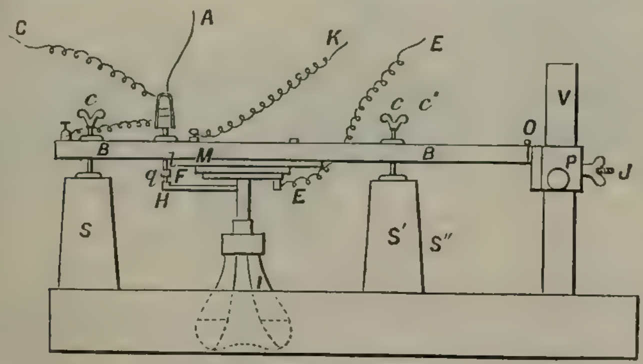

FIG. 7.—Pellat's Condenser.

Fig. 7 shows how this was done in practice. Pulling the string A raises a sliding pin with a shoulder q fixed to it a millimetre below the bar B. The pin thus first breaks contact near H, and then raises the hinged bar B B, to which the upper plate M is attached. The upper plate, being always in connection with a battery, requires no special insulation. The lower plate is carefully supported by a Thomson insulator I. The lower plate was considerably smaller than the upper one, and it was further protected from stray inductions by a guard screen. Screws c c served to regulate the distance between the plates.

neutralising the charge of a condenser by a Poggendorff or compensation method, and thus converts Kohlrausch's into a null method, for which a very sensitive electroscope is all that is needed. The plates of the two

Louis le Grand, No. 461: Juin 22, 1881. See also *Journal de Physique*, 1881, xvi. p. 68, and May 1880. 'Différence de potentiel des couches électriques qui recouvrent deux métaux en contact.'

metals set face to face are connected, not directly, but by a greater or less length of a graduated wire conveying a current; and the position of the slider on the wire is adjusted by continually separating the plates and testing until no charge at all is found. The step of potential on the wire is then precisely equal to the 'contact force' between the plates; for this would have caused a charge in a similar but uncompensated condenser, and the step of potential on the wire has neutralised it.

Compensation methods of a sort had been used before by Gerland and by Thomson. Gerland applied compensation to determine the E.M.F. of two metals dipped into a liquid, and Thomson applied it to the divided ring experiment, thus making it very analogous to that of Pellat.[1]

Pellat also adopts Sir William Thomson's view that the Volta effect is due to a true contact force between the metals, and that it represents a real difference of potential between them when in contact; at the same time he is careful to point out that no rigorous proof can be given of this, and that all that is really and certainly measured electrostatically is the difference of potential between what he calls the electric coats (*les couches électriques*), or what may be more simply called the air-films, on the two touching metals.

The following is a summary of some of Pellat's measurements, gold being the metal with which all are compared, and the numbers being given in volts:—

'DIFFERENCE OF POTENTIAL OF THE ELECTRIC COATS WHICH COVER A METAL AND STANDARD GOLD METALLICALLY CONNECTED AND BOTH IN AIR.'

Metals used	E.M.F. in Volts		Metals used	E.M.F. in Volts	
	With very clean but scarcely scratched surface	With surface strongly scratched by rubbing with emery		With very clean but scarcely scratched surface	With surface strongly scratched by rubbing with emery, or in some of the last cases with cloth or filter paper
Zinc . . .	·85	1·08	Iron . . .	·29	·38
Lead . . .	·70	·77	Brass . .	·29	·37
Tin . . .	·60	·73	Copper . .	·14	·22
Antimony .	·44	·49	Platinum .	−·03	+·06
Nickel . .	·38	·45	Gold . . .	−·04	+·07
Bismuth . .	·36	·48	Silver . .	−·06	+·04
Steel . . .	·29	·44			

[1] I find indeed that Sir W. Thomson completely anticipated Pellat in the application of galvanic compensation to the measurement of Volta effects; for in *Nature*, April 14, 1881 (vol. xxiii. p. 567), is printed an account, given in brief at the Swansea meeting of the British Association (see *Trans. of Sects.*, 1880, p. 491), which relates how the divided ring experiment naturally developed into more complete compensation with slide resistances, and that an extensive series of measurements were made on this plan in the years 1859–61 with results quite in agreement with those published by Hankel in 1862. Other experiments were made since 1861 with results confirmatory of those of Pfaff, 1821, showing the Volta effect to be independent of the surrounding gas. The description of all these experiments was therefore withheld till something new should be obtained by the method, and was not published until Pellat's

4. Meanwhile some experimenters, starting with a belief in the chemical origin of the Volta effect, had made experiments supposed to support this view. Mr. J. Brown, of Belfast, in 1878,[1] repeated Thomson's divided ring experiment, as well as Kohlrausch's condenser experiment, in other gases than air; and found a very decided difference, and even a reversal of sign, when sulphuretted hydrogen was substituted for air. The metals Brown used were copper and iron, and he obtained a one centimetre deflection in the direction indicating iron + in air, while in SH_2 he obtained a 3 centimetre deflection indicating that iron was —. On readmitting air the deflection again reversed, and so on, until the copper coated itself with a blue film of sulphide, when the deflection became undecided, owing, as Brown supposes, to 'the cessation of chemical action.'

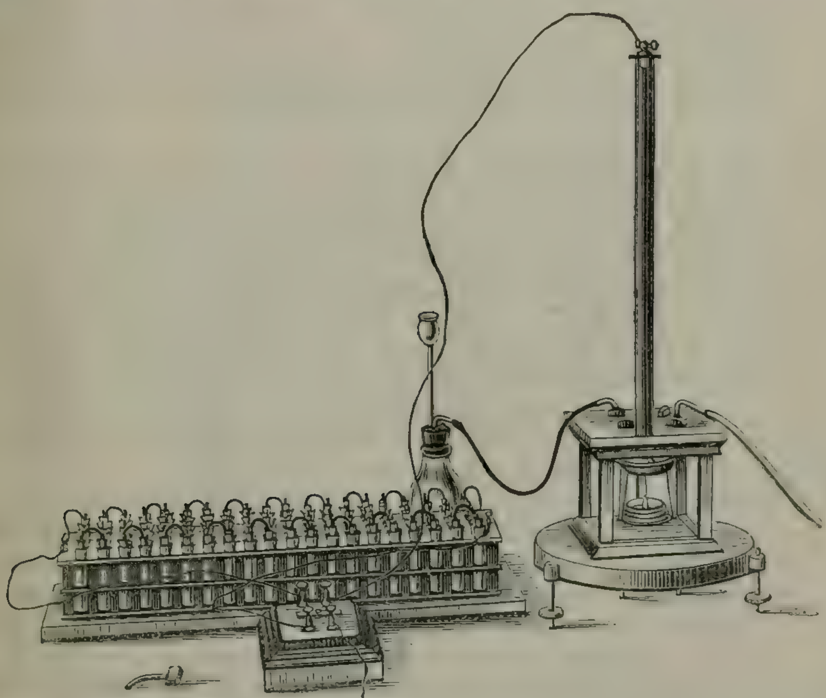

FIG. 8.—Mr. J. Brown's Arrangement for observing the Volta Effect in different Gases by Sir William Thomson's Method of a bimetallic ring with an electrified needle hanging over it.

In 1881 he observed a time change (decrease) of the Volta effect at a copper-zinc junction, and reckoned that at the first instant after cleaning the potential difference would be as high as ·9 Daniell, 'which,' he says, 'agrees with J. Thomsen's determination of the difference of the heats of combustion of zinc and copper and oxygen.' He here gives a hint of holding

paper had appeared in the *Journal de Physique*, May 1880. Fig. 10 sufficiently exhibits Sir William's arrangement. In a postscript are described a few additional experiments of the same kind as those published in 1881 by Schultze-Berge, in which a platinum plate is soaked for a certain time in dry hydrogen or oxygen, and then used in the Volta condenser. The observation is made that merely soaking a plate in gas is more effective than electroplating it with the same gas with an E.M.F. of a volt.

[1] J. Brown: *Phil. Mag.*, August 1878, Feb. 1879, and March 1881; see also Brit. Assoc., *Trans. of Sects.*, 1881, and *Electrician*, vol. vii. p. 165.

a heterodox notion which I do not find in any other of his writings, and which I believe he has abandoned even if he ever really held it.

In 1879 Brown tried a copper-nickel divided ring, substituting HCl for air, and here also succeeded in obtaining a reversal of sign. He also arranged a divided ring of wet blotting paper, and showed that there was a difference of potential when the two halves were touched with a zinc-copper couple (which is not remarkable), but he then goes on to draw a moral, and to say that the slit of the divided ring corresponds to the air-film, and the wet paper to the moisture film in the ordinary Volta condenser experiment. The film of moisture on the zinc plate is thus shown to have a + charge, and that on the copper a negative. If it be objected that the better the plates fit, the better the manifestation of contact E, it is to be replied that it is not to be supposed that there is no air between them anyhow (says Brown). Probably, he says, gas produces the difference of potential only so far as it forms a film on the surface. When a metal and a liquid are experimented on it is probably really a 2-fluid cell, the other fluid being that condensed on the surface of the metal.

Brown thus goes strongly for the activity of the films, or condensed air-sheets, which certainly exist on the surface of solids, and which may play an important part in the matter; but he supposes that these films act by corroding or attacking the plates, and that such a film is necessarily existent between surfaces nominally in contact if any Volta effect is to be produced, so that if the metal faces really and truly touched all over, they would show no charge when separated. Moreover, he lays it down that the potential difference is only observed while chemical action is going on, but that so soon as it ceases, from any cause, at once the Volta effect ceases too. In all this I entirely differ from him, but his experiments are very interesting and much to the point.

They cannot, however, be regarded as settling the question—the very important and fundamental question—as to whether the Volta effect depends on the atmosphere or medium surrounding the plates, or whether it is an absolute effect depending on contact alone. Experiments on this point are absolutely discordant, and it seems to be one of those points which it is very difficult to settle by direct experiment. For if by using a chemically-active gas instead of air, you get a positive result or change in the Volta effect, the answer from the other side is: 'Yes, of course, because your plates are corroded and coated with sulphide or chloride, or something whose contact forces come in and modify everything.' If, on the other hand, you get a negative result when you substitute some inert gas like hydrogen for air, then it is objected that you haven't removed the air film which the plates had contracted from long standing in the air, and if you answer indignantly that you did, and that your hydrogen was perfectly pure, it is replied with a sneer: 'Oh yes, it is not so easy to get pure hydrogen as you seem to think.'

Moreover, suppose a positive effect on changing the gas *was* established, what then? Nothing is settled except that the metal/air contact force is proved to be somewhat different from the metal/gas contact force. There seems to be really no way of knocking contact force on the head experimentally, and this probably because it is a reality: *there really is a contact force at every junction of dissimilar substances; and the E.M.F. of a circuit, whether it be inductive or conductive, is always the sum of such contact forces.* I do not say that the contact force at any given locality has the value ordinarily assigned to it as the result of experiment.

The earliest attempt made to examine the question as to whether the Volta effect depended on the atmosphere was made by Pfaff[1] in 1829, who

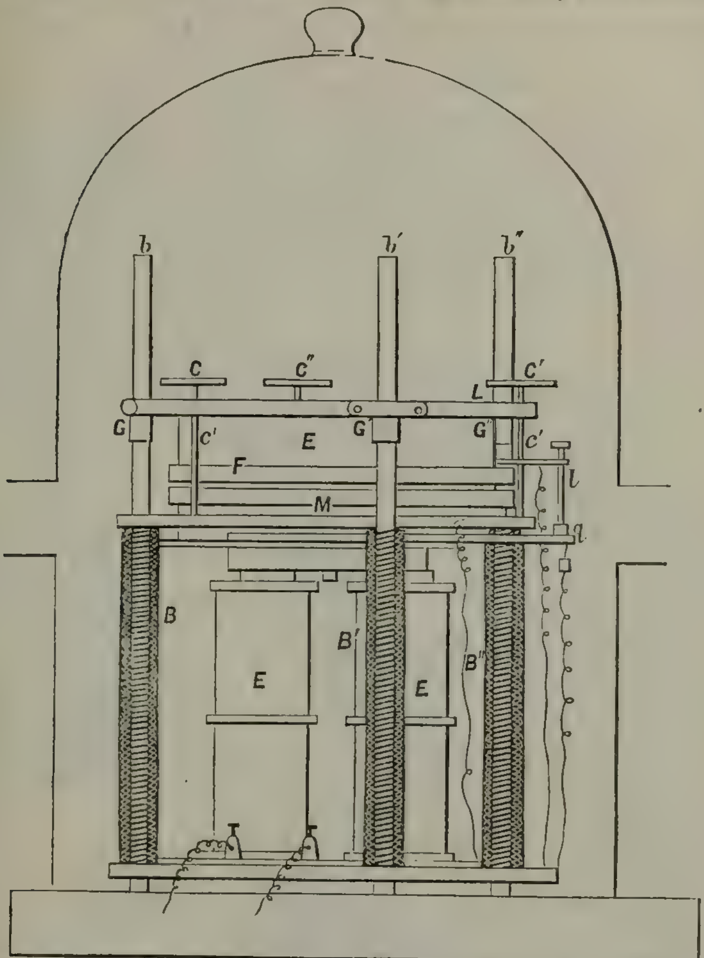

FIG. 9.—Pellat's Apparatus for experimenting in different Gases and at different Pressures.

The movable plate is now the lower one, and it is pulled down by an electromagnet E a little way against the springs B, which tend to drive it up against the screw stops C. Contact is automatically broken at q the instant before separation. The bell jar has 35 litres capacity, the diameter of each plate being 15 centimetres. It must be impossible to employ anything like pure gases in a bell jar enclosing such a bulky mass of heterogeneous material; and the pressure was found not to go below 2 or 3 centimetres of mercury. However he has since made a smaller arrangement of 1 litre capacity, with plates 9 centimetres diameter, and, what is more important, with the electromagnet outside, and nothing inside but glass, mica, and metal. In this the pressure goes down to a millimetre. But even this is not all that could be wished. Moreover the experiments described had been made with the larger apparatus.

used dry and damp air, oxygen, nitrogen, hydrogen, carburetted hydrogen, and carbonic acid, and he found that there was no difference so long as no visible chemical action occurred; but it must be noted that the opposing faces of his plates were varnished. De la Rive, on the other hand, asserted

[1] Pfaff: *Ann. de Chim.*, 2 ser. xli. 236. The metals he employed were copper, tin, and zinc.

that there was no Volta effect in the slightly rarefied air then known as 'vacuum.'

In recent times Pellat has investigated the subject, and has come to a conclusion in agreement with Pfaff, viz., that the differences are very small. The metals used by Pellat were copper and zinc, and the gases were air, dry and damp, dry oxygen, dry nitrogen, dry and pure hydrogen, dry and pure carbonic acid. He finds slight variations, but exceedingly slight, and such as Pfaff, Exner, and Brown could hardly have detected. He says: 'Au surplus, il est fort probable que, si quelques-uns des auteurs précédents avaient tenté les expériences que j'ai faites au sujet des gaz, ils auraient trouvé des résultats négatifs; les faibles variations produites par le changement des propriétés du gaz que j'ai pu mettre nettement en évidence, grâce à la précision des mesures, sont au-dessous des erreurs expérimentales de leurs méthodes, ou à peine supérieures dans les cas les plus favorables.'

In all the above gases he has also studied the effect of varying the pressure. Lowering the pressure slightly *increases* the observed difference of potential, but the change lags a little behind the pressure variation. Damp and dry air behave in the same way. In oxygen the effects of pressure are rather better marked. Nitrogen gives nearly the same numbers as air, but after it has been in for some time the numbers are slightly lower than at first. Hydrogen gives a little greater effect than even rarefied air; rarefying hydrogen does not alter it much. Carbonic acid gives the same numbers as rare air or dense hydrogen. As for liquids: plates wetted with alcohol give the same result as if immersed in plain air.

Von Zahn[1] also tried a condenser in various gases and found no difference, but when he tried a platinum zinc condenser in the highly rarefied air now known as vacuum, with some melted sodium in a branch tube to absorb all the oxygen, the Volta effect was diminished, and only represented a potential difference of half a Daniell. I am not clear whether sodium can be trusted to ultimately absorb every trace of oxygen, but I should judge it would take a very long time; and as to rarefaction—dividing the numbers of molecules in a vessel by a million or two leaves them quite numerous enough to accomplish anything they want.

Sir W. Thomson has also made experiments in different gases with negative results.[2] These experiments are not described in detail, but they were made with the apparatus shown in fig. 10.

The views of Ayrton and Perry on the subject of the effects of atmosphere underwent modification between their first paper and their third. In their first paper they say they have good reason to believe that there is no great difference of potential between a metallic or liquid surface and the air in contact with it.

Clerk Maxwell in a letter to the 'Electrician'[3] pokes fun at them for this, saying: 'A statement like this, coming from men whose scientific energy is threatening to displace the centre of electrical development, and to carry it quite out of Europe and America to a point much nearer Japan, is worthy of all attention, even without an explicit statement of their "good reason." But Mr. J. Brown has shown ('Phil. Mag.' August 1878) by the divided ring method of Sir W.

[1] Memoir quoted below.

[2] Thomson: Brit. Assoc., *Trans. of Sects.*, Swansea, 1880, p. 494. See a previous footnote.

[3] *Electrician*, April 26, 1879.

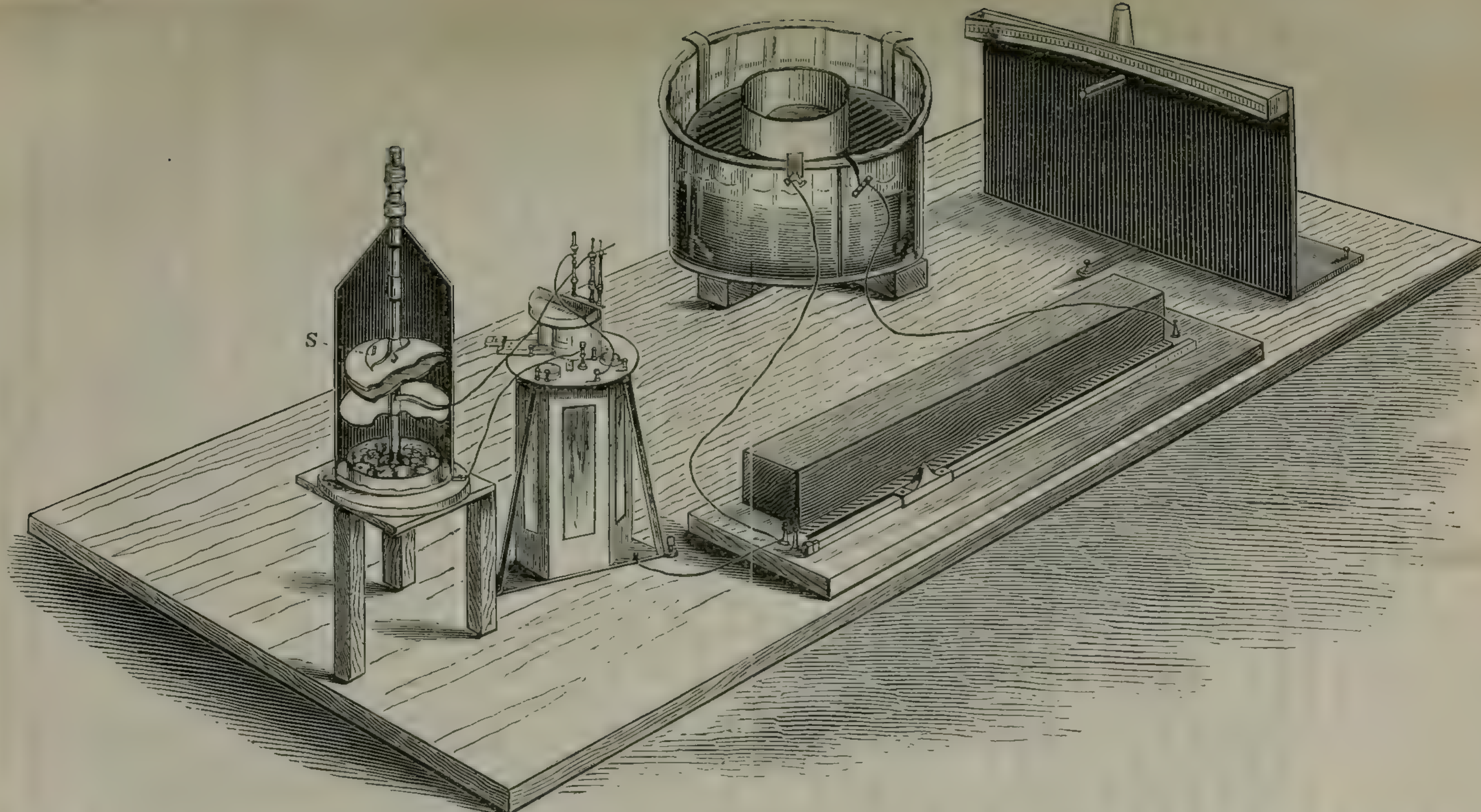

FIG. 10.—Sir Wm. Thomson's Compensation arrangement for measuring Volta-force in air and gases by a null method, devised and used in 1859, published in 1880.

The upper plate of the condenser is uninsulated, and slides up and down from one-fiftieth to a quarter or half an inch from the lower insulated plate, which is permanently joined to the electrometer. The upper plate is put in communication with the lower one momentarily through the slide resistance, and is then raised, the position of the slide being adjusted till no deflection ensues.

Thomson, that whereas copper is negative with respect to iron in air, it is positive with respect to iron in H_2S. It would appear therefore that the reason why the results of metals by the ordinary "contact force" experiments harmonise so well with the comparison by dipping both metals in water or an oxidising electrolyte, is not because the E.M.F. between a metal and a gas or an electrolyte is small, but because the properties of air agree to a certain extent with those of ordinary electrolytes. For if the active component of the electrolyte is sulphur the results are quite different, and the same kind of difference occurs when hydrogen sulphide is substituted for air.'

In their third paper,[1] therefore, we find Ayrton and Perry's views changed, and they clearly state that their experiments, like all those based on inductive methods, leave the question of air contacts quite undecided.

They then go on to say: 'One way of determining the E.M.F. of contact in volts between a substance and air, and a way we hope shortly to employ, is to repeat all these exact contact experiments in different gases [it is not quite true that this would give the results required, because it would only give differential effects; very important to observe, no doubt, but not the same as observing the actual contact force of air or of gas]. . . . We shall thus ascertain whether the contact difference of potentials of a substance and a gas differs much for different gases. Qualitative experiments in this direction have already been made with very interesting results by Mr. Brown, of Belfast, but his experiments differ from ours in not being quantitative.' [Only, as their experiments do not yet exist, Mr. Brown's have still some value.]

In vol. xii. of 'Wiedemann's Annalen'[2] I find some interesting experiments by Schultze-Berge on contact force between metals and gases. He uses a condenser and different gases, but the plates of his condenser are both of the same metal, and he coats one of the plates with a film of the gas, say chlorine, or hydrogen, or ozone, and leaves the other covered with air. To measure the potential difference he employs the compensation method of Pellat, and his arrangement seems fairly satisfactory. But he does not explicitly enter on the question as to the seat of E.M.F. in the Volta experiment (except in a controversy with Professor Exner). He assumes that a contact force between metals and metals and between metals and liquids has been established, and he wishes to extend it to the contact of a metal and a gas. Believing firmly in the existence of films of condensed gas at the surface of a solid, which films require time for their formation or removal, he deems it sufficient to soak one of the plates of his condenser in the gas to be examined, and then to take it out and measure the difference of potential between it and the other plate coated only with a film of air. Tried thus, ozone rendered gold, platinum, and brass negative as against the corresponding air-covered plate. Hydrogen rendered its platinum strongly positive, but its influence on gold was slight, and on brass uncertain. Chlorine and bromine made platinum negative, and ammonia made brass positive.

It may be readily objected that what the soaking with gas accomplished was the formation of not only a film of gas, but a film of actual chloride, oxide, or other combination. Against this is to be urged the fact that after removal from the gas the effect diminished with time, and the plates

[1] *Phil. Trans.*, 1880.

[2] Schultze-Berge: 'Ueber die Elektricitätserregung beim Contact von Metallen und Gasen.' *Ann. der Phys. u. Chem.*, xii. 293, 1881.

gradually returned to nearly their former state. He tried if he could remove the gas film from one of the plates by exhaustion under an air-pump, and the plate so treated exhibited a difference when taken out and compared with an ordinary plate; but he was cautious enough to repeat the experiment, leaving the plate under the bell jar for the same time and not exhausting. The same difference appeared, so he attributes it to possible grease.

This is the right sort of way to make experiments, and if everybody experimented with proper care there would be vastly fewer papers published in Germany, and science would progress on the whole faster.

At present it feels to me overladen with a mass of publication, mostly of necessity by men of not absolutely the first order, much of it with no sort of clearness or insight, but rough, crude, and ill-digested. A man makes a number of experiments; he does not stop to critically examine and weigh them, and deduce from them their meaning, nor indeed does he often take the trouble to examine whether any definite meaning can in their then shape be drawn from them; but he rushes with them into print, producing a memoir of wearisome length and sometimes extreme illiterateness of style.

Some one else then has the trouble of wading through the heap to see whether any fragments of value may perchance be imbedded in it, and probably he is unable to come to much definite conclusion, because he cannot be in so good a position for criticism of the experiments as the original author was. He therefore writes a paper pointing out defects and errors in the communication. Others take up the same line, the original man replies, and so there is a controversy, and nothing is really settled at all. Finally, some one else independently goes over the whole ground from some distinct point of view, makes a few well-planned, clear, and decisive experiments, describes them in a compact and readable form, and there results a definite gain to science. But how much better would it have been if this last paper had been the only one published! Unless a man is an experimental genius of the highest order, it is necessary for him to think for far more time than he experiments, if he wishes to advance, and not to lumber, his science. If it be objected, as indeed it may with great truth be, that one man's life and capacity are not sufficient for this in the present state of knowledge, the objection constitutes a strong argument in favour of the proposition that the time has come for an organisation of science and a more definite division of labour.

To return to the experiments of Herr Schultze-Berge. One is not able to say after all that they are very satisfactory, for they do not distinctly settle any question. The general conclusion he draws from them is the apparently safe one that the contact force between a metal and a gas is not in general the same as between a metal and air. Even this is not absolutely safe, however, because it might conceivably be that an air/gas contact force caused all the difference. Granting that this is unlikely, the experiments are in favour of a contact force between metals and air or gas, but they do not establish the fact any more strongly than, if so strongly as, Mr. Brown's experiments had already done: the weak point in both is the possible corrosion of the plates and formation of films of alloys or compounds, which may be the real source of the observed difference of potential.

And against the existence of a contact force between metals and various gases, the experiments of Pellat and others are to be remembered, which resulted in the conclusion that a condenser made of two different metals showed nearly the same Volta effect, whether the atmosphere surrounding the plates was air or hydrogen.

If it be assumed that the experiments of Brown and Schultze-Berge establish their point, and that Pellat's apparatus for different gases (fig. 9) is satisfactory (rather a large assumption), I am unable to reconcile the discrepancy, except by suggesting that Pellat did not take sufficient pains to remove the condensed air sheet originally on both his plates. It is of course just possible that the *difference* between the potentials of the two metals might be the same in two gases though the absolute potential of both was different, but it is improbable.

In this connection I must notice also a rather long memoir [1] by Dr. W. von Zahn, published in 1882, which reviews the whole subject, and describes an elaborate series of measurements made with an apparatus something like what one might suppose Ayrton and Perry's to become if it were arranged for use in different gases and in vacuo. He refers with admiration to Pellat's work in the preface, and I do not suppose imagines that his own numerical determinations can compare with Pellat's for accuracy where they overlap, seeing that he only makes use of a sort of combination of Kohlrausch's and Hankel's methods, with a Hankel electrometer as a measuring instrument.[2] He has tried, however, a large number of substances as well as ordinary metals such as powdered antimony, iron and nickel reduced by hydrogen, many kinds of carbon, Fe_3O_4, manganite, pyrolusite, copper oxide, lead 'hyperoxide,' iron glance, and other minerals. He has measured the Volta effect in various gases and at different pressures, and finds, like Pellat, that it does not appreciably vary.

He has also examined the effect of temperature on the Volta effect, though he appears to think that this ought to bear some close relation to the phenomenon of Seebeck, a natural mistake many years ago when made by Avenarius, whom it led most happily though fortuitously to the true, and by him experimentally verified, law of E.M.F. in a thermoelectric circuit.[3] However, Zahn finds that experiment lends no support to this view, and says that a larger series of results must be obtained before basing a theory on them. Von Zahn is a confirmed contact theorist, and he victoriously assails several experiments supposed to be distinctly in favour of a chemical view of the Volta effect. He says he publishes his results because of the extraordinary discoveries being propounded by Professor Exner (such as that a thermopile will not work in a vacuum),[4] and because of the vague

[1] *Untersuchungen über Contactelektricität*, von Dr. W. v. Zahn, Leipzig. Teubner, 1882.

[2] A Hankel electrometer is a modification of Bohnenberger's, in which a battery with middle to earth is substituted for the dry pile; the plates on either side of the gold leaf are minutely adjustable, and the motions of the gold leaf are read by a microscope. It is sometimes preferred to a quadrant for its small capacity and dead quick motion; it can be made very sensitive, but it can hardly be a satisfactory measuring instrument. Pellat used it, but only as an electroscope.

[3] Avenarius: 'Die Thermoelektricität, ihrem Ursprunge nach, als identisch mit der Contactelektricität betrachtet,' *Pogg. Ann.* cxix. 1863. See also *Pogg. Ann.* cxxii., where he proceeds to calculate Volta effects from thermoelectric data.

[4] I have been unable to find this extraordinary statement in Exner's works, but it is quoted again by Ayrton and Perry, *Phil. Mag.*, 1881, p. 49. Exner seems to have said that the thermoelectric power of bismuth-antimony is destroyed by immersing the pile in pure nitrogen, and Young of Princetown takes the trouble to examine whether it is so experimentally (see *Phil. Mag.* x. 1880, p. 450), and finds

and unsatisfactory views of physicists in general on the matter (*e.g.*, of Hart); but I am bound to say that, so far as I can judge, Dr. von Zahn's own experiments are not of that conclusive and decided character that one had hoped for from his start, and he signally fails to sum up the facts in a neat and crisp manner. He adheres to the contact view, but his adhesion scarcely seems to me to be based on strong evidence; and in fact

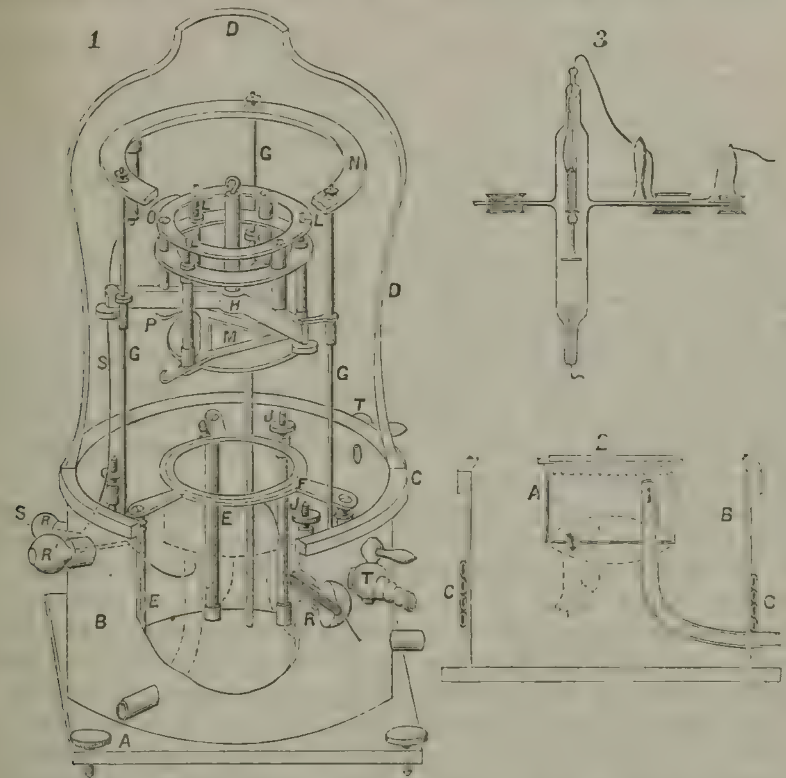

FIG. 11.—Von Zahn's Apparatus for experimenting in different Gases at different Pressures and Temperatures, and also in high Vacua.

The upper plate M is attached by glass rods to a sledge H, which slides on vertical steel rods G, being pulled up by a string. On reaching its highest point it comes into contact with an insulated platinum wire S, which communicates with a Hankel electrometer through one of the insulated exits R. The bottom plate is supported on the ring E. T is the stop-cock for exhaustion and change of gas. Fig. 2 shows the appendage to the bottom plate for warming it by a current of steam. Fig. 3 shows the apparatus used for high vacua. The two plates are zinc and platinum, and the platinum is arranged to fall by its own weight when the whole thing is inverted. The diagram shows it in its highest position, and just going to fall back into its dotted position. The friction of its guide rod seems not wholly satisfactory.

his theoretical views seem a little superficial, considering the date at which he writes, so that one may admit pretty well all he says about contact and not chemical action as the cause of the Volta effect without being deeply committed to any specially true or specially false position.[1] His

the thermoelectric power of metals the same at one-millionth atmosphere as at 1. This, however, is not conclusive, if it be regarded as a matter needing experiment to settle.

[1] I am afraid this is not peculiar to Dr. von Zahn. It may be that the German writers on the subject are too busy accumulating facts to care much about their precise theoretical bearing, but I notice a very loose and unsatisfactory way of putting forward secondary matters, as if they were the real points at issue, and of never really

best experiment, and a very crucial one if only it could be perfectly performed, is the attempt to measure the Volta effect in an absolute vacuum. A pair of zinc and platinum plates are sealed up in a glass vessel in such a way that one of them is capable of moving up and down, and thus of varying its distance from the other. Gravity is employed to separate the plates, the whole vessel being inverted. The vessel is filled with dry nitrogen and exhausted for some days, occasional heat, P_2O_5, and melted sodium being employed to improve the vacuum.

The result is that the Volta effect is very decidedly 'too small,' going down to half a Daniell, so far as the measurements made by his not entirely unobjectionable method can be trusted; but he does not seem to think that this is much of an argument either way, and, not finding any further change after some days, he did not pursue the investigation further by letting in some air and seeing whether the old value is restored, though he perceives clearly that this would be a crucial experiment. This abstinence is so remarkable that it seems necessary to quote his own grounds for it, and I do so in a foot-note.[1]

Zahn goes on to describe an experiment with bright sodium in *vacuo* instead of zinc, the sodium having been long kept melted in a laterally connected bulb before being introduced into position. He finds the sodium strongly positive to copper, but there can be nothing crucial about this experiment, I imagine, for metal in contact with glass may so easily give rise to disturbing electrifications.

I believe he must have employed the best vacuum of any experimenter on this subject, and that he has therefore gone most near to the proof of what I cannot help believing will be found to be the truth, viz., that the Volta effect in an absolute vacuum or perfectly inert gas (old air sheets *et hoc genus omne* having been thoroughly removed) is very small. But if it be the case, as I believe it is, that the effect is almost independent of the *quantity* of oxygen present, so long as it is present, the difficulty of making the experiment so as to be sure of the absence of even the last few thousand or million oxygen molecules is almost overwhelming. The question of the dependence of Volta force on atmosphere remains thus undecided, and all the evidence which I can adduce in favour of such dependence is this incipient decrease observed by

getting to the heart of the matter. It is singular that the four questions or heads under which that eminent writer, Professor Wiedemann, proceeds to discuss the attempts which have been made to settle the question of the seat of E.M.F. are such that if a categorical answer to each were, by supernatural means, vouchsafed to us, we should be, I believe, none the wiser. Wiedemann, *Elek.*, vol. ii. p. 985, new edition.

[1] 'Andere etwas bessere Beobachtungsreihen gaben ähnliche Werthe. Bei allen war die Kleinheit von C. (the apparent Volta effect Zn/Pt) auffallend. Nun stellt ja dieser Werth, wie oben besprochen, nicht die Potentialdifferenz Zink-Platin dar, für seine Kleinheit muss aber eine anderweitige Ursache vorliegen. Dieselbe kann ich zunächst nur darin finden, dass die Zinkplatte bei Anfertigung und weiterer Behandlung des Apparates sichtbar angelaufen ist (auf der einen Hälfte sogar blaue Färbung angenommen hat).

'Es liesse sich allerdings vermuthen, dass diese offenbar zu geringe Differenz in der wirklich wesentlichen Verminderung von Feuchtigkeit und Sauerstoff gesucht werden müsste, so dass der Apparat nach dem Oeffnen eine stärkere Spannung zeigen würde. Dies wäre dann wirklich ein *experimentum crucis* zu Gunsten der chemischen Theorie. Diese Entscheidung vorzunehmen wird aber erst dann nothwendig sein, wenn nach längerer Zeit, wo das eingeschmolzene Natrium noch mehr alle Reste von Sauerstoff beseitigt haben wird, eventuell noch Wiederhitzen und dergl. der jetzige Zustand des Apparates unverändert wieder gefunden sein wird.' *Von Zahn's Memoir*, p. 48.

von Zahn, the little too-mixed-up observation of Mr. Hart (described later), the measurements of Schultze-Berge, and the more decided experiments of Brown. It may indeed be readily held that the weight of experimental evidence tends the other way, since most experimenters on the subject—Pellat, Schultze-Berge, von Zahn, and, I may add, Sir William Thomson—have left off just as pure contact theorists as they began. I would attempt an experiment myself, save that I am so profoundly impressed with the difficulty of making one in which no fault or loophole can be found, and which will by everyone be deemed satisfactory and final; so I prefer to base my views on a general survey, and on fairly conclusive reasoning, rather than on a crucial but almost impossible experiment.

5. Perhaps this is now the place to refer to the somewhat erratic series of papers by Professor Franz Exner, of Vienna.[1] He sets himself to disprove the existence of contact force in the most straightforward and obvious manner, and to establish the fact that there is no electrical evolution without definite and actual chemical action. To this end he announces the following propositions: (1) that two metals in a chemically indifferent medium show no electricity; (2) that the potential difference of two connected metals in air is exactly half the difference of their heat combustion energies; and (3) that two pieces of the same metal produce contact electricity as soon as they are put into chemically different atmospheres.

The experiments by which he supports these assertions have, every one of them, been elaborately and severely criticised by Beetz, Hoorweg, Julius, Schultze-Berge, von Zahn, Ayrton and Perry, Pellat, and Wiedemann; and his numerical determinations of contact force appear to be unique.[2]

It is not necessary for me to enter into a discussion on the merit of his experiments, inasmuch as the mere fact of the existence of so great a body of hostile opinion is sufficient to show that they are not of a kind best qualified to produce conviction. The theoretical views which led Professor Exner to formulate his second statement above, that the potential difference of two connected metals is equal to half the difference of their heats of combustion per equivalent, are, I am sorry to say, quite unintelligible to me. They depend on the hypothetically necessary existence of films of oxide, between which and the metal there is supposed to be a considerable difference of potential. Perhaps a few quotations from Professor Exner's first paper on contact electricity will render his position clearer.[3]

[1] Exner: *Sitzb. der Akad. der Wissensch.* Wien: July 1878, 'On the Nature of Galvanic Polarisation'; July 1879, 'On the Cause of the Production of E. by the contact of Heterogeneous Metals'; Dec. 1879, 'On the Theory of Inconstant Galvanic Elements'; May 1880, 'On the Theory of Volta's Fundamental Experiment'; July 1880, 'On the Theory of Galvanic Elements'; Nov. 1880, 'On the Nature of Galvanic Polarisation'; July 1882, 'On some Experiments relating to Contact Theory.'

[2] Beetz: *Wiedemann's Annalen*, xii. 290; Hoorweg, *ibid.*, xi. 133, 1880, and xii. p. 90; Julius, *ibid.*, xiii. 276 and 296; Schultze-Berge, *ibid.*, xv. 440, as well as xii. 307 and 319; von Zahn, p. 41 and Preface, of his Memoir; Ayrton and Perry, *Phil. Mag.* 1881, p. 43; Pellat, *Paris, Thèses*, No. 461, p. 17; Wiedemann, *Elektricität*, ii. 992–995.

[3] I quote from Mr. J Brown's translation (*Phil. Mag.*, Oct. 1880) of a paper by Exner in Wiedemann's *Annalen* of the same year, with some abbreviations. 'An investigation concerning the nature of galvanic polarisation has led me to a quite distinct view of the origin of the so-called contact electricity, a view which will be supported by experiments following. I have shown that the original cause of the polarisation

His views are but little really different from those of De la Rive and other older 'chemical theorists,' but they are (especially in later papers) expressed in so definite and decided a manner that they have excited a sharper controversy than vaguer and more hesitating writings could. This indeed may be regarded as their special merit. The main objection which can be taken to them relates to the quantitative statements: these are vigorously made, but they seem unwarranted by facts accumulated by all other observers, though indeed some of his own experiments certainly seem to support them. It has also been objected that he misinterprets some of his experiments.

He has got hold of the notion that the heat of combustion has some sort of relation to the Volta effect, and there I am heterodox enough to agree with him. But what the relation is, and how it acts, and what sort of potential difference you ought to expect in accordance with theory, concerning all these things I am utterly at variance with him; and I deem it prudent not to attempt to represent views which I am unable to understand, because it is unlikely that I should do them justice.

Professor Exner to strengthen his position adduces a large number of very simple experiments (such as connecting first one Daniell and then two Daniells to an electrometer, and observing that in the second case the deflection is double the first), and from them he obtains equations proving algebraically that $Zn/Cu = 0$. Considered as conundrums these equations are ingenious, but it is a waste of time seriously to discuss them as Herr Julius has done in an elaborate manner. To suppose that such everyday experiments as these are in direct contradiction of the contact theory is scarcely complimentary to the great men who have held, and who still hold, that view.

Dr. C. G. Knott in 1879[1] examined the contact force between plates of

current is to be sought for not at the contact of the electrodes with ions liberated on them, but in the recombination of the latter, and the E.M.F. of the current so produced is measured by the heat value of this combination, just as the E.M.F. of any galvanic cell is measured by the heat value of the chemical process going on in it. With a so-called contact action the existence of the polarisation current, and obviously of every other current, has nothing whatever to do. The idea then suggested itself to seek for the cause of the production of electricity in the experiment of Volta, not in the contact of two metals, but in previous chemical actions of the surrounding media on their surfaces. I have expressed the opinion that so-called contact electricity is produced by the oxidation of the metal in contact by the oxygen of the air just as in galvanic cells it is evolved by oxidation of zinc. If the supposition prove true—and it has proved true—the E.M.F. of his metal in contact in air must be measured and expressed by their heats of combustion.'

Exner then points out how all Volta tension series are in oxidation order, and relates approvingly De la Rive's view that metals in air were attacked not only by water vapour, but by dry oxygen, and that electricity is produced by any kind of chemical action in proportion to the intensity of the chemical affinity. Then he gives his numerical theory and supporting experiments, and finally concludes: 'I believe we are entitled to say that no *Scheidungskraft* exists at the contact of two metals.' The following must take the place of Volta's law of the evolution of electricity: "The difference of electric potential between two metals in contact is measured by the algebraic sum of the heat value of the chemical action going on at each.'

In his theory and experiments, and all through the rest of the paper, Exner considers the difference of potential equal to *half* the difference of heat values, so the above last statement must be a slight numerical slip.

The above extracts are among the most favourable I have been able to find. It would be easy to select passages from this, and from his other memoirs on the subject, of a more surprising character.

[1] Knott: *Proc. R. S. Edin.* 1879–80, No. 105, p. 362.

the same metal at different temperatures, using the condenser or Kohlrausch method. He found that iron, copper, zinc, and probably tin, were negative when hot to the same metals cold; and the effect increases uniformly with temperature. But it is permanent, remaining after the hot plates have cooled down; hence it must be due to oxidation. A slow oxidation proceeds with time alone. Time curves are logarithmic like cooling curves, and the most oxidisable metal varies most quickly both for time variation and temperature variation. There seems to be a surface condition of a metal proper to each temperature which no polishing can change, for it establishes itself in a few seconds after cleaning, and only changes with temperature.

Mr. S. Lavington Hart, in 1881,[1] describes a mercury dropper where the mercury is contained in a funnel, and is connected with an electrometer by an iron rod dipping into it. The drops form inside an iron inductor, and they fall negatively charged. Mr. Hart so far ignores any Volta force that he considers the arrangement as an inversion of Lippmann's electrometer, the advancing drops being oxidised. It can plainly be regarded, however, as a mere Fe/Hg contact arrangement, and that is what I suppose it to be. He makes two interesting modifications: the first is to replace the air round the dropping mercury by coal-gas; the electrical effect is then zero. This is interesting because the exuding drops of mercury, unlike most pieces of metal, expose to the coal gas a virgin surface which has probably contracted no condensed air sheet: only coal gas is a rather sophisticated substance for it to be first exposed to. If the experiment is regarded as sufficiently direct and simple, this fact lends support to the view that Volta forces depend on the medium surrounding the metals.

The second modification is to bring an earth-connected iron bar close to the drops, and to show that it reduces the deflection. Mr. Hart thinks it reduces the oxidation by proximity; and certainly, provided the obvious action of a mere electrostatic screen has been considered and provided against, this action by proximity is very remarkable. A similar effect has been observed and more fully worked out by Pellat in a paper published in 1882.[2] Pellat says that if he places two metallic surfaces parallel to one another and very close together (say half a millimetre more or less: variations from 12 to ·1), each metal undergoes a slight alteration of the properties of its superficial coat, and thereby changes its position in the voltaic series. The alteration takes some minutes to produce, increases with time, but tends to a limit. When the influencing metal is removed the other returns gradually to its primitive state. Lead and iron produce the largest influence effects; copper, gold, and platinum give smaller but distinct effects; zinc produces hardly any, unless it be put within a hundredth of a millimetre or so. Pellat does not attempt to account for this interesting phenomenon further than by suggesting some possible connection with the smell of metals.

Mr. Hart's theoretical views are at first sight analogous to my own, though they are by no means the same. He considers the case of two metals immersed in liquid electrolytes, and dismisses air by calling it a gaseous electrolyte. He believes zinc and copper in contact to be at the same potential, and throws the variation of potential on the air between

[1] Hart: *Brit. Assoc. York*, p. 555, and *Phil. Mag.*, Nov. 1881, 5 ser., xii., 324.
[2] Pellat: *Comptes Rendus*, xciv., 1882, p. 1247. Influence of metals on one another at a distance.

them.[1] He considers the electrical effect brought about by the electro-negative ion oxygen combining with the zinc and charging it negatively, while some electro-positive ion combines with the copper and charges it positively, 'though not unless the two metals are in sufficient proximity to overcome electrolytic diffusion' [whatever that may mean as applied to this case]. He thinks his mercury dropping experiment in coal gas is conclusive as to the equality of potential of metals in contact. This, I fear, is rather rapid induction. I do not see how it follows on his own hypothesis that his arrangement is virtually a reversed Lippman electrometer.

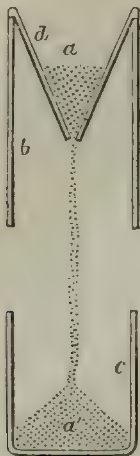

FIG. 12.—Thomson's Gravitation Voltaic Cell.

a copper filings. *c* receiver.
b inductor—zinc. *d* copper funnel.

The copper filings drop negatively charged against electrical forces. If you join *c* and *d* by a copper wire you can get a current flowing wholly through and with copper.

Sir W. Thomson's dropping arrangements or voltaic cells, in which gravity does the work instead of chemical action, are so well known that it is scarcely necessary to do more than refer to them. Mr. Hart's mercury dropper is scarcely a modification of the copper-filing dropper shown in fig. 12. Sir William also shows how to couple up such cells in series,[2] and how to construct a mechanical replenisher on the Volta principle (fig. 13).

6. In order to give this historical sketch more completeness, it may be as well to record rapidly such other memoirs as I have been able to get acquainted with: it is in the highest degree probable that several are omitted, but I hope no very important ones. Professor Wiedemann's collection of views and

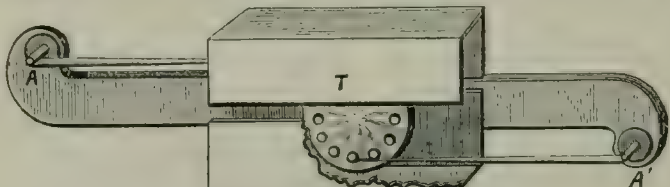

FIG. 13.—Thomson's Voltaic Induction Machine.

One of the inductors T is lined with one metal, the other with another, and the two connected. The carrier wheel is rotated, and the contact springs A A' become oppositely charged. By afterwards charging the inductors with a Daniell cell, and comparing the deflection now produced in an electrometer connected to A A' with what it was before, measurements of Volta effect can be obtained; or of course it can be made a null method.

memoirs bearing on the subject is at the end of the second volume of the new edition of his 'Elektricität.'

Edlund has published a long paper[3] in which he investigates experimentally the Peltier effect; he points out clearly at the end that there is

[1] The diagrams of potential which Mr. Hart gives of cells were given more fully by Prof. Exner in his paper on the Theory of Galvanic Elements, 1880. Mr. Hart's views are, in fact, rather similar to some of the more reasonable ones of Prof. Exner.

[2] *Electrostatic Reprints*, p. 325.

[3] Edlund: *Pogg. Ann.* cxxxvii. 474; cxl. 435; cxliii. 404, 534. See also *Phil. Mag.* (4) xxxviii. 263; xliii. 81, 213, 264; especially p. 273.

no relation between the Peltier and Volta effects, and he suggests that this is because of the contact force between the metals and the gas or air in which they are, the fact of such contact force being, he thinks, sufficiently established by gas batteries and galvanic polarisation.[1]

Majocchi, in a paper printed in 'Phil. Mag.' xxx., p. 97, regards the E.M.F. of contact as due to the 'adhesion' of the two metals for each other: pretty much the same idea as Sir Wm. Thomson's chemical action at a distance, an idea which makes the energy of the Volta effect Zn/Cu depend on and be calculable from the combination heat of zinc and copper in making brass. I must return to this matter later, because it is important in itself and crucial as regards theory.

Gassiot[2] made an experiment intended to show that there could be a difference of potential excited between metals by proximity without actual contact, or at any rate without metallic contact. Grove[3] also made a similar experiment.

Hoorweg[4] and also Nobili[5] have a theory that all galvanic currents are really thermoelectric.

In the article 'Electricity' in the 'Ency. Brit.' p. 99, Professor Chrystal gives some clear general considerations regarding the seat of E.M.F., and the opposing views which are held with regard to it. He is judicial in his attitude with regard to them, but the mere statement of the position in so clear a form is in itself a powerful argument for the views held by Maxwell.[6]

Fleeming Jenkin, in the last edition of his 'Electricity and Magnetism,' p. 216, endeavours to reconcile the contact and chemical theories. According to the chemical theory the E.M.F. of a cell$=\Sigma$ (J $\theta\epsilon$); according to the contact theory it is C/L+L/Z+Z/C. On these undoubted facts he

[1] Sundell investigates the E.M.F. of alloys in contact with copper, employing Edlund's method, and finds, like him, that for alloys, as well as for simple metals, the Peltier corresponds with the Seebeck force. The peculiar language used in this and the preceding paper may easily cause it to be imagined that they have found Volta force to agree with Peltier. In fact, Sundell is so quoted in Watt's 3rd *Suppl.*, p. 708. Von Zahn quotes Edlund in the same sense, and indeed it is probable that Edlund himself at first thought he was investigating Volta forces thermoelectrically.—Sundell: *Pogg. Ann.* cxlix. 144

[2] Gassiot: *Phil. Mag.* xxv. 1844, p. 283.

[3] Grove: *Literary Gazette*, Jan. 21, 1843. Wiedemann, *Elec.*, ii. 988

[4] Hoorweg: *Wied. Ann.* ix. 552, 1880; xi. p. 233, and xii. p. 75.

[5] Prof. Wiedemann notes, as interesting, that in 1828 Nobili held a notion that all galvanic currents are thermoelectric, thus vaguely anticipating the modern thermodynamic theory of E.M.F. See Wied., *Electricität*, ii. 985, and Nobili, *Bibl. Univ. de Genève*, xxxvii., p. 118. But Prof. Hoorweg seems bitten with the same idea in recent times, and in 1879-80 writes long papers in proof that all current energy is due to absorption of heat at junctions!

[6] Although this article is, or ought to be, easily accessible to everybody, there is one important suggestion in it which it is as well to quote, viz. that contained in the following sentence: 'We are so ignorant of the nature of the motion which is the essence of the electric current that the very form in which we have put the question [as to the locality of the E.M.F.] may be misleading. If this motion be in the surrounding medium, as there is great reason to believe it to be, it would not be surprising to find that speculations as to the exact locality of the E.M.F. *in the circuit* were utterly wide of the mark.' Prof. Willard Gibbs suggested something of the same sort at Montreal, though in a rather vaguer form. I do not myself feel any doubt that a precise location can be given to the E.M.F., notwithstanding that much of the current energy exists in the medium. The most complete attention to the distribution of energy in circuits which has yet been bestowed on the subject has been given by Prof. Poynting in his remarkable memoir, *Phil. Trans.*, 1884, and he therein locates the E.M.F. of a battery exactly where I do myself.

proceeds to found a number of statements which are true,[1] though scarcely simple; in fact, they perhaps rather tend to complicate what may be held to be a simple matter.

Schönbein, in a letter to Faraday published in the 'Philosophical Magazine' for 1838,[2] throws out a remarkable suggestion with regard to 'chemical tendency' as the possible source of a current, or rather of 'force electromotive.' His language and ideas are in many respects old-fashioned and erroneous; he uses such phrases as 'a current of tendency,' he supposes currents with no electrolytic power to exist, and of course is not troubled about energy considerations. But I feel little doubt that had he lived later he would have held that, while *currents* were due to chemical action, *electromotive force* was due to 'chemical tendency'; and this is pretty exactly my own view of the matter.

I have only just discovered this Schönbein letter, and I have also found some paragraphs in Faraday which more in detail, and with fair distinctness, express what I believe to be the true view. (See §§ 893–900, 'Exp. Res.' vol. i.) [3]

[1] Except, indeed, a doubtful statement at the end of Number 2, and an erroneous bit of reasoning at the end of Number 4, though the conclusion drawn is correct.

[2] Schönbein: *Phil. Mag.* vol. xii. pp. 225 and 311. The two most striking sentences are here extracted:—

'Before closing my letter, allow me to communicate to you in a general manner the view which I have taken of the subject in question. In the first place, I must tell you that I am by no means inclined to consider mere contact in any case as the cause of the excitement of even the most feeble current. I maintain, on the contrary, in accordance with the principles of the chemical theory, that any current produced in a hydro-electric voltaic circle is always due to some chemical action. But as to the idea which I attach to the term "chemical action," I go further than you and M. de la Rive seem to go; for I maintain that any tendency of two different substances to unite chemically with one another must be considered as a chemical action, be that tendency followed up by the actual combination of those substances or be it not, and that such a tendency is capable of putting electricity into circulation.'

And on page 314 he explains this last phrase, which he has elsewhere called a current of tendency, thus:—

'As what I term a current of tendency is no doubt in some cases nothing but that electrical state which the voltaists consider to be the effect of their "force electromotive," or of contact, it appears to me that, from some of the facts above stated, a specific and most important conclusion regarding the theory of the pile can be drawn. Even if we grant to the voltaists our current of tendency to be the effect of mere contact, the facts alluded to prove that such a current does not possess a sensible degree of electrolysing power, consequently that the chemical effects of the common voltaic arrangements have nothing to do with current electricity excited by contact.'

[3] Extract from *Faraday's Experimental Researches*, vol. i.:—

'(893.) The use of *metallic contact* in a single pair of plates, and the cause of its great superiority above contact made by other kinds of matter, become now very evident. When an amalgamated zinc plate is dipped into dilute sulphuric acid, the force of chemical affinity exerted between the metal and the fluid is not sufficiently powerful to cause sensible action at the surfaces of contact, and occasion the decomposition of water by the oxidation of the metal, although it is sufficient to produce such a condition of the electricity (or the power upon which chemical affinity depends) as would produce a current if there were a path open for it; and that contact would complete the conditions necessary, under the circumstances, for the decomposition of water.

'(894.) Now the presence of a piece of platina touching both the zinc and the fluid to be decomposed opens the path required for the electricity. Its *direct communication* with the zinc is effectual, far beyond any communication made between it and that metal (*i.e.* between the platina and zinc) by means of decomposable conducting bodies, or, in other words, *electrolytes*, as in the experiment already described [that of decomposing iodide of potassium without metallic contact by interposing it on blotting paper between the platinum and the zinc of a simple voltaic cell], For much discussion of contact electricity, and for some interesting statements of the views of Marianini, Davy, and others, refer to 'Experimental Researches,' vol. ii. p. 20, &c. From what is there said it appears that Karsten and Marianini held a modified contact theory, placing the E.M.F. at the metal-fluid junction; and that Becquerel admitted as a possibility the efficiency of chemical attraction, as distinct from combination, something in the same way as Schönbein.

Prof. Tait, in his 'Thermodynamics,' lends his powerful support to the contact view of the activity of the pile as taught by Sir W. Thomson.

Some work has been done in the direction of observing reversible heat effects at metal-liquid junctions, notably by Joule, Thomson, and Bosscha.

Joule in 1841 sent currents through several dilute acid voltameters with different electrodes, and measured the excess or reversible heat $H-RC^2$ generated in the whole cell; with the result that the excess of heat observed is that due to the observed back E.M.F. of the cell, minus that concerned in the decomposition of water. A table of his results is given by Chrystal, 'Ency. Brit.,' p. 91. For Maxwell on the same subject see 'Elementary Electricity,' p. 146.

Thomson (Math. and Phys. Papers, pp. 496, 503) says that of two decomposition cells, one with zinc cathode, the other with platinum cathode, the former showed the most heat when the same current was sent through both. Separating the electrodes by a porous cell, zinc cathode showed more heat than zinc anode; but platinum anode more heat than platinum cathode.[1] He speaks of the local heat developed at a tin surface, and shows that it is greater where hydrogen is liberated than where tin is dissolved; and suggests thermal observations on four dilute acid voltameters in one circuit with zinc and platinum electrodes, arranged according to the permutations, zinc zinc, zinc platinum, platinum zinc, and platinum platinum. Thomson attributes the extra heat at an electrode to opposing chemical affinities which have to be overcome—a doctrine of 'chemical resistance.'

because, when *they* are used, the chemical affinities between them and the zinc produce a contrary and opposing action to that which is influential in the dilute sulphuric acid; or if that action be but small, still the affinity of their component parts for each other has to be overcome, for they cannot conduct without suffering decomposition; and this decomposition is found *experimentally* to react back upon the forces which in the acid tend to produce the current, and in numerous cases entirely to neutralise them. Where direct contact of the zinc and platina occurs, these obstructing forces are not brought into action, and therefore the production and the circulation of the electric current, and the concomitant action of decomposition are then highly favoured.

'(895.) It is evident, however, that one of these opposing actions may be dismissed, and yet an electrolyte be used for the purpose of completing the circuit between the zinc and platina immersed separately into the dilute acid; for if in the above experiment the platina wire be retained in metallic contact with the zinc plate, and a division of the platina be made elsewhere, then the solution of iodide placed there, being in contact with platina at both surfaces, exerts no chemical affinities for that metal; or if it does, they are equal on both sides. Its power, therefore, of forming a current in opposition to that dependent upon the action of the acid in the vessel is removed, and only its resistance to decomposition remains as the obstacle to be overcome by the affinities exerted in the dilute sulphuric acid.

'(896.) This becomes the condition of a single pair of active plates where *metallic contact* is allowed. In such cases, only one set of opposing affinities are to be overcome by those which are dominant in the vessel; whereas, when metallic contact is not allowed, two sets of opposing affinities must be conquered (894).'

[1] Showing, I suppose, that while zinc attracts oxygen much, and hydrogen not at all, platinum attracts hydrogen more than oxygen.

Bosscha examines and develops all these matters in a series of interesting papers published about 1857.[1] He attributes the development of local heat, at a cathode against which hydrogen is liberated, to the change of hydrogen from the nascent condition to the ordinary one—in other words, to the energy of the molecular combination H, H. He finds the electro-motive forces exhibited by this local generation of heat at the surface of different metals in acid to have the following values in volts :—

Pt	Fe	Cu	Sn	Hg	Zn
·45	·49	·64	·86	1·2	1·2

One more memoir I must mention before closing this historical sketch and discussion thereon ; a valuable communication by Bouty to the 'Journal de Physique,'[2] 'On thermo-electric force at contact of metals and liquids, and on the Peltier effect thereat.' He finds the Peltier coefficient at a junction of copper with salts of copper eighty times as great as at an iron-zinc junction, and eleven times as great as bismuth-copper. He also measures the metal-liquid thermo-electric E.M.F. at different temperatures, and shows that Thomson's thermo-dynamic formula

$$J\,\Pi = \frac{T\,d\,E}{d\,T}$$

is perfectly true and in agreement with experiment in these cases also. He endeavours to see if this Peltier, or, as we had better call it for distinction, Joule or Bouty effect can be calculated from the energies of combination. After tabulating his results alongside of heats of oxidation and heats of solution, he decides that it is hopeless, and that we must give up trying to establish a relation between these quantities. Chemical action, he concludes, only disturbs the effect by altering the surfaces, and by developing parasitic heats. They may mask, but they do not produce, the true Bouty phenomenon, which he believes is probably physical.

The difficulties of making these measurements are exceedingly great, and, notwithstanding the ingenuity and skill displayed, it seems to me possible that some error or unexpected source of disturbance may have modified the results. So far as I know, they have not yet been repeated, and I can hardly regard the experimental method used as perfectly safe.[3]

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7. The result of our survey in regard to the special subject of discussion may be summed up thus : (1) that there is certainly an E.M.F. at the junction of two different substances, or even of the same substance in two different states ; and (2) that the total E.M.F. of a circuit is the algebraic sum of all such contact forces at every junction in the circuit.

I do not know that these two propositions could be passed *nem. con.*, but I believe that, provided they were properly understood, the dissenting minority would be a very small one. It is probable that Professor Exner would be in the minority, but I am unable to be sure of anyone else.

We can also make a negative proposition which will command almost universal assent—viz., that if in the above second proposition,

[1] Bosscha: *Pogg. Ann.* vols. ci., ciii., cv., cviii.

[2] Bouty : *Journal de Physique*, 1879, viii. p. 341 ; ix. p. 229, and p. 306 ; esp. p. 306.

[3] I find that a method exactly like that used by Bouty was suggested by Clerk Maxwell, *Elementary Electricity*, p. 146.

Various observations regarding the E.M.F. of different cells are made in the series of papers still appearing in the *Phil. Mag.*, by Dr. Wright and Mr. Thompson, 'On the determination of Chemical Affinity in terms of E.M.F.'

instead of the sum of the contact forces at *every* junction, we attend only to the contact forces at the *metallic* junctions, the proposition will no longer be true. This fact, that the metallic junctions are insufficient to account for all the E.M.F., was established by Becquerel, De la Rive, and others, and still more thoroughly and exhaustively by Faraday. It is the easiest possible thing to make a number of batteries which shall give a current without any metallic junction whatever. Faraday gives some thirty of them.[1]

One more certain proposition we can lay down—viz., that whenever a current is produced, the energy of the current must be maintained by absorption of heat, or by chemical action, or by gravity, or by some other such agent—not by mere contact.

So much being agreed to, what remains as subject-matter for controversy? This: A voltaic circuit contains at least three junctions; what is the value of the contact force at each of them, and especially to which junction is the major part of the observed E.M.F. due? Is it the zinc acid? or is it the copper acid? or is it the zinc copper? There is no other question. The old chemical and contact controversy has died out, but another controversy remains. Most physicists probably would say to-day that the major part of the E.M.F. of the cell resides at the zinc-copper junction. This was Volta's view, and this is the view of the text-book writers taught by Sir William Thomson. Some few would say at the zinc-acid junction, and among them I must confess myself.

It is no question between contact and something else; it is a question between a feeble energy-less metal-metal contact, and an active energetic metal-fluid contact with potentialities of chemical action straining across the junction. What is there to distinguish between the two? Electrostatic experiments with air condensers prove nothing. They add up three E.M.F.'s, air/M + M/M′ + M′/air, and give you the sum. The experimenters usually assume that M/M′ is what they are measuring, but there is no proof to be given in support of the assumption, except that if you substitute water for air the effect remains almost unaltered: but then water contains oxygen as the active element the same as air does. Well, then, it may be urged, the effect is the same in vacuo and in hydrogen as in air; and to this I answer, Not proven.

Can any further assertions be made with reference to electroscopic experiments as bearing on voltaic theory? Yes; it can be asserted that by adding up the Volta effects for A/B, for B/C, for C/D . . ., and for Z/A, you arrive at the total E.M.F. of the circuit A, B, C . . . A. True; but what then?

The Volta effect you call A/B is really	air/A + A/B + B/air;
that you call B/C is	air/B + B/C + C/air;
. . . . .	. . . . . .
and that you call Z/A is	air/Z + Z/A + A/air.
Add them up, and you get	A/B + B/C + . . . + Z/A,

which *must* be the E.M.F. of a circuit by common sense—*i.e.* without

[1] *Exp. Res.* ii. 2020. Dr. J. A. Fleming describes another of these batteries in *Phil. Mag.*, June 1874, and gives some very cogent and readable arguments in favour of the 'chemical theory' of battery E.M.F., suggesting that the difference of potential between the terminals of a battery on open circuit is due to potential chemical combination of the metals and electrolytes. He does not, however, explain the old Volta experiment; and, as Prof. Chrystal has pointed out (*Ency. Brit.* p. 99), upholders of the chemical theory are bound to explain this.

violent experimental disproof, which no one has ever attempted to give. This fact, that the sum of the Volta effects equals the sum of the true forces, in a closed circuit of any conducting materials, has nevertheless caused persons to suppose that air/metal forces are negligibly small. But it is clear that they may have any value they like without affecting the truth of the law. They could only affect it if air/M were not equal to – M/air. The experimental proof of the summation law, therefore, establishes that air/M *is* equal to – M/air, as well as the important fact that the contact force at each junction is independent of all other junctions of what kind soever.

8. Leaving electrostatic determinations as without bearing on the point at issue, let us ask, Is there no direct and straightforward way of measuring the actual E.M.F. at a particular junction without disturbance from other junctions? The answer is most clearly given by Clerk Maxwell, thus:—[1]

'Sir W. Thomson has shown that if Π is the coefficient of Peltier effect or the heat absorbed at the junction by unit current in unit time, then $J\Pi$ is the E.M.F. at that junction acting with the current. This is of great importance, as it is the only method of measuring a local E.M.F., the ordinary method of connecting up by wires to an electrometer being useless. This Peltier measurement is quite independent of the effect of contact forces in other parts of the circuit. But the E.M.F. so measured does not account for Volta's force, which is far greater and often opposite. Hence the assumption that the potential of a metal is to be measured by that of the air in contact with it must be erroneous, and the greater part of Volta's E.M.F. must be sought for, not at the junction of the two metals, but at one or both of the surfaces which separate the metals from the air or other medium which forms the third element in the circuit.'

And in another place he says:—[2]

'In a voltaic circuit the sum of the E.M.F.'s from zinc to electrolyte, from electrolyte to copper, and from copper to zinc is not zero, but is what is called the E.M.F. of the circuit—a measurable quantity. Of these three E.M.F.'s only one can be measured by a legitimate process, that, namely, from copper to zinc. If we cause an electric current to pass from copper to zinc, the heat generated in the conductor per unit of electricity is a measure of the work done by the current, for no chemical or other change is effected. Part of this heat arises from the work done in overcoming ordinary resistance within the copper and the zinc. This part may be diminished indefinitely by letting the electricity pass very slowly. The remainder of the heat arises from the work done in overcoming the E.M.F. from the Zn to the Cu, and the amount of this heat per unit of electricity is a measure of the E.M.F. Now it is found by thermo-electric experiments that this E.M.F. is exceedingly small at ordinary temperature, being less than a microvolt, and that it is from zinc to copper.[3] Hence the statement, deduced from experiments in which air is the third medium, that the E.M.F. from copper to zinc is ·75 volt cannot be correct. In fact, what is really measured is the difference between the potential in air near the surface of copper and the potential in air near the surface of zinc, the zinc and copper being in contact. The number ·75 is therefore the E.M.F., in volts, of the circuit

[1] *Electricity and Magnetism*, vol. i. art. 249. Abbreviated above because so easy of reference.

[2] Maxwell: Letter to the *Electrician*, April 26, 1879. Also *El. Electricity*, p. 149.

[3] Further on (sect. 23) I point out that this statement is not quite true, but it does not affect the main argument.

copper, zinc, air, copper, and is the sum of three E.M.F.'s, only one of which has yet been measured.'

With every word of Maxwell I cordially agree.

9. While on the theoretical aspect of the subject it may be well to see what Pellat, as one of the best experimenters on it, has to say. Pellat substantially observes as follows :—

'Does the apparent difference of potential between two metals in contact indicate a real difference of potential between them? In all rigour, No; but the slight variation of its value when different gases or even liquids are used renders it extremely probable that there is such a real difference of potential, and that it is very nearly what is measured in electroscopic experiments.'

As to difficulties connected with energy considerations and mere contact, he refers to Helmholtz,[1] and Clausius,[2] who, he says, relieve him of all responsibility on this head.

The fact that the voltaic order of the metals is much the same as their order of oxidisability must have struck nearly everybody, and must also have been felt as a difficulty by the upholders of the efficacy of mere contact. Pellat considers he disposes of it thus :—'Since the E.M.F. of a pile is that represented by chemical action, and since by experiment voltaic contact forces have much the same values as the E.M.F. of piles, it follows that there is some vague relation between A/B and the heats of combination, say of substitution of one metal for another in a salt (as in a Daniell).'

He sums up his experimental conclusions as follows :—

(1) 'Two different metals united metallically are covered, in the state of equilibrium, with electric coats of unequal potential.

(2) 'This difference of potential only depends on the superficial coat of metal. It changes notably when the surface is mechanically scratched, becoming always more positive. As the scratching effect disappears with time so does the extra difference of potential. The state of polish of the surface is immaterial, but traces of foreign substances, forming a coat so thin as to be invisible, are able to modify the value of the observed effect enormously.

(3) 'The effect depends somewhat on temperature.

(4) 'The pressure and nature of the gas surrounding the metals have a very distinct but extremely feeble influence, but, since the effect produced is a lagging one, it is probably due to some secondary cause, and it is probable that the difference of potential is really independent of the gaseous dielectric.

(5) 'The difference of potential between the electric coats on two metals united metallically has the same value as the E.M.F. of an element of a liquid pile formed by these two metals, provided that the E.M.F. is

[1] *Die Erhaltung der Kraft*, p. 47, where Helmholtz develops Volta's original hypothesis about an attraction of matter for electricity, of an amount depending on the kind of matter, so that it gets pulled one way or another across a junction of two dissimilar substances. He points out that the Volta effect is explained if zinc be granted a stronger attraction for electricity than copper has. This view he returns to in his Faraday Lecture 1881, where also he refers to Berzelius' electrical theory of chemical affinity. The opinions of Professor Helmholtz are too weighty to be merely referred to in a footnote, but we may have occasion to consider them later.

[2] *Die mechanische Behandlung der Electricität*, chap. vii. §§ 2 and 3, where Prof. Clausius follows up the above idea by considering the *rôle* which heat plays in the matter, and thus hypothetically explains the Peltier effect also.

determined before any alteration of the metallic surface wetted by the liquid has occurred; but these alterations produce themselves very rapidly.'

Pellat's theoretical conclusions being short may also be here quoted, and I will number them on with the others.

(6) 'It is extremely probable that the difference of potential between the electric coats which cover two metals connected metallically represents the true difference of potential which exists between them. No reason, either theoretical or experimental, can be invoked against the existence of a difference of potential between two metals in contact.

(7) 'This last quantity has no connection with the thermo-electric E.M.F. measured by the Peltier phenomenon.

(8) 'It has only a vague and distant connection with the difference of oxidisability of the metals.'

Concerning these propositions I may remark that while Number 2 is likely to annoy contact theorists (though I know they have methods of explaining it away), Numbers 4 and 5 are calculated to restore their equanimity. The five experimental conclusions I accept as in duty bound, only permitting myself partially to doubt the perfect generality of Numbers 4 and 5 under all circumstances; but the three theoretical ones I am unable wholly to accept. Thus with respect to the second part of Number 6, I beg entirely to differ from M. Pellat if I am called on to simultaneously admit Number 7. Whether one is prepared to accept any of his theoretical conclusions or to reject them all depends upon how one regards them. If in the way he himself intended, then I reject them all. If with one's own interpretation, then I say that the second part of 6 and 8 are true (though for 'only a vague and distant' I would substitute 'no'); and 7 is also true if it be held to refer to the quantity first mentioned in Number 6 while Number 8 refers to the other quantity. Number 6 I should also consider true if the prefix 'im' be made to the fourth word.

10. Pellat then proceeds to explain why he considers the Peltier effect to be quite distinct from, and have no relation to, the true E.M.F. of contact. In explaining this he makes use of a piece of unpleasantly plausible reasoning, which I myself have heard Professor Ayrton use, and which when unexpectedly suggested is so painfully benumbing that it is worth while to quote it and to indicate its weak point. Pellat's statement of the argument is rather long, perhaps it can with advantage be abbreviated.

Two metals A and B put into contact are at different potentials, the difference A/B being due to and equal to the E.M.F. of contact. There is then at the junction not only the contact force E, but also the equal opposite force $-\frac{dV}{dn}$, due to the difference of potential established. Either of these forces alone would resist or aid the passage of electricity across the junction, and so give rise to a Peltier effect, but both together will do nothing of the sort, and so if there be any Peltier effect it must be some small residual phenomenon, or it must be due to some other and totally distinct cause.[1]

Professor Ayrton's way of putting the argument, which I think he said he got from Sir William Thomson, was something like this. When

[1] Thus it may be, suggests Pellat, due to a slight difference between E and $-\frac{dV}{dn}$ produced by the mere fact of a current passing; *i.e.* contact E.M.F. with electricity at rest may be slightly different to what it is with electricity in motion.

Q units of electricity are transmitted against a force E, work E Q is done; also when they are transmitted up a difference of potential $V'-V$, work Q $(V'-V)$ is done; but, in an open circuit containing an electromotive junction, $V-V'$ is produced by and is equal to E. Hence at an electromotive junction no work need be done by a current; in other words, the existence or non-existence of a Peltier effect has nothing to do with the existence or non-existence of a local E.M.F.

The fallacy of the argument, in either form, lies in over-precise specification of locality; gratuitously asserts as true for *the junction* what is only proved to be true for the whole circuit. It assumes that there can be no work done at a junction if it be perfectly easy to drive electricity either way across it—*i.e.*, if there be no work done on the whole.

11. To exhibit the fallacy, consider a hydrostatic analogy. Two vessels of water connected by a pipe in which is a motor of some kind, which without leakage exerts a specified force on the water and maintains a constant difference of potentials, but then remains stationary, doing no further work. We typify it feebly in the diagram by an impracticable close-fitting water-wheel driven by a weight without friction.

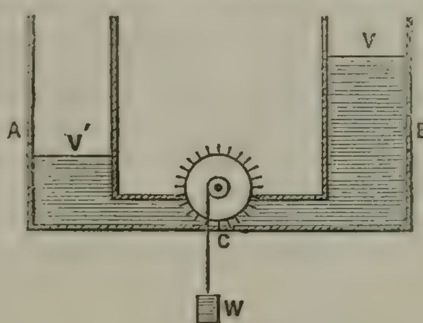

FIG. 14.

Hydrostatic analogue of the true contact or Seebeck force, and of the real though small difference of potential which it maintains between two metals in contact. W is a weight driving a water-tight wheel until stopped by the difference of potential set up. The hydraulic raising or lowering of the weight represents the Peltier effect.

$V-V'$ is the equivalent of the force exerted at the junction, and everything is in equilibrium. It is perfectly easy for water to flow from one vessel into the other under the influence of the slightest extra force, for W helps the water up the hill $V-V'$, when the flow is in that direction; and, whenever the flow is reversed, it lets the water gently down again, taking all its energy out of it. If water is made to flow from A to B, say by pouring more into A, the weight W is lowered, or energy disappears (heat absorbed) at the junction; if it is made to flow from B to A the weight is raised, or energy (say heat) is generated at the junction. Thus there is a true Peltier effect at the junction despite the existence of $V-V'$ and its equality to the junction force, and yet no resistance is offered to the flow of water either way. Thus is the first form of the argument controverted.

To pump water from A to B by any other pipe would need work to be done equal to Q $(V-V')$, and to pump water against the force of W, acting alone, would also need work E Q; but when the water goes from

A to B *viâ* W, or *vice versâ*, no work is done on the whole. Quite true; but the conclusion that no work is done *at the junction* by no means follows. Work *must* be done at the junction in proportion to the force there (by inspection of the diagram), and accordingly the existence or non-existence of a Peltier effect has *everything* to do with the existence or non-existence of a local E.M.F. This controverts the second form of the argument.

If the argument be now considered upset, are we to proceed to assert that the difference of potential, or force, concerned in the Volta effect, and the heat destruction or generation concerned in the Peltier effect, are closely connected, and in fact different ways of observing the same thing? By no means. All we have proved is that the Peltier effect accurately and necessarily represents and measures the true contact force at a junction. True, we have considered a difference of potential $V-V'$ as produced by this contact force in an incomplete circuit, and so it is; but nothing has been said to imply that this difference of potential has anything to do with what is observed in electrostatic experiments as the Volta effect. So far from this I will assert that what is usually observed when two metals are touched and separated is not primarily a difference of potential between the metals at all. They are at different potentials when separated, no doubt, because they are oppositely charged; but they may have been at the same potential until separated. The real Volta effect is almost independent of the true contact force, and of the difference of potential which it produces. In other words, a good Volta effect can be observed when there was no difference of potential whatever between the metals when in contact.

According to my view the Volta effect is produced, not by a contact force at the junction of the two metals, but by a contact force at their

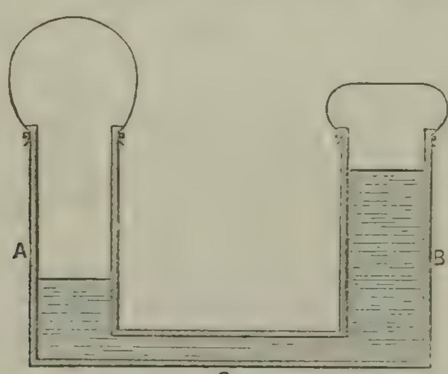

FIG. 15.

Hydrostatic analogue of the Volta effect, or *apparent* difference of potential produced by metallic contact, and of the opposite charges but uniform potential which it maintains between two metals in contact. The vessels are covered by air-tight elastic bags differently stretched.

free surfaces, between the metals and the air or other medium surrounding them. To represent this hypothesis by a hydrostatic model we shall have to maintain the difference of level in the two connected vessels, not by a force at the junction, but by a force at the surfaces; say by using closed vessels and compressed air, or more pictorially by differently stretched elastic membranes or bladders tied over the tops of the vessels.

Note that the difference of level in this case implies no difference of potential, and as before no work is required to transfer water between A and B. Hence it is not easy to distinguish this case from the former, and this difficulty of distinguishing between the two cases is what has given rise to most of the confusion. The only easy criterion is the non-existence in the second case of any Peltier effect at the junction C. Naturally it is possible and common for the two effects to be superposed, but they are essentially independent.

Since the two vessels in the second case are at the same potential, the way to observe the effect is to cut and seal the pipe at C, and then show that the vessels are differently charged; which is what Volta did. The model does not indeed represent the gradual change of potential induced as the distance between the condenser plates increases, and it is scarcely worth while to complicate the matter by making a more elaborate model. The thickening of the dielectric layer of a condenser, when its plates are separated, corresponds exactly to the thickening and strengthening of an elastic membrane; and rise of potential in the one case is accurately representable by increase of pressure in the other; but such considerations belong to general electrostatics, and have no special bearing on our present subject.

12. This is perhaps the most convenient place to introduce the notes or condensed statements which I drew up and distributed at the meeting before the discussion. They were intended to be critically exact (allowing of course for mistakes and possible slips) so as to bear analysis, and hence it is probably worth while to reproduce them here with notes and comments.

I.—Orthodox statements believed by the writer to be true in the form here set down.

A.—Volta.

i. Two metals in contact ordinarily acquire opposite charges;[1] for instance, clean zinc receives a positive charge by contact with copper, of such a magnitude as would be otherwise produced under the same circumstances by an E.M.F. of about ·8 volt.

ii. This apparent contact E.M.F. or 'Volta force' is independent of all other *metallic* contacts wheresoever arranged; hence the metals can be arranged in a numerical series such that the 'contact force' of any two is equal to the difference of the numbers attached to them, whether the contact be direct or through intermediate metals. But whether this series changes when the atmosphere, or medium surrounding the metal, changes is an open question; on the one side are experiments of De la Rive, Brown, Schultze-Berge; on the other side, of Pfaff, Pellat, Thomson, Von Zahn.[2] It certainly changes when the free metallic surfaces are in the slightest degree oxidised or otherwise dirty. And in general this 'Volta force' is very dependent on all non-metallic contacts.

iii. In a closed chain of any substances whatever, the resultant E.M.F. is the algebraic sum of the Volta forces measured electrostatically in air

[1] Observe that it is not said that two metals in contact acquire different potentials. Such difference of potential I believe to be only apparent. Compare figs. 14 and 15.

[2] I put Von Zahn on that side because he himself considers himself there, and because the great bulk of his experiments lean decidedly that way.

for every junction in the chain: neglecting magnetic or impressed E.M.F. [Verified most completely by Ayrton and Perry.]

B.—Thomson.

iv. The E.M.F. in any closed circuit is equal to the energy conferred on unit electricity as it flows round it.

[Neglect magnetic or impressed E.M.F. in what follows.]

v. At the junction of two metals any energy conferred on, or withdrawn from, the current must be in the form of heat. At the junction of any substance with an electrolyte, energy may be conveyed to or from the current at the expense of chemical action as well as of heat.

vi. In a circuit of uniform temperature; if metallic, the sum of the E.M.F.'s is zero by the second law of thermodynamics; if partly electrolytic, the sum of the E.M.F.'s is equal to the sum of the energies of chemical action going on per unit current per second.

vii. In any closed conducting circuit the total intrinsic E.M.F. is equal to the dynamical value of the sum of the chemical actions going on per unit electricity conveyed ($\Sigma \cdot J\theta\epsilon$), diminished by the energy expended in algebraically generating reversible heat.

viii. The locality of any E.M.F. may be detected, and its amount measured, by observing the reversible heat or other form of energy there produced or absorbed per unit current per second. [This is held by Maxwell, but possibly not by Thomson,[1] though its establishment is due to him.]

II.—STATEMENTS BELIEVED BY THE WRITER TO BE FALSE THOUGH ORTHODOX.

ix. Two metals in air or water or dilute acid, but not in contact, are practically at the same potential.[2] [Sir Wm. Thomson, Clifton, Pellat.]

x. Two metals in contact are at seriously different potentials (*i.e.* differences of potential greater than such milli-volts as are concerned in thermo-electricity.) [This is held by nearly everybody.][3]

xi. The contact force between a metal and a dielectric, or between a

[1] The only reason which I can think of as likely to have caused Sir Wm. Thomson to doubt or deny the validity of this proposition is given and, I hope, refuted at sections (10) and (11).

[2] The truth or falsity of this statement may be held to depend on a question of words, viz.:—the definition of potential. Sir Wm. Thomson at the meeting said he had always defined potential as the work done in bringing a unit charge close up to, but not *into*, the body. This definition explains some apparent inconsistency in one or two of his utterances which I had never quite understood. But seeing that there is no difficulty whatever in giving a charge up to a metal body, but rather the contrary, why not define its potential in the more simple manner which followers of his have unconsciously, and I believe universally, adopted, not knowing that they were thus putting themselves out of harmony with him. Given his definition, so that the potential of a body means really not its potential but the potential of the medium close to it, statements Nos. ix. and x. are undoubtedly true; and No. xi. is also true, I suppose, for it then only means that there is not much E.M.F. between the medium close to a metal and that at a little distance.

[3] It is much more natural to suppose that the potential of a metallic conductor is uniform, whether it is homogeneous or not. Indeed, it is not only more natural, but it is true, that two parts of a conductor *can* only differ in potential by reason of an E.M.F. located at the junction. Now there usually is an E.M.F. at a junction, but it is only of such a magnitude as is concerned in thermoelectricity. It, indeed, does produce a difference of potential between the metals, but nothing else can. N.B.—Always provided that by 'the potential of a metal' is meant that potential, and not the potential of air near it.

metal and an electrolyte such as water and dilute acid, is small.[1] [Ayrton and Perry, Clifton, Pellat, and probably Sir Wm. Thomson.]

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13. Before proceeding to the statements embodying my own views, it will be more interesting if I try to explain in a fuller and more connected manner what they are.[2]

Let us regard the air as a dielectric bath of oxygen, in which metals are immersed, and picture a piece of zinc surrounded by oxygen molecules which are straining at it, and endeavouring to combine with it. They may indeed partially succeed; but suppose they do not, we have here a strong potential chemical action or chemical strain, which must probably be accompanied by some physical phenomenon. Now remember that oxygen is an electro-negative element; and without endeavouring to examine too precisely what signification is involved in that statement, it will be not out of accord with orthodox views if we assume that it means that at least any dissociated oxygen atoms are negatively charged, each with the characteristic charge of a free dyad atom. Granting something equivalent to this, without pressing the form of expression too closely, we perceive that the strain of the oxygen towards the zinc will result in what I metaphorically call a slackening up, or attempted compression, of the negative electricity in it, *i.e.* to a rise of negative potential. We may therefore say that zinc is at a lower potential than the air surrounding it, and that the step of potential in crossing the boundary from zinc to air is closely connected with the chemical affinity between zinc and oxygen. Observe that this step of potential does not obviously nor probably depend on the amount of oxygen present. It is possible that a few million molecules may be as effective as a large number. Note also that the step of potential is by no means caused by actual oxidation: in so far as the zinc surface is tarnished by oxidation the strain will be diminished and the step of potential become less.

Nothing is said here about the possible effect of the nitrogen, because it is simplest in the first instance to ignore it, though whether experiment will justify this simplicity or not, I do not yet know.

We may go further and assert that if in general the chemical affinity of two substances can be measured by their energies of combination, then the step of potential in the present case may perhaps be calculable from the heat of combustion of zinc.

And one may justify this assertion thus. Let an atom of oxygen combine with an atom of zinc; it will generate an amount of heat h, and its characteristic charge, q, will be given up to the zinc and will thereby fall down the step of potential, v, which separates the zinc from the air. *Now if we suppose that the heat h is the representative and equivalent of the fall of energy $q\,v$*, it follows of course that $v = \frac{J\,h}{q}$.

Make the hypothesis and see what comes of it.

[1] The experiments supposed to establish this really prove only that there is very little difference between the air and the water in which a metal is partially immersed. I do not quite know how to understand, on Sir Wm. Thomson's plan, the potential of a metal which is half in one medium and half in another.

[2] The reason I set them forth at length is because I had no time at the meeting both to open the discussion and also to properly express my own ideas, and Sir Wm. Thomson was kind enough to tell me to write out the paper completely, and to explain the position I took up fully. This, therefore, I have endeavoured to do.

14. The oxidation energy of zinc per gramme-equivalent (*i.e.* 65 grammes of zinc or 16 of oxygen) is, according to the determinations of Julius Thomsen, Andrews, and Favre and Silbermann, 85430, 84825, and 83915 respectively.

The amount of electricity needed to deposit a gramme-equivalent of zinc, or of any dyad element, is, according to the modern determination of Lord Rayleigh,[1] 19,320 units.

Hence the value of $\frac{h}{q}$, which is a ratio evidently independent of the number of atoms dealt with, lies between $\frac{85400}{19320}$ and $\frac{84000}{19320}$ probably. Let us say it is $\frac{85000}{19320}$ or 4·4.

Now J in absolute measure is 42×10^6; so the value of e, according to the above hypothesis, comes out $1·85 \times 10^8$, that is 1·85 volts.

This, then, I say, is the step of potential between zinc and air. (To avoid circumlocution I will speak as if the above hypothesis were admittedly true, and all I now say stands or falls with it.)

All clean bright zinc is thus about 1·8 volts below the potential of the air near it: tarnished or oxidised zinc will exhibit less difference, and it is perhaps possible that perfectly oxidised zinc need show no difference of potential at all between itself and the air. The step of potential by no means therefore depends upon the occurrence of oxidation, it is the oxidation *tendency* which causes it; but so far as oxidation actually takes place the step diminishes.

Proceed to consider a piece of copper similarly. Oxygen molecules are straining at it also, but with less force. The combustion energy of copper per gramme equivalent is given by the three authorities already quoted as 37160, 38290, and 43770 respectively. These do not agree well, and it is difficult to know which to take; but Thomsen's results are, I believe, generally relied on; so, assuming his, the step of potential between copper and air will be $\frac{·42 \times 37200}{19320}$ volts; that is, about ·8 volt. This, then, is the amount by which clean bright copper differs from the air. Oxidised copper will differ less. Comparing this value for copper with that just obtained for zinc, we perceive that a piece of zinc and a piece of copper are, when separate, not at the same potential; they differ by about a volt from each other.

Now put the zinc and copper into direct metallic contact, and neglect for the present the third of a millivolt of E.M.F. developed at the junction, which acts so as to drive positive electricity from copper to zinc. A rush of electricity must take place from the copper to the zinc to equalise their potential; it is impossible that they can remain at different potentials when directly united: all parts of a conductor must be at a uniform potential, and the rush has taken place because they were not so when put into contact.

15. Picturing to ourselves the effect as produced by the straining oxygen atoms we shall perceive that they could not get at either metal when separate: first, because they surrounded it everywhere, and strained equally on all sides; and second, because being all charged with negative electricity they could not move in on all sides at once without, so to speak, compressing

[1] '4·025 grammes of silver are deposited by an Ampère current in an hour.'—*Montreal Address.* This gives the electrochemical equivalent of silver ·01118, and of hydrogen ·00010352.

the electricity in the body and giving it an absolute charge. But directly the copper touched the zinc the oxygen atoms were cleared away at the point of contact, and the stress of those at the rest of its surface was no longer counterbalanced. Moreover, they can now all move nearer to the zinc because a way of escape for electricity is provided into the copper, whose surrounding oxygen atoms will be thus driven back somewhat further from the surface, until the dielectric strain, assisting the chemical strain on the copper surface and opposing it on the zinc surface, prevents further displacement, and equilibrium is again attained. The electricity which escaped from the zinc to the copper was negative electricity (oxygen being essentially an electro-negative element), the negatively charged oxygen atoms have moved a little nearer to the zinc than their normal distance, *i.e.* the thickness of its layer of negative electricity is reduced, or its surface is positively charged; the negative layer on the copper has been slightly thickened—its surface is negatively charged.

This is a pictorial way of representing the process, and may be regarded as somewhat fanciful; it is, however, the way in which the theory originally occurred to me, and it permits more insight into the processes than a mere statement in terms of potential can; though it may well be that the imagined processes are but distant likenesses of the real ones.

The oxygen atoms have moved nearer to the zinc, it is now more easily oxidised than before; the copper, on the other hand, is by contact with zinc somewhat protected.

Observe that the contact has not developed any force; it has only, by sweeping away the oxygen from the point of contact, enabled previously existing forces to do work and produce their effect.

The air surrounding the metals in contact is in a state of slight dielectric strain, such as would be produced by two pieces of any one metal of similar size and position, charged so as to differ in potential from each other by a volt.

Zinc and copper plates in contact may therefore be regarded as the plates of a condenser, but they form a peculiar condenser, for they are not really at different potentials; the whole step of potential which throws the air into its state of dielectric strain is located on their bounding surfaces.

Let s and s' be the electrostatic capacity of the zinc and the copper respectively—think of them as two independent spheres united by a fine wire—and let x be their common potential; then the zinc has, by the fact of contact, gone up $1{\cdot}8-x$, and the copper has gone down $x-{\cdot}8$; and, since the quantity of electricity which left the one went to the other, it follows that—

$$s\,(1{\cdot}8-x) = s'\,(x-{\cdot}8),$$

$$\text{or } x = \frac{1{\cdot}8\,s+{\cdot}8\,s'}{s+s'},$$

There is no necessary relation between s and s' in general, but in the ordinary form of the Volta experiment the two plates are of equal size and shape; in which case $s=s'$, and $x = 1{\cdot}3$ volts below the potential of the unconstrained air.

All this is wholly unlike a condenser investigation. To treat it as a condenser we must consider the air surfaces close to the two metals as the plates of the condenser, and we can then speak of its electrostatic capacity

S in the ordinary way, and say that it is in the present case charged with the E.M.F. of a volt.

The quantity of electricity on either plate of such a condenser is S (1·8−·8) or S; hence

$$s\,(1{\cdot}8-)x = s'\,(x-{\cdot}8) = S\,(1{\cdot}8-{\cdot}8).$$

And the general relation between the three S's is like that of two Leyden jars in cascade, viz.

$$S = \frac{s\,s'}{s+s},$$

If the two pieces of metal are circular discs each of radius r, and at a distance z apart, the value of S is of course $\frac{r^2}{4z}$.

In Volta's form of the experiment, two plates are put near each other, connected for an instant, then removed from each other, and the potential of one of them observed. This measures $\frac{S\,(1{\cdot}8-{\cdot}8)}{s+x}$, where x is the capacity of the electrometer used.

In Pellat's form the charges acquired by contact are neutralised, and the oxygen atoms driven back to their normal distance, by an extraneous E.M.F. carefully adjusted until the plates, after separation, exhibit no charge. This measures 1·8−·8 directly.

16. So far I have spoken as if I were sure that (granting the hypothesis) the potential of clean zinc is 1·8 volts below the air; but I am not really sure that this is anything better than an approximation. The fact that no actual combination occurs makes the matter perhaps a little indefinite. If an oxygen atom unites with a zinc atom, one has a right to say distinctly that q has stepped down v; but suppose they are only facing one another, and wishing to combine, are we justified then in asserting that the step v is ready for q to go down, and that it is the same v as before? It almost seems to depend on whether chemical attraction becomes greater as two atoms approach one another, or becomes less.

Suppose, first, it becomes greater, which is the natural hypothesis, then the v calculated from data obtained by permitting the combination to occur will be too large for the step of potential caused by the attraction of metal for oxygen over a standard distance. On the other hand, the differential force urging electricity across a junction of two metals, which is observed in the Volta effect, may be somewhat greater than simply the differences in their pull reckoned at standard distances, because the approach of atoms to the zinc will increase it on this side, and the recession of atoms from the copper will decrease it on that. Hence the Volta effect may perhaps be expected to agree better with calculation than the air/metal potential-difference does, if this latter could be experimentally observed, which it never yet has been.

Next, suppose that chemical attraction becomes less as atoms approach; the step of potential between a metal and air will now be greater than that calculated from chemical data; nevertheless the Volta effect will be somewhat less than that due to the differences of such steps for two metals, and may thus possibly agree pretty well with calculation.

The agreement or non-agreement of Volta effects with calculation does not therefore quite establish the accuracy of our calculated metal-air contact forces. But we have no right to assume that even Volta effects will agree with calculation particularly well so long as our data are so slender. They have no chance of accurately agreeing unless the metals used are pure and perfectly clean—a most difficult condition to attain for even a few seconds.

Before leaving this subject it may be well to point out that, whereas the *calculation* of a Volta effect depends on data obtained by allowing oxygen atoms to approach the metal completely and actually combine, the *experimental determination* by Kohlrausch's and similar methods depends on letting the atoms approach somewhat nearer to one metal and recede somewhat further from another; while the *compensation form* of the experiment employed by Pellat and others depends upon forcing back and restoring the atoms to their original or standard positions. Now if the views here just expressed have any sense or signification whatever in actual fact, it would be very natural to suppose that the numbers obtained in these three ways might be slightly different. But to specify the direction in which we should expect the differences, if any, to lie would require us to have made up our minds as to the probable variation of chemical attraction with distance. Assuming an inverse variation, the Pellat method should give the least, the Volta or Kohlrausch method the next, and the calculation method the greatest, value for the Volta effect.

But all these ideas complicate the matter somewhat, and they are quite possibly unnecessary. If it be considered that we have no data at present it may be permitted to work on the simplest hypothesis, viz. that the step v is independent of how nearly chemical action has occurred—that it is the same for atoms straining at one another at their normal distance as for atoms on the verge of combination. And it may be argued in favour of this view that we really have some data, viz. these.

If it were not true, results obtained by Pellat's method could not be expected to agree exactly with those obtained by Kohlrausch's (of which Ayrton and Perry's or Clifton's may be taken as the best examples). Now results obtained by these different methods do agree very fairly well; exact agreement cannot be predicated, for the most trifling circumstances cause large variations in the Volta effect, but no decided disagreement is observable. Again, if it were not true, the Volta effect observed when two metals far apart in the series (*e.g.*, zinc and platinum) were employed would be inconsistent with the results obtained by using metals nearer together, say zinc and tin, or tin and platinum; and if this were so, the metals could not be arranged in the linear series which eighty years ago Volta showed they could be. These arguments throw no light on what may happen *just* before actual combination, still they are encouraging so far as they go.

17. Let us therefore endeavour to suppress further qualms, and calculate a series of metal-air contact forces from the heats of combustion; remembering that all we have to do, in order to convert heats of combustion per dyad gramme-equivalent into volts, is to divide by $\frac{19320 \times 10^8}{42 \times 10^6}$; that is, by 46000.

But the decision as to what numbers we shall take to represent heats of combustion is a matter of some difficulty, for not only do the numbers obtained by different observers for the same reaction differ, sometimes considerably, but it is not obvious when different oxides are formed which of them we are to consider as most applicable to the case of the Volta experiment. Perhaps one should take the most common or stable oxide; perhaps, seeing that no combination is supposed actually to occur, and since the metal is, so to speak, in excess, it is most reasonable to take the lowest oxide which the substance will form. It may be that the data are not known for this; it may even be that they have only been obtained for the hydrate instead of for the oxide.

I must therefore do the best I can, and quote several numbers wherever there is obvious doubt. I imagine that J. Thomsen's are the most reliable when they are available.

But it must be remembered all through that since it is only the *tendency* to chemical action which is the cause of the Volta effect, whereas combination heats are obtained by permitting or causing the combination to actually occur, the numbers obtained by calculation are not likely to be quite right; and they may be expected to err on the side of excess, the calculated number being higher than the actual value if directly observed.

Energy of Combination of Metals with Oxygen.

Metal	Molecule	Authority	Heat of Formation	The same reduced to Volts	Extreme Values	Mean or Probable Value
Zinc	Zn,O	Thomsen	85430	·1·85		
		Joule	77000	1·66		
		Andrews	84825	1·84		
		Favre and Silbermann	83915	1·82		
	Zn,O,H_2O	Thomsen	82600	—		
Tin	Sn,O	Andrews	67100	1·46		
	Sn,O,H_2O	Thomsen	68090	—		
	$\frac{1}{2}(Sn,O_2)$	Andrews	67680	—		
	SnO,O	"	69584	—		
Lead	Pb,O	Thomsen	50300	1·15		
	"	F. and S.	55350	1·20		
Iron	Fe,O	"	75656	1·64		
	Fe,O,H_2O	Thomsen	68280	1·48		
	$\frac{1}{3}(Fe_2,O_3)$	"	63730	—		
	$\frac{1}{4}(Fe_3,O_4)$	Andrews	66448	1·44		
Nickel	Ni,O,H_2O	Thomsen	60840	1·32		
Cobalt	Co,O,H_2O	"	63400	1·38		
Copper	Cu,O	"	37160	·81		
	"	Andrews	38290	·83		
	"	F. and S.	43770	·95		
	Cu_2O	Thomsen	40810	·89		
	CuO	Joule	37486	·81		
Mercury	Hg,O	Thomsen	30660	·67		
	Hg_2,O	"	42200	·92		
Silver	Ag_2,O	"	5900	·13		
	"	F. and S.	12226	·27		
Hydrogen	H_2,O gas	Thomsen	68360	1·49		
	H_2,O liquid	"	78000	1·70		
	"	Dulong, Hess, Grassi, Joule, Berthelot	79600	1·72		
Potassium	2(K,H,O)	Thomsen	208000	—		
	2(K,H,O,Aq)	"	232920	—		
	K_2,O,Aq	"	164560	3·56		
	K_2,O	Woods	136000	2·95		

Energy of Combination of Metals with Oxygen.—continued.

Metal	Molecule	Authority	Heat of Formation	The same reduced to Volts	Extreme Values	Mean or Probable Value
Sodium	2(Na,H,O)	Thomsen	204060	—		
	2(Na,H,O,Aq)	"	223620	—		
	Na_2,O,Aq	"	155260	3·36		
	Na_2,O	Woods	151600[1]	3·28		
	"	Hypothetical	130000	2·82		
Calcium	Ca,O	Thomsen	131360	2·85		
	CaO,H_2O	"	146400	—		
	CaO,Aq	"	149400	3·24		
Barium	BaO	"	130380	2·84		
	BaO,H_2O	"	14800	—		
	BaO,Aq	"	158260	—		
Strontium	Sr,O	"	130980	2·84		
	SrO,H_2O	"	148180	—		
	SrO,Aq	"	157780	3·41		
Magnesium	Mg,O	"	145860	3·16		
	Mg,O,H_2O	"	148960	—		
Palladium	Pd,O,H_2O	"	22710	·50		
Cadmium	Cd,O,H_2O	"	65680	1·43		
Thallium	Tl_2,O	"	42240	·92		
Manganese	Mn,O,H_2O	"	94770	2·05		
Aluminium	$\frac{1}{3}(Al_2,O_3,3\,H_2O)$	"	129600	2·81		
Lithium	Li_2,O,Aq	"	166520	3·62		
Arsenic	$\frac{1}{3}(As_2,O_3)$	"	51530	1·12		
Bismuth	$\frac{1}{3}(Bi_2,O_3)$	Woods	13200	·29		

Numbers obtained from unsatisfactory oxides and hydrates, like those of aluminium, arsenic, and bismuth, are not likely to be useful for our present purpose. I know of no better data yet available however.

It is now easy to write down a Volta series obtained by pure calculation from heats of combustion. We can then see how far it agrees with the results of direct experiment. The principle on which I determine which of the preceding numbers to select is simply to choose Thomsen's when it refers to the simplest oxide, and in other cases to take what one can get. Metals about which there is obvious uncertainty, as for instance sodium, aluminium, bismuth, &c. are omitted. I only take the common ones.

Calculated Volta Series.

Lithium and Magnesium	3·0	Nickel	1·32
Potassium	2·95	Lead	1·15
Calcium, &c.	2·84	Thallium	·92
Zinc	1·85	Copper	·81
Iron	1·64	Mercury	·67
Tin	1·46	Palladium	·5
Cadmium	1·43	Silver	·13
Cobalt	1·38		

To compare this series with those obtained by experiment, we may as well take zinc as the metal of reference, and write down the Volta effect between it and the other metals, first as abstracted from the above table, and then as found by different observers. Strictly, one ought first to

[1] This number for sodic oxide agrees with Thomsen's value for the hydrated oxide, whereas for K, Ba, Sr, Ca the oxide is distinctly below the hydrate. By analogy, one would expect to have to subtract some 25,000 from the hydrated oxide Na_2,O,Aq, and this gives the 130,000 which I put down as a hypothetical number for Na_2,O.

subtract Peltier forces from the observed numbers before comparing them with theory, but these forces are too small to make any appreciable difference.

Volta Effects in Air.

Metal Pair	Calculated from Heats of Combination	Observed by				
		Pellat		Ayrton and Perry		Clifton
		Clean	Scratched	Using Commercial Zinc	Using Amalgamated Zinc	—
Zinc—						
Tin . .	·39	·25	·35	·28	·46	—
Lead . .	·70 or ·65	·15	·31	·20	·35	—
Iron . .	·21 or ·4	·56	·70	·60	·74	·75
Nickel . .	·53	·47	·63	—	—	—
Copper . .	1·04 or ·9	·71	·86	·75	·89	·85
Mercury .	1·18	—	—	1·06	1·20	1·07
Silver . .	1·71 or 1·58	·91	1·12	—	—	—
Platinum .	—	—	—	·98	1·13	—

The alternative calculated number sometimes given is merely to show the kind of variation probable in those cases from uncertainty of data. In each case of agreement the calculated number is a little higher than the observed, as was to be expected. No reason occurs to me for the breakdown, and apparent interchange, in the case of lead and iron but such vague guesses as may occur to everyone.

Measurements of the E.M.F. between clean metals plunged into distilled water or weak acid have been made by Clifton and by Beetz.[1] I suppose one is justified in calling them—

Volta Effects in Water.

Metal Pair	Calculated from Heat of Combination	Observed by	
		Beetz	Clifton
Zinc—			
Copper	1·0	·98	·82 to ·92
Silver	1·7	1·23	—
Platinum . . .	1·8 or less	1·52	1·3 (Smee)
Sodium Amalgam—			
Zinc	1·0	·78	—
Copper	2·0	1·79	—
Silver	2·6	2·05	—
Platinum . . .	2·8	2·31	—

I do not wish to blink the fact that some of the numbers in the former of the above tables afford a rather poor support to my theory; but it must be remembered, on the other hand, that they are not relative numbers only that we have calculated, but absolute; and the fact that the heats of combustion reduced to volts are numbers of the same order of magnitude as the Volta effects, is of itself a strong confirmation of the belief that chemical strain at the air contacts is the real cause of the apparent contact force at the junction of two metals.

[1] Beetz, *Ann. der Physik*, x. 348, 1880.

The agreement of the numbers, though not exact, seems to me too close to be the result of accident. One may, I think, claim that the hypothesis whence the calculated numbers are obtained is justified by the figures as far as they go. It is not put forward as a completed theory, but only as a first step to such a theory. I believe it to be a step in the direction of the truth, but it requires working out and elaborating by a scientific chemist.

18. Not many measurements of metal pairs have been made even in air, for mere permutations such as copper-tin, tin-silver, &c., follow at once from the numbers given above, by Volta's series law; but in gases other than air one has at present no experimental guidance, beyond the barest qualitative one given by Mr. Brown, that copper-nickel reverses its sign when changed from air to hydrochloric acid, and that copper-iron is reversed in sulphuretted hydrogen. But satisfactory observation in these gases is difficult, because they not only *tend* to attack the plates, but they *do* attack them; and so a film is formed and everything is rendered uncertain.

Another complication results from the fact that when metals are taken out of air and put into a foreign gas, they are already coated with a film of oxygen, and it is not clear in what way this will affect the action of the new gas. It may have to be replaced almost by substitution; the affinity to be considered in chlorine, for instance, being something like $M,Cl_2 - M,O$. In a compound like HCl, the hydrogen also may have to be provided for, the resulting chemical strain being, for instance, $M,Cl_2 - M,O + H_2,O - 2\,(H,Cl)$; but the consideration of the hydrogen affinities will not affect *differences*, and therefore will leave comparisons with experiment unaffected. Taking the metals as clean, however, and without air films, we must suppose the following series to be right:—

Energies of Combination of Metals with Chlorine; and Calculated Volta Series in that Gas.

Metal	Molecule	Authority	Heat of Combination	Calculated Volta Series in Volts
Zinc	Zn,Cl_2	Thomsen	97210	2·1
	„	F. and S.	100592	—
	„	Andrews	101316	—
Lead	Pb,Cl_2	Thomsen	82770	1·8
	„	F. and S.	89450	—
Iron	Fe,Cl_2	Thomsen	82050	1·78
	„	F. and S.	99302	—
Nickel	—	No data	—	—
Copper	Cu,Cl_2	Thomsen	51630	1·12
	„	F. and S.	59048	—
	„	Andrews	60988	—
Mercury	Hg,Cl_2	Thomsen	63160	1·38
Silver	$2(Ag,Cl)$	„	58760	1·28
	„	F. and S.	69600	—
Hydrogen	$2(H,Cl)$	Thomsen	44000	·96
	$2(H,Cl,Aq)$	„	78640	—
	$2(H,Cl)$	F. and S.	47566	—
	$2(H,Cl)$	Alvia	48174	—
Potassium	$2(K,Cl)$	Thomsen	211220	4·62
	„	F. and S.	201920	—
	„	Andrews	208952	—
Sodium	$2(Na,Cl)$	Thomsen	195380	4·24

This series will hold, as far as *differences* are concerned, for hydrochloric acid also; because, whatever effect the hydrogen affinity may have in changing the numbers, it will have the same effect on all.

It is easy to write down the hypothetical series in bromine and iodine in the same way—

Calculated Volta Series in Bromine and Iodine.

Metal	In Bromine	In Iodine
Potassium	3·85	3·50
Zinc	1·74	—
Lead	1·40	·87
Silver	1·10	·60
Copper	·89	·23
Hydrogen	·40	−·13

All this supposes the metals to be perfectly clean, and not covered with a film of foreign gas like oxygen. On the hypothesis that the metal has been taken recently out of air, and that the film of oxygen with which it is covered has to be torn from the metal, though it was not actually combined with it, the Volta series in chlorine or hydrochloric acid would be quite different, and more like this.

Hypothetical Volta Series of Air-coated Metals in Chlorine or HCl.

Silver	1·8	Copper	·9
Lead	1·2	Zinc	·85
Iron	1·1		

Unfortunately I can get no data for the heat of chlorination of nickel, but assuming it not very different from iron, the above series gives copper and nickel in the right order, as observed by Mr. Brown, whereas the other one did not. I have no experiments with which to compare the numbers.

Calculated Volta Series of Clean Metals in Sulphur or Sulphuretted Hydrogen.

Metal	Heat of Sulphurisation per gramme equivalent	Volts
Potassium	91276	1·95
Zinc	41880	·87
Iron	35506	·76
Lead	19112	·41
Copper	18266	·39
Silver	11048	·34
Hydrogen	5482	·12

But it will be observed that this is nothing like the order to be expected in sulphuretted hydrogen; for it is popularly known that copper is more easily sulphurised in this gas than iron. Now assuming that the metal had been covered with an air film, and that the oxygen of this has to be replaced by sulphur, the chemical tendency, instead of being M,S, is something more like M,S − M,O, or possibly M,S − M,O + H_2,O − H_2,S; and either of these will give a quite different order. Data are given on p. 624 of Naumann's 'Gmelin-Kraut,' vol. i., for the neutralisation heats of various bases by H_2S, such as $CuO + H_2S$, &c. These are something like what we want, and from them we reckon the following:—

Hypothetical Volta Series, in Sulphur or Sulphuretted Hydrogen, of Metallic Oxides, and possibly of Air-coated Metals.

Metal	Heat of Reaction $MO + H_2S = MS + H_2O$	Volts
Silver	55800	1·20
Mercury	48700	1·04
Copper	31600	·68
Lead	26600	·57
Zinc	19200	·41
Iron	14600	·31
Sodium	7700	·16

The series so obtained gives copper and iron in their proper order; but it is scarcely likely to be really correct, because it assumes that the *oxides* of the metals are exposed to the gas rather than the metals themselves. It is quite possible that it is not very incorrect for tarnished metals—*i.e.* metals coated with a film of oxide; but for ordinarily clean metals, coated, not with a film of oxide, but with a film of oxygen, it is nothing but a rough approximation, given because we have no better data.

It is to be noted that, as the film of oxygen diffuses away, the Volta effect depending on it must diminish; until at length the active affinity causing the chemical strain is nothing more than M,S, or perhaps M,S − H_2,S. A gradual falling off and ultimate even reversal of sign was observed by Mr. Brown in both HCl and H_2S. In so far as actual chemical action occurs and a film of chloride or sulphide forms, so far, of course, also will the effect diminish; because it depends essentially on the unsatisfied chemical strain, not on the accomplished chemical action.

For a summary of the views here expressed see section 22.

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19. Having now explained why I believe the main part of the Volta effect to take its rise at the surface of contact between metal and medium rather than between metal and metal, it remains to consider whether this belief requires one to assert that there is no true contact force at all at the junction of two metals. By no means; the existence of such a force is undoubted; but for metals it is usually very small and may be neglected in comparison with the Volta force, though, strictly speaking, what is observed electroscopically is a mixture of the two. It is the true contact force which gives rise to the Peltier effect, and its variation with temperature (assisted by the Thomson effect) causes thermo-electric currents. A contact force exists, as Thomson has shown, not only at the junction of two different metals, but also between parts of the same metal at different temperatures.

In another place[1] I have endeavoured to gain some insight into the nature of this true contact force and to suggest its cause. This has been done by many others; but I may be permitted to repeat my own notion—vague and incomplete though it avowedly is. Molecules of matter do not move in independence of electricity; at any rate, the converse is certainly true—electricity does not move independently of matter. Electricity, in flowing through a wire, meets with resistance; there is something analogous to friction between the matter and the electricity, and the opposing force is precisely proportional to the strength of the current. This much is

[1] *Phil. Mag.* December (suppl.), 1876, 'On a Mechanical Illustration of Thermo-electric Phenomena.'

expressed by Ohm's law, $E = RC$, which is a carefully verified though empirical statement. But, analysing R into specific resistance of material (ρ) and sectional area of conductor, and permitting ourselves to regard $\frac{C}{\text{area}}$ as proportional to the velocity of electricity in a circuit of different thicknesses, we perceive that Ohm's law means that

$$\frac{dV}{dx} = \rho \times \text{velocity}.$$

Let us then postulate, between electricity and any given kind of conducting matter, a connection which shows itself as an E.M.F. proportional to the speed of their relative motion and to the specific resistance of the material. Molecules of matter are not at rest, but (say) vibrating at a rate depending on, or rather itself determining, the temperature. These motions cannot be independent of electricity, but they result in no force urging it to flow because their motions are symmetrical. But place two metals in contact—one hot, the other cold; or one copper, the other iron—at the junction symmetry disappears, there must be constraint and accommodation; and, in whatever precise way this acts, it seems probable that it can be conceived of as having the same effect as a layer of molecules moving faster on their outward journey than on their return. If any such dissymmetry of velocity were produced, it would exert a propelling force on electricity[1] in the direction of the greatest velocity, because the force is proportional to the velocity. This is the crude and tentative way in which I picture to myself the Seebeck or true contact force—the cause of thermo-electricity and of the Peltier phenomenon.

But now why is this force so small in ordinary metals? Because it depends on ρ, the specific resistance, and this is small. Choose badly-conducting metals like bismuth and antimony, or still better selenium and tellurium, and the force will be greatly increased. Choose so-called non-conductors, like glass and silk and ebonite, and it becomes enormous. But when one uses non-conductors we cannot expect to excite currents flowing in closed circuits; we can only expect electrical displacement and electrostatic phenomena; and indeed it is no such easy matter for electricity to move in such substances, even though the force urging it be excessive; and a little mechanical violence (friction) may be necessary to help it to move. But remember that no amount of friction can determine the motion in one direction rather than another: working a pump piston exhausts no air unless there are valves. Friction may supply some of the energy, but the directing force must be in the substances in contact.[2] To assist the passage it is customary in electrical machines to touch together a conductor and insulator rather than two insulators. I doubt not that when metal touches glass the surface of contact would become chilled as soon as any transfer of electricity were really produced by the force; but the heat developed, by the friction apparently necessary to aid the transfer, effectually masks any chilling.

[1] I do not say necessarily on *positive* electricity. It seems a complication, but Sir William's researches show that it is positive in some metals and negative in others. In the case of lead only does the grip on both electricities seem the same.

[2] Mr. Joseph Thomson (*Proc. Roy. Soc.* 1876) endeavoured to extend ordinary contact methods to non-conductors. He was hardly likely to get very clear results; but he was able to find some electrical transfer as the result of mere contact, if it be admitted that it is possible to apply mere contact and no sort or kind of violence, a supposition which is probably inadmissible. Yet the least violence destroys all novelty and sends us back to Thales.

Measurement of contact force between insulators is beset with difficulties, because it is so difficult to make electricity pass across the junction. No limit to the force has at present been observed: whenever an electrical machine reaches its limit and refuses to charge its prime conductor, or a Leyden jar, to a higher potential, it is accounted for by saying that the rate of leakage is now equal to the rate of production (which is undeniably true), but nothing is said about whether the rate of production is the same as it was when the jar was uncharged. It is a difficult matter to settle, because most of the leakage takes place close to the rubber; and, though it is quite possible, it is unlikely that a limit to the force will be discovered, by finding the activity of a frictional machine less at high potentials than at low. When the substances in contact are two metals it is impossible for them to drive electricity very hard, for it would, so to speak, slip through their fingers; but when an insulator is concerned, its grip is so great that probably there is no limit to the force until its insulating power is overcome, and through it also electricity begins to slip. Certainly any upper limit must be a very high one, for the force can readily pile up a charge till it produces sparks a foot or more long.

Whether *Volta* forces, or contact-forces between substances and the medium surrounding them, exist for insulators also we do not know; we have no reason whatever to deny their existence; but whereas in the case of metals these exceeded the forces acting between the substances themselves, here in the case of insulators they are absolutely negligible by comparison. For intermediate substances they may have correspondingly important values, and it seems not unlikely that at the junction of metals with electrolytes, and of electrolytes with one another, the total contact force may be a complex one; partly chemical, and due to the possibilities of chemical action straining across the junction; and partly physical, due to different velocity of the molecules.

20. The preliminary experiments of Bouty have caused him to believe in the existence of physical contact forces, at the junction of metals with electrolytes, which cannot be brought into harmony with energies of chemical action. And though the subject is too unexplored in this direction to be ripe for discussion, it may be well to point out that these contact forces are important in the theory of the voltaic cell even in its simplest form.

Why is the E.M.F. of a zinc-copper battery less than that of a zinc-platinum?

Why is the E.M.F. of a zinc-lead or iron battery smaller than either?

The same chemical action goes on in each, zinc is dissolved at one end and hydrogen liberated at the other; how then can the E.M.F. be different if it is calculable from the chemical reactions? [1]

If we picture to ourselves the actual forces in action we shall get a kind of answer indicated to us. In a zinc-iron cell the E.M.F. is due to the zinc pulling at oxygen harder than the iron does; but, since the iron does pull too, with no inconsiderable strength, the balance of force is not so great as if the iron were replaced by copper, which pulls less, or

[1] Professor Exner cuts this knot in characteristic fashion by asserting roundly that the E.M.F. of all such cells is the same, and that it matters nothing what metal is opposed to the zinc of a cell so long as it does not alter the chemical action going on. He further asserts that all batteries are non-polarisable and quite constant as soon as they have got rid of dissolved air, and before sulphate of zinc has accumulated. He verifies these extraordinary statements, to three significant figures, by straightforward experiment. See his paper 'On Inconstant Voltaic Batteries,' cited above.

by platinum, which barely pulls at all until it is coated and alloyed with hydrogen.

This answer cannot be considered as complete, and in order to complete it consider a more precise experiment.

Arrange a series of common dilute acid voltameters with their plates respectively, zinc-zinc, zinc-iron, zinc-copper, and zinc-platinum. Pass one current through the series from zinc to the other metal, and measure the differences of potential between the plates in each cell. Now the same chemical action is going on in each. In each, zinc is dissolved at one side and hydrogen evolved at the other—the only difference being that it is liberated from surfaces of zinc, iron, copper, platinum, in the four cases. What is to prevent the E.M.F. between the terminals of each voltameter from being the same? But it is not the same (*pace* Prof. Exner): the zinc-zinc cell shows the greatest difference of potential between its terminals, the zinc-iron less; and the zinc-platinum may easily show a reverse difference because it helps the current on instead of hindering it. It will be understood that the *precise* behaviour of the cells is determined by the intensity of the current (*i.e.* current per area)—if it is weak, even the zinc-iron cell may help it on, but the zinc-platinum will help it on most; if it is very strong, even the zinc-platinum will retard it, but the others will retard it more, and the zinc-zinc most.

Now why is all this? Take the difference between the heats of formation of Zn, SO_4 and of H_2, SO_4, at the comma, and you will have the total energy assimilated by the current in each cell. This energy is the same in all the cells, but not in all does it take the same form. In the zinc-platinum cell it mainly results in driving the current forward. In the zinc-zinc cell it wholly results in a Peltier (or Bouty) generation of heat. In going out of the cell by a cathode zinc plate, it has to move hydrogen towards it, and (*ipso facto*) oxygen away from it, in opposition to the strong chemical attraction; thus it will do work and liberate energy, which, since there is nothing better to do, must exhibit itself as heat. At an iron surface less heat is generated, and at a copper less still; but, at any cathode which attracts oxygen, some heat must be generated by a current made to do work in opposition to this attraction.

In the zinc-zinc cells there is no propulsion of electricity at all by the cell: on one side, where the current enters, zinc is dissolved and the current helped forward with the full energy (or nearly the full energy) of the combination, so that no (or nearly no) waste energy or heat is there produced; but on the other side, where the current leaves, the same combination is (not exactly undone but) opposed and the current hindered with (probably something less than) the full energy of the combination, and there the heat of combination is generated.

Thus, regarding the passage of hydrogen to the cathode as a virtual separation of O (or SO_4) from it, we may say in general that in any one of the above cells, used as a voltameter, the energy available for helping the current on is that represented by the difference between the combination energies of the substances respectively attacked and liberated; *i.e.*, $Zn, SO_4 - H_2, SO_4$; but that besides this the combination M, SO_4, is virtually undone, and since its energy appears as a generation of heat at the cathode, it is so much to be subtracted from the propelling force available for the current, only the balance being left for this purpose, viz.—

$$Zn, SO_4 - H_2, SO_4 - M, SO_4.$$

Whether one ought to write SO_4 or O in these expressions I am not sure, but it is not essential to decide this at present.

Another way of regarding the matter is to say that the force propelling the current is that due to the difference of energies Zn,O − M,O, but that as soon as a current actually passes and hydrogen is liberated it coats the cathode more or less thickly, and an extra term must be subtracted from the above to represent the opposition force of this hydrogen. The efficacy of this hydrogen as a current opposer must depend in some way on the intensity of the current itself, since with a feeble current it will be able to dissipate itself faster than it forms, and with a strong current it will thoroughly coat the plate and the balance will escape. Suppose then we represent the force exerted by the hydrogen as $H_2,O\, f\,(C)$; where $f\,(0) = 0$, and $f\,(\infty) = 1$ or something like 1; then the force available for urging the current forward in any of the above cells is, in volts,

$$\tfrac{1}{46000}\,\{Zn,O - M,O - H_2,O\, f\,(C)\}.$$

There is an obvious objection to be taken to this last hypothesis, viz., that it supposes the second metal M completely operative, even though it be thoroughly coated with hydrogen. This is hardly reasonable, and a compromise between the two preceding hypotheses is afforded by one of greater generality in which the available force is symbolically represented by

$$Zn - M\,\phi\,(C) - H_2 f(C),$$

where ϕ is a function such perhaps that $\phi(C) = 1 + n.\, f\,(C)$. On this hypothesis the propelling E.M.F. is

$$e = \tfrac{1}{46000}\{Zn,O - M,O - (H_2,O + n.\, M,O) f\,(C)\}.$$

This is too much like miscellaneous guessing, and we will make no more of such hypotheses; but if experiment could fix an empirical formula for this force in any case, we could apparently at once obtain the Joule or Bouty effect,[1] or rather the difference of two such effects, for that case, because we should have the E.M.F. experimentally observed on the one hand, and that calculated from pure energy considerations on the other; as

$$\frac{Zn,O - H_2,O}{46000} + B_M - B_Z\,;$$

where the two B's stand for the Bouty coefficients at the zinc and the other metal respectively. The only objection is that in the cells now under discussion M is coated more or less with hydrogen, and hence the Bouty effect obtained is nothing very easily definable.

21. To see if the actual behaviour of such cells at all bears out a hypothesis formed on the above plan, I have made some rough experiments on the lines suggested; that is, I passed the same current through different simple cells. There are so many sources of uncertainty and of variation, that it would be very difficult to get really definite and reliable results. Thus, for instance, the back E.M.F. will depend considerably upon how long the current has been flowing, and so the readings will differ according to the time they are taken. The metals I used were zinc-zinc, zinc-copper, and zinc-platinum; and it was found necessary to put the cathode plate in a porous cell to avoid deposition of zinc on it. But it was now difficult to compare the cells easily when arranged in series, because different porous pots had different resistances. I therefore ultimately decided to use the same porous pot and the same anode zinc plate, and to substitute

[1] That is, the thermo-electric contact force at a metal-liquid junction. See section 6.

the other plates one after the other, making the current as nearly the same each time as convenient (by adjusting resistance) and allowing for outstanding discrepancies. An ampèremeter placed in circuit measured the current, and the voltameter used was a reflecting galvanometer with some 30,000 ohms in its circuit. Its indications were interpreted absolutely by tapping off, at the same time as the cells, the difference of potential between the terminals of an ohm (or $\frac{1}{4}$ or $\frac{1}{8}$ ohm) coil placed in the circuit.

Any two values of the strength of current enabled the internal resistance of the cell to be calculated, provided its E.M.F. remained constant. With low currents it did seem to be fairly constant, and a mean value of the internal resistance r is reckoned from these as $\frac{1}{5}$ ohm.

The area of each plate under the liquid was exactly the same, and measured 3 inches by $2\frac{3}{4}$ inches. Both faces of each plate were exposed, though naturally one face was more active than the other.

The arithmetical reductions are rather long; the results are all that I give. It will be perceived they are anomalous in places, a great deal of this being dependent on whether the reading of E.M.F. was taken soon after a current-change or not. As I said before, the plan of experiment is avowedly rough, though the actual readings were carefully taken; but without understanding more about the circumstances of the case, and what possibilities of variation there are, I do not see how to plan a perfect system of experiment on the subject.

I will first give relative numbers, simply comparing the differences of potential between the terminals of the three cells when the same current is going through each, the resistance of each being the same, viz. $\frac{1}{5}$ ohm; and then I will interpret the observations absolutely, calculating the E.M.F. of the cell under different currents, and seeing what empirical formula will best fit it.

Relative differences of potential between the terminals of three voltameters of the same resistance, through each of which the same current is driven by an auxiliary battery. Anode of each cell, zinc; cathode, zinc-copper and platinum respectively.

Current flowing through each cell in Ampères	Deflection of Electrometer attached to the Terminals of		
	The Zinc-zinc cell	The Zinc-copper cell	The Zinc-platinum cell
·55	−125	+70 to +90	+ 87
·94	−148	+ 26	+ 40
1·88	−486	− 15	+ 50
1·5	−440	+ 15	+110
2·4	−535	− 65	+ 15
2·0	−486	− 8	+ 80
2·4	−626	−140	−100
1·96	−575	− 77	− 30
3·2	−700	−225	−201
2·73	−630	−250	−116
4·2	−800	−347	−335
3·4	−741	−250	−210

In the above table the difference of potential between the terminals is written negative when it opposes the current, and positive when it helps it on.

We will now interpret similar measurements absolutely, reckoning the actual E.M.F. of each cell, and try to fit an empirical formula to it on the plan of those (in sect. 20) already guessed; assuming f(C) a linear function, for simplicity, until forced to try something more complex. It is quite impossible that $f(C)$ can be a linear function really, but it very likely begins by being so, and only for big currents diverges notably. A hyperbolic tangent function, at a guess, would seem most likely to represent the case properly.

Electromotive force of a ZINC-ZINC, *dilute sulphuric acid, cell; of resistance* $\frac{1}{5}$ *ohm, through which the specified currents are driven by two or three Groves. Each plate exposing* 53 *square centimetres on each face.*

Current in Ampères C	Difference of Potential between Terminals in Volts	Observed E.M.F. of Cell (obtained by adding rC to the preceding column)	E.M.F. calculated from the Formula $e=-\frac{1}{2}C$
·552	− ·37	− ·26	− ·276
·424	− ·34	− ·25	− ·212
·936	− ·44	− ·25	− ·468
·744	− ·40	− ·25	− ·372
1·88	−1·46	−1·08	− ·94
1·5	−1·32	−1·02	− ·75
2·4	−1·61	−1·13	−1·20
1·97	−1·46	−1·07	− ·99
2·4	−1·88	−1·40	−1·20
1·94	−1·80	−1·41	− ·97
3·22	−2·10	−1·46	−1·61
2·68	−1·88	−1·34	−1·34
3·36	−2·22	−1·55	−1·68
4·24	−2·40	−1·55	−2·12

The agreement between the observed and calculated columns is not very bad, and the polarisation E.M.F. does not show decided signs of breaking away from the law of simple proportion until a current strength of 4 ampères is reached; say an intensity of ·04 ampères per sq. centimetre of total surface.

Electromotive force of a ZINC-COPPER, *dilute sulphuric acid, cell; of resistance* $\frac{1}{5}$ *ohm, through which the specified currents are driven by two or three Groves. Each plate exposing* 53 *square centimetres on each face. E.M.F. reckoned positive when it helps the current forward, negative when it opposes it.*

Current in Ampères C	Difference of Potential between Terminals in Volts	Observed E.M.F. of Cell (obtained by adding rC to preceding column)	E.M.F. calculated from the Formula $e=\cdot 8-\frac{1}{4}C$	E.M.F. calculated from the empirical Formula $e=\cdot 58-\frac{1}{5}C$
·55	+ ·24	+·35	+·66	+·47
·94	+ ·078	+·27	+·54	+·39
·76	+ ·108	+·26	+·61	+·43
1·88	− ·045	+·33	+·33	+·20
1·52	+ ·045	+·35	+·42	+·27
2·4	− ·195	+·28	+·20	+·10
2·0	− ·024	+·38	+·30	+·18
2·4	− ·42	+·06	+·20	+·10
1·98	− ·221	+·18	+·30	+·18
3·22	− ·675	−·031	−·05	−·06
2·75	− ·75	−·2	−·11	+·03
4·16	−1·04	−·21	−·24	−·25
3·44	− ·75	−·06	−·06	−·11

Here two alternative formulæ are given; it is a matter of opinion which shows the least divergencies from the column of observed values.

The first is the one most naturally suggested by the theoretical considerations of section 20, the ·8 standing for Zn/O − Cu/O, or what is commonly called Zn/Cu.

Electromotive force of a ZINC-PLATINUM, *dilute sulphuric acid, cell; of resistance* $\frac{1}{7}$ *ohm, through which the specified currents are driven by two or three Groves. Each plate exposing 53 square centimetres of surface on either side. E.M.F. reckoned positive when it helps the current on.*

Current in Ampères C	Difference of Potential between Terminals in Volts	Observed E.M.F. of Cell (obtained by adding r C to preceding column)	E.M.F. calculated from the empirical Formula $e = ·4 - ·1$ C	E.M.F. calculated from the Formula $e = 1·2 - \frac{1}{3}$ C
·552	+ ·26	+·37	+·35	+1·02
·44	+ ·30	+·39	+·36	+1·05
·936	+ ·12	+·31	+·31	+ ·89
·784	+ ·17	+·33	+·32	+ ·94
1·88	+ ·15	+·52	+·21	+ ·57
1·52	+ ·33	+·63	+·25	+ ·69
2·4	+ ·45	+·93	+·16	+ ·40
2·0	+ ·24	+·64	+·20	+ ·53
2·4	− ·30	+·18	+·16	+ ·40
1·96	− ·09	+·30	+·20	+ ·55
3·22	− ·60	+·04	+·08	+ ·13
2·72	− ·35	+·20	+·13	+ ·29
4·16	−1·0	−·17	−·16	− ·19
3·36	− ·63	+·04	+·06	+ ·08

Here also are two alternative formulæ given, of which the first agrees best with the experimental results. But it is very strange that the E.M.F. of this cell should be so low when the current is feeble; it is scarcely more than that of the copper cell. The only way I see of accounting for the error—if error it be—is, that the platinum was put into the liquid after the copper plate, and it was sometimes found coated with a very thin evanescent film of copper when taken out. Theoretical considerations would suggest something more like the second formula as the probable E.M.F.; the 1·2 being what is ordinarily called Zn/Pt.

22. I can now continue the quotation of the remainder of the preliminary notes with the certainty that they will be at any rate intelligible: I begin with statements intended to be true for substances of every kind, and then specialise them for the case of metals.

III.—Statements believed by the writer to be true though not entirely orthodox.

xii. A substance immersed in any medium tending to act upon it chemically will (unless it is actually attacked) be at a different potential to the medium in contact with it, positive if the active element in the medium is electro-positive, negative if the active element is electro-negative.

xiii. The above difference of potential can be calculated approximately from the potential energy of combination between the substance and the medium, the energy being measured by compelling the combination to occur, and observing the heat produced per amount of substance corresponding to one unit of electricity.

xiv. In addition to this contact force, due to potential chemical action or chemical strain, there is another which is independent of chemical properties, but which seems to be greatest for badly conducting solids, and which is in every case superposed upon the former contact force, the two being observed together and called the Volta effect. Very little is known about this latter force except in the case of metals; and in these it varies with temperature, and is small. In the case of non-metals it is often much larger than the chemical contact force.[1]

xv. The total contact force at any junction can be experimentally determined by measuring the reversible energy developed or absorbed there per unit quantity of electricity conveyed across the junction. [Practical difficulties, caused by irreversible disturbances, being supposed overcome.][2]

xvi. In a chain of any substances whatever, the resultant E.M.F. between any two points is equal to the sum of the true contact forces acting across every section of the chain between the given points (neglecting magnetic or impressed forces).

xvii. In a closed chain the sum of the 'Volta forces,' measured electrostatically in any (the same) medium, is equal to the sum of the true contact forces; whether each individual Volta force be equal to each individual true force or not. See section (7).

xviii. Wherever a current flows across a seat of E.M.F. there it must gain or lose energy at a rate numerically equal to the E.M.F. multiplied by the strength of the current.[3]

Development of the above and special application to metals.

xix. A metal is not at the potential of the air touching it, but is always slightly below that potential by an amount roughly proportional to its heat of combustion, and calculable, at any rate approximately, from it. For instance, clean zinc is probably about 1·8 volts below the air, copper about ·8 volt below, and so on. If an ordinary oxidising medium be substituted for 'air' in the above statement it makes but little difference.

xx. Two metals put into contact reduce each other instantly to practically the same potential, and consequently the most oxidisable one receives from the other a positive charge, the effect of which can be observed electrostatically.

xxi. There is a slight true contact force at the junction of two metals

[1] I here assume, what I suppose is recognised as true, that what is known as frictional generation of electricity is really due to a contact force between the substances rubbed; a force which is exceedingly great for insulators, see section (19). Davy seems to have held this view, from a note on p. 50 of his Bakerian lecture in 1806, cited before.

[2] These difficulties are, however, tremendous for most substances except metals. M. Bouty's is the only attempt I know of to examine junction energy between metals and solutions of their salts, which is the case next in simplicity to metals. Observe that the statement says *energy*, not heat only.

[3] A current gains energy at any junction at which heat is absorbed, or chemical combination permitted, or any other form of energy destroyed, by the passage of the current. The current gains the energy which has in the other form disappeared. A current loses energy at a point where it causes other forms of energy to make their appearance; *e.g.*, generation of heat, decomposition of chemical compounds, &c.

which prevents their reduction to *exactly* the same potential, but the outstanding difference is small and varies with temperature. It can be measured thermoelectrically by the Peltier effect, but in no other known way. It is probably entirely independent of surrounding media, metallic or otherwise.[1]

xxii. If two metals are in contact, the potential of the medium surrounding them is no longer uniform: if a dielectric it is in a state of strain, if an electrolyte it conveys a current.

xxiii. In the former case the major part of the total difference of potential is related closely to the difference of the potential energies of combination, and is approximately calculable therefrom. In the latter case the total E.M.F. is calculable accurately from the energy of the chemical processes going on, minus or plus the energies concerned in reversible heat effects.[2]

xxiii*a*. 'The E.M.F. of an electro-chemical apparatus' whose energy is entirely expended in maintaining a current 'is equal to the mechanical equivalent of the chemical action on one electro-chemical equivalent of the substance.' (Thomson.)

xxiii*b*. 'If the action in a cell consists in part of irreversible processes, such as: (1) frictional generation of heat; (2) diffusion of primary or secondary products; (3) any other action which is not reversed with the current; there will be a certain dissipation of energy, and the E.M.F. of the circuit will be less than the loss of intrinsic energy corresponding to the electrolysis of one electro-chemical equivalent. It is only the strictly reversible processes that must be taken into account in calculating the E.M.F. of a circuit.' (Maxwell: 'Elementary Electricity,' p. 148.)

xxiv. There are two distinct and independent kinds of series in which metals (and possibly all solids) can be placed; one kind depends on the dielectric or electrolytic medium in which the bodies are immersed, the other kind depends on temperature. The one is the real Volta series, but it is the commonly observed Volta series minus the Peltier, the other is the Peltier or thermoelectric series. To reckon up the total E.M.F. of a circuit we may take differences of numbers from each series and add them together.

23. It is necessary to illustrate the meaning of this last statement, No. xxiv. By 'real Volta series' I mean such series as we have attempted to calculate from purely chemical data, because they depend on chemical tendencies. By 'Peltier or thermoelectric series' I mean those giving a purely physical E.M.F., produced we know not quite how, whose energy-source is not chemical but thermal. We have on the one hand a number of Volta series, each for a special medium, and on the other a table of thermoelectric powers at different temperatures. The latter can be conveniently represented by a number of curves, because temperature varies continuously; Volta series, on the other hand, can hardly be represented geometrically, because the transition from one medium to another is

[1] To distinguish between Peltier force and Volta force henceforward it will be best to write Bi/Sb or Zn/Cu for the former, and Zn/Air/Cu or Fe/Water/Pt for the latter. The force electroscopically observed is Air/Zn/Cu/Air, but this involves both; the right way of denoting the Volta effect pure and simple is Zn/Air/Cu.

[2] Such, for instance, as we have been discussing under the head of inconstant or simple voltaic batteries (sections 19-21). These reversible heat effects indicate the presence of thermal contact forces which, wherever they exist, prevent chemical data from giving E.M.F. accurately: they also must be taken into account. We have called them Joule or Bouty effects.

probably *per saltum*; at least, it is not known what is the effect of mixing media, and so passing gradually from one to the next.

We have given several Volta series; and, for the sake of completeness, I will now give some Peltier series for a few substances according to the experiments of Professor Tait at different Centigrade temperatures. Expressing each number as a function of the temperature, we are able to give an infinite number of Peltier series in one table. The range of temperature over which this table may be interpreted is from −18° to 400° or so, provided the metals do not begin to melt. Non-metallic substances have not yet been introduced into such series: much experimental work remains to be done before they can be. The metals used by Tait were not chemically pure.

True Contact E.M.F. or Peltier Series. (Microvolts.)

Metals	At any Temperature t° C.	At 10° C.	At 100° C.
Iron	$-4760 - 3{\cdot}94t + {\cdot}0487t^2$	−4795	−4667
Hard Platinum	$-718 - {\cdot}54t + {\cdot}0075t^2$	− 722	− 697
Soft Platinum	$+168 + 3{\cdot}63t + {\cdot}011t^2$	+ 205	+ 641
Magnesium	$-618 + {\cdot}36t + {\cdot}0095t^2$	− 613	− 487
German Silver	$+3310 + 26{\cdot}17t + {\cdot}0512t^2$	+3577	+6439
Cadmium	$-731 - 14{\cdot}46t - {\cdot}0429t^2$	− 880	−2606
Zinc	$-613 - 8{\cdot}95t - {\cdot}024t^2$	− 735	−1778
Silver	$-590 - 6{\cdot}26t - {\cdot}015t^2$	− 654	−1366
Lead	0	0	0
Copper	$-374 - 3{\cdot}96t - {\cdot}0095t^2$	− 415	− 865
Tin	$+118 - 1{\cdot}08t - {\cdot}0055t^2$	+ 107	− 45
Aluminium	$+211 - {\cdot}31t - {\cdot}0039t^2$	+ 207	+ 141
Palladium	$+1718 + 16{\cdot}15t + {\cdot}036t^2$	+1883	+3693
Hypothetical[1] Mercury (Gaugain)	$+1800 + 4{\cdot}6t - {\cdot}007t^2$	+1845	+2190

To find the E.M.F. of a junction at specified temperature we have only to subtract the numbers in the above table, inserting the value of the temperature. Thus a junction of zinc and copper at 10° has an E.M.F. of 320 microvolts, acting from copper to zinc; and a unit current sent across such a junction from copper to zinc, or from zinc to copper, absorbs or generates heat at the rate of 320 microvolts, and the current gains or loses energy at the same rate. Clerk Maxwell says that the force is one microvolt, and that it acts from zinc to copper ('Elementary Electricity,' p. 149, *note*); but he only means, I suppose, that the E.M.F. of a zinc copper *circuit* with one junction a degree hotter than the other is a microvolt, and is such as to drive the current from zinc to copper across the cooler junction; at least this is true above − 60° or − 80°.[2]

[1] This row of numbers is little better than a guess from some curves given in Wiedemann's *Elektricität*. A more probable deduction from some quite new experiments of C. L. Weber (Wied. *Ann.* November 1884) gives, for Mercury, $1181 + 5{\cdot}68t + {\cdot}005t^2$ (cf. note to section 27).

[2] It is always easy to tell from thermo-electric data which way the force acts at a junction; but it is not always the same way as the current flows, by any means. A current, excited by differences of temperature in a simple metallic circuit, may be urged against the force at *both* junctions. This is the case, for instance, in a copper-iron circuit with one junction above 275° and the other below it by a greater amount. It is customary to say that the current flows across a hot junction from the metal of higher to the metal of lower thermo-electric value: this is not necessarily true. The safe statement is to say that the electromotive force acts from high to low thermo-electric value, at either junction.

Hitherto we have supposed the circuit to be all at one temperature; but if different parts are at different temperatures, we shall have to use a yet further series, viz., a Thomson series, for the E.M.F. acting in any one substance with a difference of temperature between its ends, or the force acting at a junction of two pieces of the same metal at different temperatures. This series can be deduced from the preceding, using only the coefficient of t^2, and multiplying it by the difference of the squares of the *absolute* temperature of the two ends of the piece of metal. Such a series then stands thus:—

Thomson Series, or E.M.F. in a metal whose ends differ in temperature. (*Microvolts.*)

Iron . . .	$\cdot0487\ (t_1-t_2)\{274+\frac{1}{2}(t_1+t_2)\}$
German silver .	$\cdot0512\ (t_1-t_2)\{274+\frac{1}{2}(t_1+t_2)\}$
Zinc . . .	$-\cdot024\ (t_1-t_2)\{274+\frac{1}{2}(t_1+t_2)\}$

and so on.

Whether a series of this sort can be made to include any non-metallic conductors also has not yet been discovered. M. Bouty's experiments provisionally indicate the very interesting fact that Sir W. Thomson's general thermoelectric laws of the thermoelectric circuit apply perfectly to circuits which include some electrolytes as well as metals.

Now the meaning of statement No. xxiv. is as follows: regard zinc and copper in contact as a circuit completed by air or by water, as the case may be, and let the temperature be uniform, and say 10°; to reckon up the total E.M.F. we must look in the proper Volta series for Zn/air (or Zn/water), which we find 1·8 say; for Zn/Cu, which we don't find, or find zero; for Cu/air, which we find ·8. Then we must look in the 10° Peltier series for Zn/air or Zn/water, which at present we shall not find there for want of data (possibly we have no right to put them there if we had data); for Zn/Cu, which we find about 320 microvolts; and for Cu/air, which again we don't find. Add them all up with their proper signs, and we have the total E.M.F. of the circuit.

Again, consider the case of a Daniell cell at a given temperature producing a current; we shall have to look in each series for $Zn/ZnSO_4$, for $ZnSO_4/CuSO_4$, for $CuSO_4/Cu$, and for Cu/Zn, and add them all up. It is true that these tables of numbers have practically yet to be made, for at present they include so few substances: that does not affect the question of the existence and independence of these two kinds of series.

It is, of course, a question how far *all* E.M.F. of contact may be found to depend on chemical tendency. For instance, when bismuth and antimony are put into contact, does the E.M.F. developed measure the alloying affinity of these two metals? When sodium is dropped into mercury, does the heat produced represent the thermoelectric power of a sodium-mercury junction? When metal touches glass, does the tremendous E.M.F. developed represent a tendency of the metal to combine with the glass? These are questions for experiment to decide; but to me it does not seem probable that it will reply in the affirmative.

We know that Sir W. Thomson, and Davy before him, considered the apparent contact force at the junction of zinc and copper to be due to the chemical affinity between these two metals, and to be measured by the heat of formation of brass; but this we have seen strong reasons for disbelieving. It sounds more probable that the real contact force at a junction of bismuth and antimony should be due to the chemical affinity between these metals;

but perhaps it is no more true. The greater part of a contact force of this kind is probably due to a physical difference between the metals, such as difference in atomic velocity, and has no close relation to their chemical affinities for each other. It is, however, just possible that part of a metallic junction-force is due to chemical tendency between the two metals in contact. For instance, take the case of zinc and copper. There is, I suppose, an undoubted affinity between them, as shown by the formation of brass under proper conditions. [If chemists assume the right to demur to this on the ground that the two metals mix equally well in any proportions, one can choose any other pair of metals—say, perhaps, copper and tin—for which the statement does not hold.] Now does this affinity result in any E.M.F. between them on making contact? This question, I apprehend, is to be answered by passing a current for a long time across a copper-zinc junction and seeing if any brass does, after a long time, result. Thermopiles show a curious secular deterioration with use, and it may be that some alloying action goes on, though I have never heard of its being noticed. But if no such alloying goes on during the passage of a current, then I should say that, in whatever ways chemical affinity between two metals is able to show itself, it does not show itself as an E.M.F.

Observe, I do not for a moment question the existence of a few hundred microvolts of E.M.F. at a zinc-copper junction. I only ask, is this chemical, or is it physical, or is it a mixture of the two? Statement No. xxiv. is general enough to take into account the possibility of its being a mixture of the two at every kind of junction. It is easy to write one of them zero, if so it turns out.

24. We have been led into a pretty wide discussion of contact force in general; and, before digressing again on the question of a contact-force-determination of the size of atoms, it may be convenient here to quote the remainder of my preliminary notes, which aim at summarising, in a compact form, the main argument with respect to the immediate subject of discussion, viz., the seat of electromotive force in a voltaic cell, and in ordinary Volta condenser experiments.

IV.—Brief summary of the argument.

xxv. Wherever a current gains or loses energy *there* must be a seat of E.M.F.; and conversely, wherever there is a seat of E.M.F. a current must lose or gain energy in passing it.[1]

xxvi. A current gains no appreciable energy in crossing from copper to zinc, hence there is no appreciable E.M.F. there.

xxvii. When a current flows from zinc to acid the energy of the combination which occurs is by no means accounted for by the heat there generated, and the balance is gained by the current; hence at a zinc acid junction there must be a considerable E.M.F. (say at a maximum 2·3 volts).

xxviii. A piece of zinc immersed in acid is therefore at a lower potential than the acid, though how much lower it is impossible precisely to say, because no actual chemical action occurs. [If chemical action does occur it is due to impurities, or at any rate to local currents, and is of the nature of a disturbance.]

[1] *Note added January* 1885.—My attention has just been called to an article by Mr. O. Heaviside, in the *Electrician* of February 2, 1884, in which he states views very like those contained in these statements. Had I known of this paper earlier I should of course have mentioned it, but I did not know of it.

xxix. A piece of zinc, half in air and half in water, causes no great difference of potential between the air and the water (Thomson, Clifton, Ayrton and Perry, &c.), consequently air must behave much like water.

xxx. If it makes the air slightly positive to the water, as it does (Hankel), it may mean that the potential energy of combination of air with zinc is slightly greater than that of water, or it may represent a difference in the thermoelectric contact forces between zinc and air and zinc and water, or it may depend on a contact force between air and water. [If such a contact force between air and water exists, it is obviously of great importance in the theory of atmospheric electricity, for the slow sinking of mist globules through the air would render them electrical.] [1]

xxxi. Condenser methods of investigating contact force no more avoid the necessity for unknown contacts than do straightforward electrometer or galvanometer methods; the circuit is completed by air in the one case and by metal in the other, and the E.M.F. of an air contact is more hopelessly unknown than that of a metal contact.

xxxii. All electrostatic determinations of contact force are really determinations of the sum of at least three such forces, none of which are knowable separately by this means.

xxxiii. The only direct way of investigating contact force is by the Peltier effect or its analogues. [Maxwell.]

xxxiv. Zinc and copper in contact are oppositely charged, but are not at very different potentials; they were at different potentials before contact, but the contact has nearly equalised them.

xxxv. The potential of the medium surrounding them is, however, not uniform. If a dielectric, it is in a state of strain; if an electrolyte, it is conveying a current.

Size of Atoms.

25. I may now claim to have accomplished my task, and terminate this long paper; but there are several interesting points which arise in connection with Sir Wm. Thomson's deduction of a limit to the smallness of atoms from contact data, and these I may be permitted to indicate. Indeed, it evidently becomes a question whether or not his argument remains quite valid if the chemical-strain view be taken of Volta's force.

Let us then inquire whether any modification has to be made in Sir Wm. Thomson's argument, if the hypothesis set forth in this paper be adopted. He says (virtually) take a number of plates of zinc and copper of specified thickness, arrange them alternately like the leaves of a book with the covers doubled right back, and then shut the book. Directly they touched at one edge they became oppositely electrified and attracted each other, and therefore did work as they approached. By making the leaves numerous and thin enough, and shutting them up close enough, any required amount of work can be thus done with given quantities of metal, provided the thin plates retain the same properties as masses of metal possess; *i.e.*, provided they are not only a few atoms thick. So far there is no possible objection; but Sir William proceeds to consider the attraction as depending on the affinity of zinc for copper, and the work he requires of his plates is that evolved in the formation of brass. But if we regard the attraction as depending on the difference of combustion energies, Zn/O—Cu/O, we must, to keep the charge constant, not only

[1] Cf. Lecture on 'Dust,' *Nature*, January 22, 1885.

take the plates several atoms thick, but we must suppose films of air of sufficient thickness to preserve their normal activities in the way of chemical strain to be shut up with the plates. Given these, the amount of work which he has calculated would certainly be done in shutting the book, and a corresponding amount of heat generated. But would this heat have anything to do with the making of brass? So far as I can see, nothing whatever.

If we intend to make brass, must we not regard the air surrounding the plates as a simple accident, and imagine all air-films removed before beginning the operation? Work with the zinc and copper plates in absolute vacuum, where (on my hypothesis at any rate) the only difference of potential between them is a minute thermoelectric one; there will be an attraction caused by this difference of potential, and work will be done in shutting the book; but to get any appreciable amount of heat the plates must be terribly thin. How much heat is really produced in the formation of brass I do not believe anyone knows; but if it be enough to warm the metals sixty degrees, the lower limit to the size of atoms becomes greatly depressed.

In a note at the end of this paper I show that a rise of from $\frac{1}{4}$ to 2 degrees is all that is probable, on the usual estimate of atomic dimensions; the smaller evolution of heat being caused by alloying the metals at 10° C, the larger being produced by alloying them at 400° C.

26. *Is* there much heat produced in the formation of brass? Is there any way of attacking the question simply? The only way which has occurred [1] to me is to dissolve brass in acid, and to see whether one gets appreciably less heat than by dissolving its constituent copper and zinc separately. When an alloy is dissolved, I suppose the affinities of its constituents are unloosed, or the combination undone; hence the heat developed during the solution of an alloy, subtracted from that produced during the solution of its constituent metals and mixing of those solutions, ought to measure the heat of formation of the alloy. Dr. Forster Morley, of University College, London (also on the boat), said he might be willing to undertake this observation, which is doubtless a delicate one, for he was engaged in some thermo-chemical researches. It may not be practicable for the actual case of brass, because of the complication and uncertainty introduced by secondary products, but a better pair of metals may no doubt be readily found.

Adhering to zinc and copper as convenient for explanation, the argument, though obviously not the order of experiment, will stand as follows: Take definite weights of zinc and copper, dissolve them separately, getting heats H_1 and H_2 respectively, then mix the solutions, getting a possible further heat production h. This is one plan of passing from separate zinc and copper to a solution of a salt of brass.

Next take the same weights of zinc and copper as before and alloy them, getting heat H, then dissolve the brass in the same acid as before, getting heat H_3. This is another plan of passing from separate zinc and copper to a solution of a salt of brass.

Now, unless external work and secondary products are different in the two cases, we are justified in writing the heats evolved in the two cases equal:—

$$H_1 + H_2 + h = H + H_3.$$

[1] It occurred in conversation with Professor S. P. Thompson and Dr. Fleming on board the Quebec excursion steamer *Canada*, and I am unable to say who suggested it.

H is the unknown quantity to be determined, and its determination involves four separate measurements, H_1, H_2, H_3, h.

The only one of these at all easy to observe is h, and this my assistant, Mr. Butler, has done. Proportions of zinc and copper sulphate, containing equal weights of zinc and copper, are dissolved in as little water as will keep in solution any double salt that may be formed on mixing. The zinc sulphate is enclosed in a thin bulb or tube inside the other solution, and left, screened from stray heat, for some hours. The bulb is then broken, or the liquid otherwise blown out of it, and the liquids mixed. No certain rise of temperature so great as a hundredth of a degree has been observed.

27. In thinking over what metals were more suitable, it struck me that the heat of formation of amalgams was a subject easy of direct attack. I therefore, as a preliminary, have dissolved a little granulated tin in mercury. Of course the latent heat of liquefaction of tin has to be allowed for, and the actually observed result is a cooling; but I hoped that the cooling observed would be less than what the latent heat would account for, and that I might then calculate the real evolution of heat due to combination. Unfortunately the only data I know of with reference to the latent heat of tin relate to its ordinary melting point, at which point it is given by Rudberg as 13·3 and by Person as 14·25. We have no ground whatever for believing latent heat to be constant, and I am therefore utterly in the dark as to what the latent heat of tin at ordinary temperature may be. That liquid tin could be super-cooled to ordinary temperatures without solidification is unlikely. I give, however, the data of my experiment (which was carefully performed) in case better latent heat data are known to someone else:—2·10 grammes of thin granulated tin at 12°·4 were dropped into 502·00 grammes of mercury at a steady temperature of 10°·85, contained in a large thin protected test-tube, of which the part sharing the temperature of the mercury weighed 8 grammes. After solution, which took ten minutes, the resulting temperature was found to be 8°·82. Three minutes later it had risen to 8·99 from surrounding influences. The thermal capacity of the immersed part of the thermometer was equivalent to ·48 gramme of water.

Working on these data, and taking the specific heat of tin as ·056, latent heat 14·25, specific heat of glass ·19, and of mercury ·033, we find:—

Heat disposed of in cooling and liquefying tin . .	30·45 units
Disappearance of heat actually observed	43·57

more than can be accounted for, without any combination heat at all! This is rather depressing, but it only shows how wrong is the estimate of 14·25 for the latent heat of liquid tin at 10° Centigrade.

Ignorance of the true latent heat thus effectually prevents our obtaining any information whatever, about the heat of combination of tin and mercury, from the experiment. It seems indeed easier to observe the combination-heat by a process of dissolving the amalgam and the metals separately, in acid, as already explained for brass; and then to use the above experiment to calculate latent heat from. One might perhaps thus get the latent heats of fusion at various temperatures for metals soluble in mercury.

Another alternative however presents itself. Instead of trying to reduce the latent heat to ordinary temperatures, one might form the amalgam at a temperature just below the melting point of tin, and obtain (if possible) the nett evolution of heat then.

Suppose the heat of combination of the 2·1 grammes of tin with mercury to be somehow or other determined, we have next to suppose the amalgam made otherwise, bringing the molecules together in a reasoned way. Let the same quantity of tin be brought to within molecular distance of the mercury in successive pieces of very thin foil, first made to touch at one corner and then laid down.

It is quite true that each flake would be charged with a Volta E.M.F. of, say, ·6 volt, and so would attract the mercury and do a certain amount of work in laying itself down. But it is not fair to compare an operation thus conducted in air with the dropping of a solid mass of tin into mercury; to be able to compare the two operations one must perform the foil experiment in absolute vacuum. This being done, the contact E.M.F. is no longer ·6 volt, but only about ·00015 volt according to the experiments of Matthiessen. Good data for this quantity are however wanting; mercury is not one of the metals included in Professor Tait's series. It was observed by Gaugain; and by rather hypothetical deduction from his numbers, as given pictorially in Wiedemann's 'Elektricität,' I make the tin-mercury Peltier force 1·75 millivolts at 10°.[1]

Taking one of these numbers (15,000 or 175,000 in C.G.S. units), or a better one when determined, we can calculate how near the given mass of tin must be brought to the mercury in order to generate the actual heat of combination, provided one knows the specific inductive capacity of absolute vacuum.[2] But I do not know it. Thus the supply of data for this case is distinctly unsatisfactory.

[1] Since this was in type, a paper by C. L. Weber has appeared in Wiedemann's *Annalen* for November 1884, on the thermoelectric properties of amalgams, in which mercury itself was examined; and from the data there recorded, together with Tait's value for copper, I reckon the thermoelectric value of mercury at $t°$ Centigrade as

$$431 + \cdot 5t \text{ absolute electro-magnetic units.}$$

Whence the Peltier force at the same temperature is

$$1181 + 5\cdot 68t + \cdot 005t^2 \text{ microvolts.}$$

The Peltier force between tin and mercury at 10° is therefore 123,800 absolute units, or 1·24 millivolts, which agrees well enough with the rough estimate above.

[2] Taking this as 1 and assuming the estimate of molecular dimensions hereafter established and working backwards, one can show that the Peltier force of tin and mercury at 10° is connected with the heat of combination of our 2·1 grammes of tin with the 502 grammes of mercury by the relation,

$$J\,\Pi = 3\cdot 6 \times 10^6 \sqrt{H}.$$

The two rough estimates of $J\,\Pi$ deduced from Matthiessen and Gaugain respectively (15,000 and 175,000) thus give H as about $\frac{1}{4}$ and $\frac{1}{10}$ of a unit respectively. Either of these is too small a quantity to be observed in the process of dissolving tin in mercury; so neglecting it we get, from that experiment, the latent heat of molten tin at 10° C. as 20·4. Another experiment made in a similar way gave 19·6.

If the above reasoning be regarded as legitimate, a combination of thermoelectric measurements with observed heats of solution in mercury may furnish a means of estimating latent heats of fusion at various low temperatures in general.

Working back similarly to the heat of combination of 1 gramme of copper with 1 gramme of zinc, we calculate ·077 unit as the heat developed at ordinary temperatures; only enough to raise the mass of brass formed through three-eighths of a degree Centigrade. At a higher temperature such as 400° C. the Peltier force for these metals is greater, being 4,600 microvolts, and the calculated heat of combination is then $\frac{1}{3}$ of a unit per gramme of each; sufficient to raise the whole mass of metal through nearly 2 degrees Centigrade. This, then, is the sort of elevation of temperature one may expect in making brass at a temperature of 400°.

28. Let us try whether we cannot do better with a single metal exposed to air, not troubling about the contact of two metals, which is unnecessary, but simply considering one metal in contact with air.

Take a gramme-equivalent of any metal, say 65 grammes of zinc, and imagine it rolled out into a thin sheet of foil, of area A. The difference of potential between it and the air being V in electrostatic units, $\frac{V}{300}$ in volts, its charge will be $\frac{2AV}{4\pi x}$, where x is the distance between it and the air, a quantity of molecular magnitude. The electrical energy of this charge is $\frac{AV^2}{2\pi x}$, which must therefore have been the electrical work done (*i.e.*, the amount of potential chemical energy transmuted into electrostatic energy) in spreading out the zinc over so much surface. [Capillary tension is part of the *mechanical* work done.]

Now let it be rolled so thin that every atom of it is in contact with air, *i.e.*, let its thickness be also of molecular magnitude, x. We can regard its potential energy in two ways: either as chemical or as electrical. Chemically, its energy, measured by heat of combination, is

$$46{,}000 \text{ VJ},$$

where V is expressed in volts. Electrostatically its energy is

$$\frac{A}{2\pi x} \cdot \left(\frac{V}{300}\right)^2.$$

Equating these two values, and writing for the quantity of metal $m = Ax\rho$, we have the general relation

$$mV = \cdot 828\, \pi \rho\, x^2\, J \times 10^{10};$$

whence, taking $m = 65$, $\rho = 7$, and $V = 1{\cdot}8$, we get, as our estimate of linear molecular dimensions,

$$x = 4 \times 10^{-9}.$$

The data in this calculation are all very definite, hence if the reasoning is legitimate this estimate ought to be a pretty good one. It is true that another metal would give a rather different estimate, unless $\frac{mV}{\rho}$ were constant for all. For ordinary metals, *e.g.* zinc, iron, copper, mercury, silver, this is not so outrageously far from being the case; but discrepancies arise with such metals as sodium on the one hand, and platinum on the other. But it is very doubtful whether platinum could be regarded as an oxide, however thin it were beaten; and sodium would probably take fire long before the proper molecular thinness was reached.

The several estimates of Sir William Thomson for the size of atoms were given in 'Nature,' March 1870, and are reproduced in 'Thomson and Tait,' Part II., Appendix F. In a lecture on the size of atoms delivered at the Royal Institution in February 1883, he re-states these estimates with slight modifications thus:—

If atomic dimensions are comparable with 10^{-8} centimetre, brass would rise 62° C. at the instant of formation; while if atoms are so small as $2{\cdot}5 \times 10^{-9}$, it would rise 1000° C. Hence 10^{-8} is to be regarded as a limit of smallness.

A soap-film so thin as 10^{-8} centimetre would raise itself 280° by collapsing; therefore there are not several molecules in this thickness.

The theory of gaseous collision, combined with the density of liquids, suggests a range lying between 7×10^{-9} and 2×10^{-9}.

The dispersion of light seems to require atomic dimensions to lie between 10^{-7} and 10^{-9}.

The final estimate made by Sir Wm. Thomson is something between 2×10^{-7} on the one side, and 10^{-9} on the other. But if the reasoning in the present paper be admitted as correct, it would seem possible to reduce this range of uncertainty and to make an even more precise estimate.

On the Archæan Rocks of Great Britain. By Professor T. G. BONNEY, *D.Sc., LL.D., F.R.S., Pres. G.S., Fellow of St. John's College, Cambridge.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

Two methods of dealing with this subject, on which I have been asked by the Organising Committee of Section C to prepare a paper, naturally suggest themselves. The one is to treat it historically, by giving in chronological order a *précis* of the papers or books in which reference has been made to the Archæan rocks of Britain; the other to describe, as accurately as is possible in a limited space, the petrology of the several districts, stating briefly at the same time the reasons which have led the writer, in common with many other geologists, to consider their rocks as more ancient than the Cambrian period.

The former method has doubtless many advantages, and would be the fit one, had I been called upon to 'report' on the Archæan question; but it does not commend itself to me, in this particular case, as the one most likely to be helpful to those who are more especially engaged in petrological studies. Speaking for myself, I always find it, in the case of a district not yet visited, more useful to be informed as exactly as may be what are the mineral and physical characters of its rocks, and what their stratigraphical relations, than what opinions have been entertained as to their antiquity. For this purpose it is not enough to have them named, unless the grounds of the writer's nomenclature are given. There has hitherto been so much latitude assumed in the use of such terms as 'schist' and 'slate,' not to mention others, that they become of little value unless what we may term the 'personal equation' of the writer be known. Accordingly, in this paper, I shall endeavour to give as exactly as is possible, without entering into minute details, the mineral characters of the Archæan rocks in each district noticed, and the relations in which they stand to those of ascertained geologic age. I may add that throughout I shall use the term 'schist' to denote a more or less foliated rock—that is, one in which presumably great mineral changes have taken place since its materials were first deposited, so that, if they were originally clastic, few, if any, traces of the constituent grains can be recognised; 'schistose,' to denote that a rock looks like a schist, but in this case I imply no more than an external resemblance. By the term metamorphic rocks I mean those which, like schists, have undergone great mineral changes—not rocks which, like many which are schistose, have been in reality but slightly altered, whose changes have been only micromineralogical. The word 'slate' is never applied to a foliated rock, only to cleaved rocks of distinctly detrital, more or less argillaceous materials.

(A) England.

(1.) *Cornwall: The Lizard Region.*—A considerable portion of the peninsula south of the Helford river consists of metamorphic stratified rocks, which are well displayed in the fine cliffs forming its picturesque coast; inland, as a rule, exposures are few. The neighbourhood of the Lizard Point is the only part where a complete and continuous section is obtained, as masses of intrusive rock occupy no small portion of the district, and frequently rise directly from the sea. The metamorphic stratified rocks may be divided into three groups, between which, however, there does not appear to be any very sharp line of demarcation mineralogically, or any reason to suppose a discontinuity. Still, as each is distinguished by marked and dominant mineral characteristics, it is convenient to describe them separately.

There is a good deal of rolling, much disturbance from the intrusion of igneous rock, and faults are numerous in this district; but probably there are no very vast dislocations, and there are no indications of sharp flexures on a large scale, or overthrows such as are frequent in districts which are or have been mountainous, so that it seems safe to follow the ordinary principles of lowland stratigraphy in working out the geology. Enumerating the groups in ascending orders, we have—

(*a*) *Micaceous Group:* characterised by rather compact dull green schists, whose exact mineral composition cannot be readily decided in the field, and by brownish mica-schists. These, as a rule, are composed of very minute constituents, moderately fissile, sometimes with a slightly 'flinty fracture,' not seldom very beautifully corrugated on a small scale. The rocks, though the constituent minerals are in many cases very small (considerably less than ·01″ diameter), are completely metamorphosed. The green schists, on microscopic examination, are seen to be composed of an acicular light green variety of hornblende, of a green filmy mica, or perhaps in some cases a chlorite, of quartz, of a little magnetite, hæmatite, or pyrite, with epidote, a colourless garnet (rare), and a kaolin-like mineral perhaps replacing felspar. The green minerals and quartz are, however, the dominant constituents, so that the name 'Talcomicaceous,' which was assigned to the series by De la Beche,[1] was macroscopically appropriate, although, strictly speaking, there does not appear to be any true talc. With it, but not largely developed, occurs a brownish, slightly silvery mica-schist, in one place more coarsely crystalline than the above, consisting chiefly of brown and green micas (probably biotite and its alteration products), and paragonite (?), with quartz and a few small garnets. This group, as stated, is well exposed in the southern cliffs of the Lizard from a short distance to the north of the Quadrant Headland to the neighbourhood of the Lighthouse. Its strike is roughly from WNW. to ESE., with a dip on the northerly side, but there are many minor twists and rolls. The same group is exposed for a very limited extent in the cliffs on the south side of Porthalla Cove.[2]

(*b*) *Hornblendic Group.*—This group is much more extensively developed than the former in the cliffs forming the eastern and western faces of the Lizard peninsula, and a considerably greater vertical thick-

[1] *Report on the Geology of Cornwall and Devon*, p. 29.

[2] Associated with this is a band, a few feet thick, of a granitoid rock; it may be an intrusive vein-granite modified by compression, but looks as if it were interbedded.

ness of it must be exposed. It is a distinctly bedded, strong, hard rock, only slightly fissile ; sometimes quite massive in fracture, and almost like a diorite, but in other places exhibiting very distinct alternating laminations differing in mineral character. The materials are distinctly crystallised, though they do not generally exhibit a definite crystalline outline. The dominant mineral is hornblende, macroscopically a dark green, almost black, microscopically a rich green, strongly dichroic. With it occur in variable quantities the following minerals : quartz, felspar (generally, so far as is recognisable, a plagioclastic variety), and epidote, with more or less magnetite, pyrite, &c. ; occasionally the felspar occurs in rather irregular 'eyes,' giving a subporphyritic character to the rock, but as a rule its texture does not very greatly vary. Occasionally the absence of any distinct structure makes the rock almost indistinguishable from a diorite of moderately fine texture ; but often it is beautifully banded, layers of the quartzose, felspathic, or epidotic constituents alternating with those in which hornblende predominates. The bands may vary in thickness from half an inch or more to mere films. They are parallel with the apparent rather 'slabby' bedding which is generally characteristic of the series. Further, at a place called Hot Point, is a structure which, although the rock is perfectly crystalline, is so marvellous an imitation of false bedding that it is difficult to believe it due to any other cause than the deposition of the original constituents ; these, and indeed much of the group, may possibly have once been basic tuffs.

(c) *Granulitic Group.*—Into this the one last described passes almost insensibly. It is even more conspicuously bedded than the last, and it is distinguished from it by the prevalence of bands of a lighter colour. The latter consist chiefly of quartz and felspar, with a little hornblende or, less commonly, black mica. Sometimes a specimen resembles macroscopically a piece of vein-granite, consisting of little else than quartz and felspar: sometimes it might almost be a fragment from the group above described ; but, as a rule, the hornblende is much less abundant and less definitely crystalline. Thus, macroscopically and microscopically, the group is rather readily distinguishable, and, notwithstanding the rarity and inconspicuousness of garnets, I have ventured to call it the Granulitic group. It seems impossible to explain the frequent and repeated interchanges of laminæ and bands of these two principal varieties of rock—distinguished so readily by the eye, as the one is a warm, light reddish grey, the other quite a dark grey—except on the hypothesis that they indicate original sedimentation, and I have described and figured a case from Kennack Cove which seems indicative of irregular lamination.[1] Owing to the frequent interruption of igneous rocks, and the numerous faults (in which however the throw is probably not great), it is very difficult to assign a thickness to the metamorphic series of the Lizard. The base of the micaceous group is not seen, the hornblendic group must be of considerable thickness, but I should not allot more than three or four hundred feet to the granulitic group.

Igneous Rocks.—In the above metamorphic sedimentary series we find the following rocks, which it may be well to enumerate, though it is no part of my present plan to describe them in detail. Some of these also are now entitled to the term 'metamorphic,' as they have undergone great mineral changes.

(a) Serpentine: a very handsome rock ; sometimes almost black,

[1] *Q. J. G. S.*, vol. xxxix. pl. 1.

more commonly richly mottled red and green, frequently containing metallic bronzite. There is strong evidence that this rock is a hydrated peridotite, and there is as clear and distinct proof of its intrusive character as there is of any dolerite or felsite that I have ever seen.

(β) Troktolite: that is, a rock consisting mainly of anorthite (or an allied felspar) and olivine, more or less changed into serpentine, with but little of a pyroxenic constituent; occurs only in one locality (Coverack Cove).

(γ) Olivine-gabbro: in one great mass, and in numerous dykes and veins on the east coast only.

(δ) Vein-granite: chiefly, if not entirely, on the west coast.

(ϵ) Diorites, hornblendic diabases, and basalts more or less altered; in small dykes and veins on the east coast.

The chronological order of these rocks is that in which they are enumerated, except that the granite is nowhere seen to cut the gabbro, and it is impossible to fix the age of all the rather diverse members of (ϵ), though many of them are seen to cut both the serpentine and the gabbro. As it happens, only one igneous rock—a kind of diabase—is seen intrusive in the micaceous group (if the granitoid rock already mentioned be of sedimentary origin); though, of course, as we may presume it to underlie the later groups, it must be cut by the rocks which intrude into them.

Evidences of Geological Age.—The metamorphic rocks of the Lizard peninsula are bounded on the north by a fault, which is exposed in section on the west in the cliffs at Polurrian Cove, on the east at Porthalla Cove. In the former we see very characteristic hornblende-schist in apposition with a dark satiny slate, parted by about a yard of fault breccia; the fault—as is so common in these cases—is a reversed one. At Porthalla Cove the greenish schists of the micaceous group are faulted against some filmy-looking mudstones. Here, as the two rocks have more macroscopic resemblance and the rocks are much broken up by parallel faults, it is more easy to imagine a transition; but careful study with the microscope will show that two rocks of very different characters are faulted together. Further, at Nare Head, in the newer series, about a mile to the north, is a conglomerate, containing, though rarely, fragments of the true hornblende-schist and pebbles of a granitoid gneiss, not unlike a vein-granite. This series cannot be later than the Devonian period, and is very probably rather older.[1]

(2.) *South Devon (Start Point and Bolt Head).*—The area occupied by metamorphic rock is in greatest extent about nine miles from east to west and two miles from north to south. Here also we are chiefly dependent on the coast cliffs for our sections. In these are exposed two kinds of rock—a lead-coloured mica-schist and a greenish chloritic rock —varying from a moderately foliated to a rather massive rock, in the lower part of which some thin bands of a rather dark mica-schist occur. The former rock consists of quartz, generally rather inconspicuous macroscopically, and of three varieties of mica—a dark brown mica, a pale olive-green mica (or possibly chlorite), and a silvery white mica, probably

[1] Full descriptions of the macroscopic and microscopic characters of the metamorphic and igneous rocks of the Lizard district are given in my papers, *Quart. Journ. Geol. Soc.* vol. xxxiii. p. 884, and vol. xxxix. p. 1. Sir H. De la Beche's *Geological Report on Cornwall and Devon* is still a great storehouse of most valuable information.

paragonite or margarodite—with specks of iron peroxide, and possibly a little graphite, with a granule or two of epidote. In the bands associated with the chloritic rock are a few grains which may possibly be felspar, but have rather more resemblance to kyanite. The chloritic rock has for its most abundant mineral a chlorite, with epidote, quartz, and sometimes the mineral just described (kyanite ?), and with occasional calcite and iron peroxide. As mentioned above, there are several minor varieties. I am not aware that there are any igneous rocks intrusive in this series.

Evidences of Geologic Age.—The stratigraphy of this district is difficult. The beds have been thrown into a series of repeated gigantic and almost vertical folds, and there is very distinct evidence that this disturbance has been subsequent to their metamorphism. It is thus extremely difficult to say whether there is a thick bed of mica-schist both above and below the chloritic schist; or whether the lowest rock seen is the interbanded chloritic- and mica-schist, and the upper mica-schist is repeated by the folding. I incline to the latter opinion. The metamorphic series is bounded on the north by a fault, and succeeded by a slaty series, generally of a dark colour, which from the fineness of its argillaceous materials and the hypometamorphic effect of the pressure to which it has been subjected, often has a considerable macroscopic resemblance to the true mica-schist, but can be readily distinguished under the microscope and, after careful examination, even in the field. This rock is considered to be of Devonian age.[1] The date of the great folding is no doubt post-Carboniferous and pre-Triassic.

In addition to the above-mentioned regions, true gneiss of a marked Archæan type has been described, by Mr. A. R. Hunt,[2] from the reefs about the Eddystone Lighthouse, and specimens of coarse gneisses have been dredged up from various parts of the Channel off the South Devon coast. Gneisses, of a type which occurs in the lower part of the Archæan series, occur in the Channel Islands, and those of Guernsey have been described by the Rev. E. Hill and myself.[3]

(3.) *Malvern Hills.*—We are indebted to Mr. H. B. Holl[4] for a careful description of the petrology of this district, and some analyses of the rocks were made by the Rev. J. H. Timins,[5] but at present no complete study of their microscopic structure has been published. The ridge of Archæan rock runs nearly north and south, and is a little more than seven miles in length. The greatest breadth from east to west is about half a mile, but it is commonly less. The strata strike roughly from NW. to SE., and are inclined at high angles, being often nearly vertical; but it is probable that those at the southern end are higher in the series than those at the northern. Some isolated bosses protrude through Silurian rocks still further to the north, the last exposure at a distance which makes the entire length of the area about sixteen miles. At the northern end are granitoid gneisses, generally coarse, occasionally almost binary compounds of quartz and reddish felspar, but more commonly containing in addition dark green hornblende or blackish mica, and so passing into hornblendic or micaceous schists. In the southern part the gneisses become finer-grained and more thinly bedded, the schists more frequent; mica, perhaps, being more common and conspicuous than in the north; chlorite and

[1] For a detailed description of the district, see my paper, *Q. J. G. S.*, vol. xl. p. 1.
[2] See papers in *Trans. Devonshire Assoc.* 1880–4.
[3] *Q. J. G. S.*, vol. xl. p. 404.
[4] *Q. J. G. S.*, vol. xxi. p. 72.
[5] *Q. J. G. S.*, vol. xxiii. p. 352.

epidote are also present, the former being sometimes abundant. Orthoclase and plagioclase have been recognised among the felspars, and sometimes the latter predominates; the quantity of quartz is very variable. There are intrusive diorites, and perhaps diabases, and 'granite-veins,' which, however, are more probably 'segregation veins.'

On the eastern side of the Herefordshire Beacon, an area of rock occurs, forming a series of buttresses to the hill, which may possibly belong to the latest part of the Archæan series. The outcrops occur over an area of about a mile from north to south, and half that distance from east to west, and have been described by Dr. C. Callaway.[1] The dominant rock is a very compact, flinty argillite, of a greyish or reddish-grey colour, which has occasionally an ashy aspect. There is also some of a felspathic rock, which appeared to me to be more probably a true quartz-felsite and possibly intrusive. It is difficult to come to any conclusion as to the dip and strike of the rocks, which are of a rather monotonous and uninteresting character. They are certainly much newer than the gneisses and schists of the main range, and are older than the Hollybush sandstone, but their claim to be pre-Cambrian rests only on lithological characteristics, which in this case, it must be admitted, are not very conclusive. The Archæan age of the gneissic series is now so generally admitted that no proofs need be given in this summary.

(4.) *The Wrekin District.*—This hill, so familiar to every Salopian, forms a bold ridge, with the minor summits of the Ercal and Primrose Hill at the northern and the southern end. On the Geological Survey map the ridge is coloured as 'intrusive greenstone,' and surrounded with a zone of altered Caradoc. Attention was first directed to the interesting petrology of the district by Mr. S. Allport,[2] and the stratigraphy of the region was worked out by Dr. Callaway,[3] to whose paper is appended a note on the lithology of the district by myself. The Wrekin is only the loftiest of a series of outcropping ridges which extend interruptedly in a NE. to SW. direction from Lilleshall Hill to the south of the Caer Caradoc chain—in all about twenty-nine miles from the most extreme points. It will be convenient to describe first the rocks of the Wrekin, the most important portion of the chain. The Wrekin group, a line of steep hills, is rather less than three miles long, and the area occupied by the older rocks is at most about a third of a mile wide. The Wrekin proper consists of a series of volcanic agglomerates and compact felstones. We have in it, beyond all doubt, a portion of an ancient volcanic hill, which has ejected rhyolitic lavas and scoria; fluidal structure is common in the fragments, spherulitic and perlitic structures are occasionally seen; the prevailing tint is a purplish red. Chemically the 'felstone' is almost identical with the perlite of Schemnitz,[4] and, except that the rock is now devitrified, there is no reason why the names rhyolite and pitchstone should not be applied to some of its varieties. The fragments included in the coarser agglomerates are often several inches in diameter. There are indeed one or two small bosses of intrusive dolerite, but the area occupied by them is so insignificant that it cannot justify the designation of the whole *massif* as greenstone. The rhyolite is exposed at the extreme north of the range (Ercal Hill), and is seen (in a large quarry) to be overlain at a high angle by a coarse (rather decomposed)

[1] *Q. J. G. S.*, vol. xxxvi. p. 536.
[2] *Q. J. G. S.*, vol. xxxiii. p 449.
[3] *Q. J. G. S.*, vol. xxxv. p. 643.
[4] Allport, *Q. J. G. S.*, vol. xxxiii. p. 459.

granitoid rock. This continues for about a quarter of a mile, and is then abruptly succeeded by rhyolite (the commencement of the main *massif*), the junction being probably a faulted one. It is possible that the junction on the northern side may also be a fault, but to myself the appearances appear much more favourable to the idea that the rhyolite has broken through the granitoid rock. The latter consists of quartz, felspar (orthoclase, oligoclase? and probably microcline), with some iron peroxide and a small quantity of a chloritic mineral. It is extremely difficult to say whether it be a true granite or a granitoid gneiss (granitoidite), but it seems impossible to doubt that it is a much more ancient rock than the rhyolite. At Primrose Hill, at the southern end of the range, the rhyolite again gives place to 'granitoidite' of the Ercal Hill type, with gneiss of Malvernian type and a little diorite.

Evidences of Geological Age.—Even if we consider the 'granitoidite' igneous, it must be older than the rhyolitic group, and we can hardly hesitate to recognise in some of the Primrose Hill rocks a reappearance of the ancient Malvernian gneisses. At any rate, the rhyolitic group is much earlier instead of later than the Caradoc, for Dr. Callaway has shown that the quartzite which flanks the Wrekin is considerably older than the Hollybush sandstone[1] (Lingula Flag), and it contains in parts fragments of the rhyolitic rocks of the Wrekin. Hence the latter must, at the latest, be Cambrian, or even older.

The rhyolitic group reappears to the north-west of the Wrekin, at a distance of rather more than a mile, in the neighbourhood of the village of Wrockwardine; and near the southern end, at Lea Rock, there is a fine mass of the ancient 'pitchstone,' exhibiting in parts beautiful perlitic and spherulitic structures, which have been described and depicted by Mr. Allport.

At Charlton Hill, along the same line to the south-west, there are argillites, tuffs, and felstones, some of the latter being of the Wrekin type, but one is porphyritic and apparently rather less acid, together with a very interesting conglomerate, containing well rounded fragments of quartz, felspar, gneiss, and various schists, indicating that the materials were derived from a series of metamorphic rocks.

Lilleshall Hill, a low ridge, about five miles to the north-east of the Wrekin, consists of hard argillites, ashy slates, and rhyolitic agglomerates, with a small *coulée* (?) of rhyolite, the latter closely resembling the same rock in the Wrekin. Average dip 40° to NNW.

There are exposures of rocks resembling the above described volcanic group in the district between the Wrekin and Caer Caradoc, at the latter locality, at Hazler Hill, Raglett Hill, and near Hope Bowdler, and some more west of the Longmynds, but as they are inferior in interest to those already described it may suffice to mention them.[2]

(5.) *The Lickey Hills.*—This range forms the eastern boundary of the Severn valley, lying rather more than twenty miles north-east from the Worcester Beacon (the culminating summit of the Malvern chain) and about the same distance south-east of the Wrekin. The principal rock is a quartzite bearing considerable resemblance to that which flanks the Wrekin, the constituents of which have probably been derived from granitoid rocks. Formerly this rock was regarded as altered Llandovery

[1] *Q. J. G. S.*, vol. xxxiv. p. 754.
[2] See Callaway, *loc. cit.*, and vol. xxxviii. p. 119.

sandstone, but the investigations of Mr. F. T. Houghton, Professor Lapworth, and others, have shown that, while there is a quartz-grit of Llandovery age, the quartzite proper is an older rock.[1] Professor Lapworth has also discovered that at the south-western end of the range there are felspathic ashy beds, and a felstone, with a general resemblance to that abounding in the Wrekin area.

(6.) *The Hartshill Ridge.*—Extending for about two and a half miles in a north-westerly direction from the town of Nuneaton, is a ridge of quartzite forming the eastern flank of the Carboniferous district of Warwickshire, and bounded in that direction by a fault, on the other side of which are the Keuper beds. This quartzite has been mapped and described by the Geological Survey as altered Millstone Grit. Professor Lapworth, however, has recently discovered that it is overlain by a series of Upper Cambrian beds, containing characteristic fossils, which are succeeded by the Coal-measures of the district, and is underlain by felspathic mudstones and ashes, among which occurs intrusively a quartz-felsite.[2] Certain diorites intrusive in both quartzite and the Upper Cambrian beds have been described by Mr. S. Allport.[3]

(7.) *The Charnwood Forest Region.*—This interesting district lies to the north-west of the town of Leicester, and consists of a group of hills cropping out from beneath Triassic beds, which have occupied its ancient valleys, and possibly once buried many of its summits. It is, in short, a pre-Triassic highland region which has been again laid bare by denudation. The area occupied by the older rocks measures, roughly, nearly nine miles from NW. to SE., and rather more than four from SW. to NE., but it is somewhat interrupted by overlying Trias. At the north-west end, in close proximity to the older rocks, a patch of dolomitized Carboniferous limestone is exposed, and along the north-west flank is the Leicestershire Coalfield. The district has been investigated by the Rev. E. Hill and myself,[4] and the following is a brief *résumé* of our conclusions. Omitting for the present sundry masses of igneous rock, generally rather coarsely crystalline, the Charnwood Forest series forms probably the more southern portion of an elongated anticlinal dome. The axis of this points from rather N. of NW. to S. of SE. The mass is severed by an anticlinal fault, and, as I think, by a larger parallel one to the west. The beds on the opposite side of these are rather dissimilar, but we think that sundry horizons may be identified with tolerable certainty, and the following general succession established. The lowest group, exposed only at the northern extremity of the Forest, consists of slates and gritty beds. The latter have been called quartzites, but they are not at all normal representatives of this group, and they appear for the most part to be fine volcanic detritus of an acid character. To this succeeds a great series of grits, slates, volcanic ash, and agglomerates, some of the last-named being very coarse and containing at certain horizons rounded masses of a rhyolitic rock, at others large fragments of a greenish slaty rock. Then comes, on the western side, at High Sharpley, a schistose porphyritic rock, overlain apparently by a less schistose variety called the Peldar Tor rock, over which come more agglomerates. Yet higher,

[1] *Proc. Birmingham Phil. Soc.*, vol. iii. p. 206.

[2] For information on these two regions, and for the opportunity of examining some of the more important sections, I am indebted to Professor Lapworth.

[3] *Q. J. G. S.*, vol. xxxv. p. 637.

[4] *Q. J. G. S.*, vol. xxxiii. p. 754; xxxiv. p. 199; xxxvi. p. 337.

apparently, are sundry slaty beds and a few bands of a pebbly quartz-grit and quartzite, over which, in the southern region, are the well-known workable slates of Swithland and Groby.

Thus from first to last volcanic materials are recognisable, often as very coarse agglomerates, the fragments of lava being quite unmistakable. This is a compact quartz-felsite (old quartz-trachyte or rhyolite), containing in one case as much as 79 per cent. of silica. It is difficult to decide upon the true nature of the Sharpley and the Peldar Tor rocks; quartz and felspar occur porphyritically in a compact devitrified matrix, which is curiously devoid of any very characteristic structure, and the micro-mineralogical changes which have occurred help to increase the difficulties. It may be regarded as a certainty that they are of volcanic origin; but the difficulty is whether we should regard them as lavas originally glassy, upon which a rude cleavage has been impressed, and which, owing to subsequent changes, have become slightly schistose in character, or as tuffs of similar chemical composition, indurated, cleaved, and slightly altered, so that the original fragmental structure has been practically obliterated. When I wrote last upon the subject I inclined to the latter view, but prolonged study of these and other rocks of volcanic origin, ancient and modern, together with field work among the Ardennes porphyroids (some of which closely resemble the Sharpley rock), has made me more sensible of the difficulties of this hypothesis, and removed some of those in the other view. At the same time I would not venture to speak positively, except to say that whether these particular rocks, with a little of those at Bardon Hill, be sheets of lava or not, a very large portion of the Charnwood Forest series, like the Borrowdale group in the Lake country, is of volcanic origin, and the district was probably the site of a number of cones, perhaps individually of no great size. The changes, it must be remembered, are never more than 'micro-mineralogical.' The felspar has been somewhat decomposed, and replaced by various minute products of secondary origin; augitic or hornblendic minerals have been replaced by 'viridites'; in the porphyroids a minute filmy mineral, possibly allied to sericite, has been produced, and lavas once glassy have assumed a devitrified structure; but usually the original clastic character of the rock, the structure of the volcanic lapilli, with abundant crystallites of felspar and some other minerals and with small crystals of felspar and quartz, are as clear as in many volcanic deposits of Ordovician[1] age. The very local 'contact metamorphism' at Brazil Wood is the only instance of important mineral change *in situ* in the whole region, the difficulties at Sharpley, Peldar Tor, and Bardon Hill only arising from the minute and indefinite character of the rock structures. So far as the evidence obtainable goes, the rock must be much older than the Carboniferous limestone, and is probably anterior to the Silurian. The reason for assigning it to the latest Archæan rather than to the Cambrian (as it is named by the Geological Survey) will be mentioned hereafter.

The Intrusive Igneous Rocks.—(*a*) A mass of hornblendic granite at Mountsorrel, which is surrounded by Trias. This, as discovered by Mr. Allport, is intrusive in a slate, probably belonging to the uppermost

[1] I adopt this term, proposed by Prof. Lapworth to include the beds from the base of the Arenig to the base of the Upper Llandovery, to avoid the ambiguity of the boundary of the Lower Silurian.

series, which near the contact is converted into a highly micaceous rock, the so-called gneiss of Brazil Wood.[1]

(β) Some large masses of a coarse syenite on the south and south-western part of the Forest, also found to be intrusive in the upper portion of the Charnwood series. The rock, from both microscopic and chemical analysis, appears to be intermediate between a syenite and diorite.

(γ) Some smaller masses of a rock less coarsely crystalline, rather more basic, and distinctly dioritic, occurring in the more northern parts of the Forest. Notwithstanding some chemical difference, there seems good reasons for considering these two groups of intrusive rocks to be closely connected.

(δ) A varied series of dykes and small intrusive masses, diorites, diabases, and, at Mountsorrel, a compact felsite cutting the hornblendic granite. As a rule they occur only in the above igneous masses.

The rocks of the Forest area are probably prolonged underground beneath the Trias and Coal-measures for a considerable distance, since they have been struck once or twice in borings, and a number of bosses of crystalline rock crop out from the Trias in the neighbourhood of Narborough, to the south of the Forest. The most northern of these occurs at Enderby, about five miles south of Groby, and the most distant is about five miles from that in a south-westerly direction. All the bosses are igneous, but at Enderby quarrying has shown one of them to be intrusive in a slaty rock, having a general resemblance to the upper part of the Forest series. The dominant rock is a quartz-syenite or quartz-diorite (for it is really intermediate), but at Narborough we have a boss which might almost be called a quartz-felsite.

(B) Wales.

(8.) *Pembrokeshire.*—The region of Pembrokeshire about St. David's has become classic ground in the history of Archæan rocks. The presence of these was asserted by Dr. Hicks in 1871,[2] and their petrology has been worked out in a series of papers in which his views were gradually developed.[3] These may be thus summarised: that the base of the Cambrian series in this part of Pembrokeshire (where it has now proved to be fossiliferous) is marked by a conglomerate, in which pebbles of quartz, quartzite, and felstone are present in large but variable quantities. Beneath this, and unconformably overlain by it, comes a series of argillites, volcanic breccias, and schistose rocks, under which is another series of quartz-felsites and 'hälleflintas'—*i.e.*, silicious rocks of dubious origin—perhaps in some cases sedimentary, in others compact felstones. At the base of this comes a granitoid rock, which Dr. Hicks considered to be associated with thin bands of chloritic schist and of an impure dolomite, and to be non-igneous in origin. To this last group he gave the name 'Dimetian,' to the middle one of 'Arvonian,' to the upper one of 'Pebidian.' The correctness of these views was impugned, in the year 1883, by the present Director-General of the Geological Survey, Dr. A. Geikie,[4] whose views may be thus briefly summarised:—

[1] *Geol. Mag.*, Dec. ii., vol. vi. p. 481.
[2] Harkness and Hicks, *Q. J. G. S.*, vol. xxvii. p. 384.
[3] *Q. J. G. S.*, vol. xxxi. p. 167; xxxiii. p. 229; xxxiv. p. 153; xxxv. p. 285. For other references, see Geikie, vol. xxxix. p. 261.
[4] *Q. J. G. S.*, vol. xxxix. p. 261.

There is no break at the base of the conglomerate, and further there is evidence of volcanic action in the admitted Cambrian, so that there is no reason for separating the Pebidian from it. The so-called Dimetian is not an ancient granitoid gneiss, but a true granite, and is intrusive in the Cambrian series; the Arvonian consisting partly of apophyses from this granite mass, partly of a volcanic series, inseparable from the so-called Pebidian, and thus from the Cambrian.

To this attack Dr. Hicks has replied, admitting (as indeed had been done previously) that some of the indications upon which he had relied to prove the metamorphic character of the Dimetian—viz., the chloritic schists and dolomitic beds—were fallacious, the former having been found on microscopic examination to be diabase dykes, rendered schistose by subsequent compression; the latter, to be probably bands of infiltration along lines of fracture or crushing—but asserting unhesitatingly (and here his view is supported by independent microscopic study on the part of Mr. T. Davies) that the Dimetian rock, whatever be its true nature, has contributed recognisable fragments to the basement conglomerate of the Cambrian, as have many of the supposed apophyseal felsites; that the latter frequently cut the granitoid (Dimetian) rock; that the supposed cases of intrusion of the last-named into the superjacent beds are non-existent; that there is no evidence (but the contrary) of a great fold asserted by the Director-General to exist in the volcanic series; that there is a marked break below the conglomerate at the base of the Cambrian, and that the asserted proofs of volcanic action in the latter are of a very slight and uncertain character.

Between the publication of the two papers one had been written by Professor Blake,[1] who confirmed in strong terms the existence of a marked line of separation between the Pebidian and the Cambrian, and the non-intrusive character of the Dimetian, but regarded it as a true granite—the core of the volcano which had ejected the rhyolitic lavas and tuffs (Arvonian of Hicks) which formed the lower part of the volcanic series. He thus maintained the existence of a pre-Cambrian series, but regarded it as one approximately continuous group.

Perhaps, as I have examined a portion of the district rather carefully, and have studied a very considerable collection of microscopic slides, including all those submitted to Mr. T. Davies, I may venture to express my own opinion, which is this—that I fully agree with him in recognising 'Dimetian fragments,' as well as those of Archæan schists (not now visible *in situ*), in the Cambrian conglomerate: that while in the present state of our knowledge I will not venture to say whether the Dimetian be a granite or not, I feel certain that there is no valid evidence of its being connected with any of the felstones, and none whatever (but much to the contrary) of its being intrusive in the stratified series; and that the Cambrian and Pebidian appear to be at least as widely separated as the Ordovician and the Silurian, the break at the base of the Cambrian, physically and lithologically, being far more marked than any one that occurs between it and the top of the Ordovician. Of the advisability of separating the Arvonian from the Pebidian I have always been more than dubious; but, with this exception, I think that Dr. Hicks's main position as regards the geology of St. David's remains unshaken. He also notices in his last paper[2] one or

[1] *Q. J. G. S.*, vol. xl. p. 294.
[2] *Q. J. G. S.*, vol. xl. p. 507.

two other areas in Pembrokeshire where he believes that there are outcropping ridges of Archæan rock.

(9.) *Carnarvonshire and Anglesey.*—This district, since the publication of the first edition of the 'Geology of North Wales' by Professor Ramsay (vol. iii. of the Memoirs of the Geological Survey), has been the subject of several papers by Dr. Hicks, Dr. Callaway, Professor Hughes, myself, and others.[1] Several of these were published before the issue of the new edition of the above work (dated 1881), but are not mentioned therein. The facts upon which all geologists agree are that the Cambrian series of Carnarvonshire is a group of quartzose grits and slates, beneath which occur large masses of a compact reddish felsite, and that near the town of Carnarvon is a ridge of granitoid rock, which extends to the north-east for three miles, being flanked by conglomerates and grits, chiefly of quartz, after which the ridge is continued by a felsite just like the last; this extends nearly to Bangor, and is overlain by grits, breccias, and slates, generally differing much in aspect from the indubitable Cambrian of the Llanberis region. The view expressed in the Survey maps and memoir is that the felsite, grits, &c., are metamorphosed beds of Cambrian age, and that near the northern end of Llyn Padarn, the lower part of the Cambrian (here conglomeratic) may be seen to be gradually melted down into the felsite, the granitoid rock being probably a part of an intrusive mass connected with the above metamorphic action.

The following facts are so patent to every person accustomed to microscopic as well as field work that they may be now regarded as indisputable:—

(*a*) That the felstone mentioned above, except for the presence of a devitrified structure and sundry marks of age, is no way chemically or microscopically different from a modern rhyolite, and is a lava-flow or group of flows. It exhibits fluidal structure,[2] is somewhat porphyritic, and in one place (where perhaps it breaks through the granitoid rock) is spherulitic.

(*b*) That the granitoid rock appears in some places to be distinctly gneissose; at Twt Hill, near Carnarvon, however, it very closely resembles the granitoid rock of the Wrekin area, and is not unlike the Dimetian of St. David's.

(*c*) That the conglomerate at Llyn Padarn shows no signs of melting down into the rhyolite, but is full of fragments (many of them being well-rounded pebbles of considerable size) exactly resembling it. Pebbles also of the Twt Hill rock are occasionally found, and in other localities fragments of hard argillite (usually more angular) abound.

(*d*) That at the base of the admitted Cambrian in the region south of the Menai Straits is a conglomerate of well rolled pebbles, chiefly derived from the above rhyolite; a spherulitic variety has also been found (by Dr. Hicks[3]).

(*e*) That between this conglomerate and the rhyolite is a series of beds—argillites, grits, and breccias—into which indubitable volcanic scoria and fragments of rhyolitic lavas largely enter, probably indicating contemporaneous volcanic action, or, if not, the destruction of proximate cones connected with the above-named rhyolite flows. As to the exact

[1] These are published in *Q. J. G. S.*, commencing with vol. xxxiv., and shorter papers appear in the *Geol. Mag.* for 1878 and following volumes.

[2] Bonney, *Q. J. G. S.*, vol. xxxv. p. 309.

[3] *Q. J. G. S.*, vol. xl. p. 187; Bonney, *id.* 200.

vertical extent of this formation there is still a difference of opinion. I regard it as consisting of the series of green argillites and breccias, well exhibited in Bangor mountain, and of a lower series of argillites, grits, and peculiar breccias. The latter, however, are regarded by Professor Hughes as repetitions of the Bangor series and of the Cambrian conglomerate by faults; but to myself the zones appear to be too well marked and traceable over too large areas for this to be possible. On the existence of a volcanic series between the rhyolite and the Cambrian conglomerate, all of the 'newer school' are agreed.

Schists, of a type resembling some of those described below, are said to occur in the Lleyn peninsula on the west side, but further information is needed. From my personal knowledge, I can only say that the rock mapped at Porthdinlleyn as serpentine has no claim to the name.[1]

As regards the island of Anglesey, it is admitted on all hands that a portion of the shore at the southern end of the Menai Straits, like the opposite mainland, is fringed by Carboniferous limestone, and that there is a tract of similar rock at the north-east angle, not far from Beaumaris. Carboniferous limestone, with overlying Coal-measures, and possibly Permian in one part, extends across the island from slightly north of the above-named tract to the western shore near Maeldreth Marsh. To the north of this is a thin strip of 'Lower Silurian,' and yet further north a considerable tract which extends diagonally across the island, and sends off a prolongation at right angles to the northern shore.[2] Fringing the part just named on the south, and extending to the western shore, is a strip of 'granite,' and the rest of the island is coloured on the Geological Survey map as metamorphosed Cambrian, &c. As to the unaltered Palæozoic rocks there is substantial agreement, except that the age of the lower portion is uncertain, Professor Hughes believing that he has identified Tremadoc beds in Anglesey, which is doubted by Dr. Callaway. The Survey view may be stated in the words of the Memoir:[3] 'The Cambrian strata of Anglesey being wholly metamorphic, and the Silurian rocks being metamorphosed in part, there is reason to believe that their metamorphism was contemporaneous and of Lower Silurian date, being connected with the presence of granite, probably of the same age with the imperfectly granitic rock and quartz porphyry on the opposite side of the Straits' (as has been shown above, both these rocks underlie the Cambrian). There is no doubt much in the very complicated and difficult geology of Anglesey which must still be regarded as unsettled, but I think that there is a general concurrence of all who have studied the subject, both in the field and with the microscope, as to the following points:—

(*a*) That this region of 'metamorphic Cambrian and Lower Silurian' is separable into two, one strictly speaking metamorphic—schists, micaceous and chloritic, fine-grained gneisses, quartzites, &c.; the other hypometamorphic, as it has been termed by Dr. Callaway, consisting of slaty or schistose rocks, sometimes apparently of volcanic origin. Further, the so-called granite consists in part of coarse gneisses and micaceous or hornblendic schists, and it is doubtful (as at Twt Hill and the Ercal) whether even the most granitoid beds are a true granite. Including this coarsely crystalline group with the schists, the metamorphic rocks of

[1] *Q. J. G. S.*, vol. xxxvii. p. 40.
[2] There is also a little Lower Silurian near Beaumaris.
[3] *Mem. Geol. Survey*, vol. iii. p. 177.

Anglesey occupy three areas—one, a strip roughly parallel with the Menai Straits, extending from the western to the eastern shore, consisting mainly of micaceous or chloritic schists, with some rather decidedly crystalline hornblendic schists; another (in which the granitoid rocks are included), extending from the western shore at Porth Nobla, near Ty Croes and Llanfaelog, about two-thirds way across the island, with sundry outcropping patches to the north-east which show that an Archæan floor underlies the Palæozoic rock right up to the eastern shore; and, lastly, a rudely triangular patch, consisting of the island of Holyhead, and a still larger tract on the adjacent mainland.

(*b*) That at the base of the indubitably Palæozoic series, there is in many places a conglomerate which contains fragments of the granitoid rock, the schists, and the schistose or slaty beds of the 'metamorphic Cambrian and Lower Silurian region' of the Survey. Hence, that whether this conglomerate is Cambrian, as is the opinion of Professor Hughes and Dr. Hicks, or very low down in the Ordovician, as seems to be the view of Dr. Callaway,[1] there is a very important break between it and the 'metamorphic series,' in which also the upper member contains pebbles of the lower.

(*c*) The greater antiquity of the granitoid series and its non-intrusive character is placed beyond doubt by the following section:[2] Near Llanfaelog the granitoid series and the so-called Lower Silurian can be seen in close proximity[3] and traced for a considerable distance. Not only are grits in the latter formed of débris closely resembling the constituents of the former, but also there are occasionally bands of well-rounded pebbles, sometimes more than four inches in diameter, which are absolutely indistinguishable macroscopically and microscopically from the varieties of the granitoid rocks of the Llanfaelog ridge.

When we come to the classification of the truly metamorphic series, there is at present considerable discordance of opinion, and it will doubtless take much careful work, both in the field and with the microscope, before the subject can be regarded as settled. Dr. Hicks gives the following succession in ascending order:—(1) Granitoid series. (2) Compact quartzose rocks. (3) Quartz-schist, and chloritic or micaceous schist (the most abundant rock in the metamorphic series of Anglesey). The lowest series he correlated with the Dimetian, the 'hälleflinta' with the Arvonian, and the 'chloritic series' with the Pebidian. In my opinion, over much importance has been assigned to the 'hälleflinta' zone, which is made up partly of some compact quartzomicaceous or quartzochloritic rocks not very distinctly foliated (for which it is difficult to find a satisfactory name), partly of some felstones, almost certainly intrusive, and so giving no help in classification. Further, the great 'chloritic' series cannot be correlated with the Pebidian (*i.e.*, the series underlying the Cambrian conglomerate at St. David's and near Bangor), without setting aside all the conclusions to which we are led by the use of the microscope in studying the British rocks. Dr. Callaway gives the following succession in ascending order:—(1) Hälleflinta. (2) Quartz-schist. (3) Grey gneiss. (4) Dark schist. (5) Granitoidite. The dark schist (4) includes the dull lead-coloured or greenish, chloritic

[1] *Q. J. G. S.*, vol. xl. p. 567.
[2] Hicks, *Q. J. G. S.*, vol. xl. p. 187.
[3] About 30 yards at the nearest point—Hicks, *supra*, p. 192.

or micaceous, schist, which constitutes so large a portion of Anglesey; the quartz-schist (2) including the well-known 'quartzite' of Holyhead mountain and some other quartzose rocks. It is quite true that, near Craig-yr-Allor,[1] the granitoid series appears to pass down into some dark micaceous or hornblendic schists; but I doubt the identity of these with some rather similar bands low down in the 'dark schist' series, and I may say, with regard to the position assigned to the granitoid group, that if it overlay (except by intrusion) rocks with the microscopic structure of the Holyhead quartzite and the Menai and Holyhead schists, it would be a succession so abnormal as to show that neither microscopic structure nor metamorphic character could be of the slightest value as a factor in rock classification.

Briefly to state my own view, it is that at present it is safer to regard the metamorphic rocks of Anglesey as belonging to two great groups—(*a*) the lower, a series of granitoid gneiss and highly crystalline schists, in which there may be rocks indistinguishable from granite, but of which all are among the oldest Archæans; and (*b*) a more modern series, consisting mainly of well-bedded schists and some quartzites, the former being generally chloritic or micaceous, and all, as a rule, composed of rather minute mineral constituents. These I should conjecture to be decidedly more modern than the granitoid rocks, down against which, near Llanfaelog and Ty Croes, they appear to be faulted, but still to be decidedly more ancient than the volcanic series of the mainland, with its great subjacent rhyolitic lavas, which is probably more nearly of an age with the hypometamorphic series of Dr. Callaway, and both of which may be provisionally named Pebidian.

It may be well before passing across the Scottish border to recapitulate briefly the reasons for which the less altered members of the above regions are assigned to the great Archæan series. I take it as proved that there is a good base to the Cambrian in South Wales in the conglomerate which underlies the flaggy beds, containing Lower Cambrian fossils, and in North Wales in the great conglomerates of Carnarvonshire, even if we differ as to some points of detail concerning these, and regard it as still an open question whether the Anglesey conglomerate is to be considered Cambrian or very low down in the Ordovician. Accepting, then, the above conglomerate as a base, there is in Britain no evidence of volcanic activity on a scale of any importance during the Cambrian period. It was apparently one of subsidence and quiet sedimentation, during which, by the detrition of older rocks, large deposits of sediments, generally rather fine in texture, were accumulated. But it was preceded in North and South Wales, as periods of subsidence often are preceded, by one of volcanic activity, and it was followed in the same districts by new outbreaks of the volcanic forces, though perhaps from slightly different foci. Again, the lavas of these two epochs—though agreeing in belonging to the acid division, *i.e.*, in having a high silica percentage—differ considerably in their minor characteristics, so that in a great number of cases no hesitation would be felt by a practised collector as to which group a specimen should be referred. Now there is macroscopically no inconsiderable resemblance between the 'old rhyolites' of the Bangor-Carnarvon area and those of the Wrekin; and chemically the relationship is very close. Again, the former have a close resemblance to the average 'felsites' of the St. David's district, putting aside certain exceptional varieties.

[1] Callaway, *Geol. Mag.*, Dec. ii., vol. vii. p. 117.

Now the Wrekin volcanic rocks must be distinctly older than the Ordovician; hence we refer them to the same set of outbursts as the late Archæan volcanoes of Wales. But there are considerable resemblances between these and the oldest rocks at the Lickey, Hartshill, and the more rhyolitic lavas of Charnwood (not to mention resemblances of the ordinary detrital beds), and all these differ markedly from the lavas of the Arenig or Bala beds of Wales. Hence it seems reasonable to suppose that in the latest part of the Archæan period there were numerous volcanic outbursts of very similar materials in Britain, and that of these the beds already mentioned are records.

(C) Scotland.

(10.) *The Highlands.*—This mountainous region has for full thirty years been a battle-ground for rival theories, and the war which was so keenly waged between Murchison and Nicol has now, after a truce of exhaustion rather than of agreement, again broken out. In the limited space of this paper it would be impossible to enter into the details of the controversy, so that it must suffice to give the main outlines of the chief conflicting views. First, as to the points on which the main body of competent observers are agreed. Along the western border of the N.W. Highlands and in the Outer Hebrides, is a great area of metamorphic rock, which clearly forms the foundation-stones of the district. This, the Fundamental gneiss, Lewisian gneiss, Hebridean gneiss, &c., of different authors, is clearly a series of great antiquity; its characteristics recall those of the Lower Laurentian series of America, and the most ancient rocks of Scandinavia, the Alps, Bohemia, we may say of any locality in the world where we seem to touch the records of the dawn of geological history. Its rocks may be described in the words of Dr. A. Geikie, the present head of the Geological Survey of Great Britain: 'They consist of a tough massive gneiss, usually hornblendic,[1] with bands of hornblende-rock, hornblende-schist, actinolite-schist, eclogite, mica-schist, sericite-schist, and other crystalline rocks. In two or three places they enclose bands of limestone.[2] . . . . In traversing the western seaboard, from Cape Wrath to Loch Torridon, I have ascertained that these ancient rocks are disposed in several broad anticlinal and synclinal folds, the angles of dip not exceeding 30° to 40°, and the strata succeeding each other with unexpected regularity, though here and there showing great local crumpling. The lower portions of the series are on the whole more massive than the upper, and more traversed by pegmatite veins.'[3] Above this metamorphic series comes a mass of indurated reddish grit, sometimes a conglomerate or breccia, commonly called the Torridon sandstone. This is of very variable thickness; in the Loch Maree district it is supposed to be 'at least 8,000 feet thick,'[4] while near Loch Eriboll it is practically absent. It overlies, with great unconformity, the Hebridean gneiss, and is in turn overlain, it is generally said unconformably, by a group of quartzites, which are succeeded conformably by calcareous beds. It is proved, on the evidence of fossils, that these limestones and the underlying quartzites are of Ordovician age; hence the 'Torridon sandstone' is considered to be Cambrian. In apparent succession to the Ordovician lime-

[1] Black mica also is by no means wanting.—T. G. B.

[2] Highly crystalline, so far as I know.—T. G. B.

[3] *Text-book of Geology*, p. 640, ed. 1882.

[4] Geikie, *ibid.* p. 656.

stones comes a series of 'gneiss, mica-schist, chlorite-schist, clay slate,' &c., called by Murchison the Newer Gneiss series, characterised generally by a marked bedding and general 'flaggy' aspect, which readily distinguishes it in the field from the normal Hebridean series. These rocks constitute the greater part of the grand hilly mass designated by the name of the Scotch Highlands, central and northern.

It was contended by the late Sir R. Murchison—and the view is upheld by his fellow-labourer and successor, Dr. A. Geikie, and has been ever since consistently maintained by the Geological Survey—that these 'newer' or 'eastern' gneisses distinctly overlie the group of quartzites and limestones, and thus are the metamorphosed equivalents of the Ordovician rocks of the southern uplands of Scotland, representing in the main the Bala beds of Wales; though the possibility of the reappearance of sundry bosses of the Hebridean gneiss was distinctly admitted. This opinion, contested by Professor Nicol, has of late years been opposed by Dr. Hicks, Dr. Callaway, and others, who maintain that almost all the rocks included in the Newer or Eastern Gneiss series are really more ancient than the 'Torridon sandstone,' and are Archæan, though in the main they belong to a newer part of that series than the typical Hebridean group.

It will be long before all the difficulties of the complicated stratigraphy of the Highlands are solved, but the two following general statements will not be denied by any student of the more ancient rocks:—

(1) That the results of work in similar regions during the last few years has been to diminish the probability of great masses of metamorphic rock being of post-Archæan age.

(2) That great caution is needed in applying the principles of lowland stratigraphy to the Highlands, which is evidently an ancient mountain region—viz., that the observer must be prepared, not only for faulting and folding on a grand scale, but also for gigantic inversions and overthrusts.

Within the limits of this summary it will not be possible to discuss the many questions that have been raised in relation to Highland stratigraphy, but I shall endeavour to state briefly the principal views which have been maintained, the lithology of each group, and the facts which have to be taken into account in coming to a conclusion.

It is of course universally admitted that there is a vast break between the Torridon sandstone and the Hebridean series, and that the quartzite (whether conformable or not to the latter, and whether there be two or, as is now generally held, only one group of quartzites) is in close sequence with and is followed by the limestone.

The views, then, are the following:—

(1) That the eastern gneiss[1] follows in conformable succession with the limestone that overlies the quartzites; that, as these are Ordovician, it too cannot be earlier than that period (Murchison, Geikie, and the British Geological Survey).

(2) That the eastern gneiss is nothing but a portion of the Hebridean brought up again by faulting, and so is older than the Torridon sandstone (Nicol, followed, with modifications, by Hicks and Callaway).

(3) That the eastern gneiss is newer than the limestone overlying the quartzite, but that this is not identical with the fossiliferous lime-

[1] I think this term preferable, as not involving any theory.

stone of Durness. Hence, that although it and some associated beds are Ordovician, yet this is no proof of the age of the Torridon sandstone, quartzite, and eastern gneiss, which may be Archæan (Heddle).

The last view at one time seemed to offer a promising way out of the difficulties, but the recent examinations of the more critical sections by more than one skilled stratigraphist seem to show that the quartzite must be admitted to be of Ordovician age, and fully confirm the views of Murchison and his helpers, Mr. Peach and Dr. A. Geikie; so that if the eastern gneiss do overlie it in true succession, its Palæozoic age is settled.

Thus the great question at issue is, What is the relation of the eastern gneiss to the admittedly Palæozoic group? Is the conformable upward succession a real one, or only an apparent one, due to faulting with overthrust on a grand scale? The question is one of unusual difficulty, where to have erred is only human.

Perhaps the simplest way of explaining the difficulties will be by describing one of the sections generally regarded as among the most important, that on a line passing roughly along or parallel with Loch Maree as far as the valley, which is followed by the railway from Dingwall to Loch Carron:—

In many places by the shore of Loch Maree the great masses of the Torridon sandstone are seen to rest upon the Hebridean series. This consists in the lower part (well exposed along the eastern shore of the more southern part of the lake) of coarse granitoid gneisses of a pinkish colour, often traversed by veins of pegmatite. The characteristic structures of a granite are not revealed by the microscope. Among the felspars, orthoclase, albite, or oligoclase and microcline, can be identified. A greenish mineral, present in variable quantities, is sometimes an altered biotite, sometimes hornblende. Sphene, garnet, and white mica are occasionally present. Foliation, as a rule, is rather faintly marked. Massiveness, constancy of mineral constitution through considerable thicknesses, and slowness of change, are the dominant characteristics. As the series is traced upwards indications of bedding, evidenced by change in mineral character, become more marked; the gneiss is more distinctly foliated, and contains well marked beds of hornblende-schist, mica-schist, and (though rarely) of crystalline limestone; the general strike is, roughly from NW. to SE. Of the succession Dr. A. Geikie (as above quoted) says, 'In traversing the western seaboard, from Cape Wrath to Loch Torridon, I have ascertained that these ancient rocks are disposed in several broad anticlinal and synclinal folds. . . . The upper division cannot be sharply defined, but is on the whole marked by the relative thinness of its beds, with a much larger development of schists, and a great diminution of the quantity of pegmatite—characters particularly well seen at Gairloch.'

In Glen Laggan, or Logan, near the head of Loch Maree, the Ordovician limestone, here dolomitic, dips down towards the bed of the glen, at an angle of some 30°, and is then cut off by a mass of granitoid rock of variable breadth; on the opposite side of this rises the escarpment of the eastern gneiss, forming the steep craggy left bank of the valley. Its dip and strike, though not identical with that of the limestone, is not very divergent, and its lithological characters are so different from those of the Hebridean series as to be insisted upon by Murchison as one of its best distinctions. This difference happens to be especially conspicuous at this place, where the stratified character is so marked that one observer has denied that the strata are more metamorphosed than many of the 'Lower Silurian flags in Wales.' I will describe the lithological characters of the eastern gneiss along the above-named line of section, as it is followed southwards. Specimens have been examined from more than one point along this northern edge. Undoubtedly some of the rocks have, macroscopically, a very flaggy, stratified, and but slightly altered aspect; all, however, under the microscope show that there has been considerable change. 'They consist chiefly of quartz and a micaceous mineral, with a fair amount of felspar, some epidote, &c. Minute grains of quartz, as it were agglutinated together, compose the greater part of the slide, with the micaceous mineral, both disseminated and in wavy bands, parallel with the stratification. In this ground-mass are scattered longer subangular grains, lying generally lengthwise, with the mica scales bending round them, so that they form, as it were, "eyes" to the slide. Often most of these are felspar, many are plagioclase, one or two probably microcline. The micaceous constituent is rather fibrous, fairly dichroic, showing moderately bright colours with the two nicols, and is probably a hydrous magnesia mica, but there may be more than one mineral present; there are many small grains of epidote, a fair number of iron peroxide, probably hæmatite.'[1] Calcite, chlorite (?), and perhaps a few minute garnets occur in some cases. Thus the series is metamorphic, but evidently (if we may trust the microscopic indications) much more modern than the typical Hebridean rocks, and possibly even formed of their débris. In this region (and in others whence I have had specimens) this eastern gneiss reminds me, in many respects, of the great uppermost zone of schists, so largely developed in the Alps (the *schistes lustrées* of Lory, part of the *Bundner schiefer* of Von Hauer), of which (to avoid ambiguity) we may take the schists in the Binnenthal, below the village of Binn (Canton Valais), as an excellent type. These are so perfectly bedded that at a moderate distance it would be impossible to assert positively that they were metamorphic rocks, while, on close examination, especially with the microscope, they are indubitably much altered. The eastern gneiss, south of Loch Maree, in the above-named line of section, is cut roughly across the strike by the valley of Glen Docherty. The rocks exposed in its crags maintain the same macroscopic characters, except that, as we proceed up it, the metamorphism becomes rather more marked, macroscopically and microscopically; quartz-schists, fine-grained gneiss, and a lead-coloured mica-schist with small garnets, being noted among others. In the lower part of Ben Fyn, on the north side of the valley traversed by the Dingwall and Skye railway, we have flaggy quartz-mica-schists, or gneisses poor in felspar, with red garnets; in the upper part, mica-schists and fine-grained micaceous gneisses, still inclined to be flaggy, but indubitably highly altered.

Now it cannot be denied that in this section there is some evidence, even taking the microscopic character, in favour of the Murchisonian view, that this series overlies the quartzite-limestone group, and that there is a progressively increasing metamorphism as we proceed southwards. The elaborate paper, already mentioned, by Murchison and Geikie, brings forward other instances where there is apparently a true succession from the quartzite-limestone series into the eastern gneiss.

[1] Bonney, *Q. J. G. S.*, vol. xxxvi. p. 102.

It must, however, be noted that elsewhere, as in this district, we find intervening between these two series, either an interval of granitoid rock, as in Glen Logan, or a fault cutting out a part of the supposed lower series, as at the mouth of Glen Torridon.

This granitoid rock (variously called syenite, diorite, granulite, &c.) was by both the principal disputants, Murchison (with Geikie) and Nichol, as at first by Hicks, considered to be an intrusive igneous rock, to which the obscuration of the succession was mainly due. After a visit in 1879 to the Loch Maree neighbourhood I pointed out that there were none of the usual indications of the intrusion of a granitic rock, but every indication of a faulted junction, and that lithologically the Logan rock (as it has been called for purposes of reference) is inseparable from the older part of the Hebridean series, and often exhibits indications of intense crushing.[1] This view is supported by specimens from Assynt collected by Dr. Callaway, and from Eriboll, by Professor Lapworth and others; it is maintained by them, and is now accepted by Dr. Hicks.[2] We have then to deal with the fact that between the eastern gneiss and the quartzite-limestone group there is often an irregular wedge of the old Hebridean floor, bounded on the one side by a fault whose throw is equal to the whole series from the base of the Torridon sandstone upwards (all the Cambrian and Ordovician), and on the other (according to the Murchisonian hypothesis) by one somewhat greater. It has been shown by Dr. Callaway and Professor Lapworth that a prolonged study of the assumed sequence of the limestone or quartzite and the eastern gneiss in the Durness and the Eriboll regions brings to light most serious stratigraphical difficulties, and that the apparent conformities (where they exist) are better explained by an overfold or overthrust in faulting.[3]

Further, all would admit that the great mass of the central Highlands, wherever it has been studied (excluding some in-folded masses of grit, quartzite, schistose and slaty beds, very probably Palæozoic), consists of schists and gneisses corresponding very closely with those typified by the rocks in the above-described section from Glen Logan southwards, especially by the more highly altered or more southern members of it. Now, dealing for a moment simply with the lithological aspect of the question, it has been shown by Dr. Hicks[4] (and his view is confirmed by Mr. T. Davies, and accords with my own studies of his specimens) that rocks in the main agreeing with the upper portion of the admitted Hebridean series predominate over a broad strip extending in a NNE. direction from Loch Shiel and the head of Loch Eil; that on the south of this region, about the lower part of Loch Eil and the southern part of the Caledonian Canal, rocks bearing a general resemblance to those of Ben Fyn, near Achnasheen, occur, and on the north of it a district occupied by similar rocks extends inward from the western coast about Arisaig to the north shore of Loch Carron; this, crossing the valley leading down to the sea so as to include Ben Fyn and the hills on the north side, stretches northward to include the head of Glen Logan and the region of Loch Fannich; and, further, that similar rocks occur at Gairloch, flanked on the eastern side by the Upper Hebridean, which

[1] *Q. J. G. S.*, vol. xxxvi. p. 92. Nearly the same view had independently occurred to Mr. Hudleston, *Proc. Geol. Assoc.*, vol. vi. p. 75.

[2] *Q. J. G. S.*, vol. xxxix. p. 143.

[3] *Q. J. G. S.*, vol. xxxix. p. 355; *Geol. Mag.*, Dec. ii., vol. x.

[4] *Geol. Mag.*, Dec. ii., vol. vii.

extends to the shore of Loch Maree, and on the western by similar rocks, but bounded on the northern and southern by the Palæozoic grits and quartzites. I have examined typical specimens from these areas, and it seems to me indubitable that the lithological evidence is in favour of Dr. Hicks's mapping; and Mr. T. Davies, whose opinion is of the greatest weight, is very clear in asserting that the more foliated beds of Gairloch (accepted by Dr. Geikie, in the passage above quoted, as representing the highest part of the Hebridean series) are lithologically identical with the Ben Fyn series. I may add that this Ben Fyn and Gairloch group has a general resemblance to the more friable gneisses and silvery schists which in the Alps are seen to underlie the zone of well-bedded schists (Binnenthal, Val Piora, &c.), and of which we may take the well-known schists of the Val Tremola (south side of the St. Gothard Pass) and of the Val Piora as types. These are likened by Dr. Sterry Hunt to the Montalban series of the American continent. It cannot be denied that the stratigraphical difficulties which are presented by this view of the infraposition of the Eastern Gneiss to the Palæozoic series are very great, but they are not greater than exist in many sections in the Alps which have been so successfully unfolded by Heim, Baltzer, and others.

The more modern reading of this district of the north-western Highlands, and of that forming the same part of the central Highlands, would be that the Archæan series consists (in ascending order) of (*a*) coarse gneisses (called by Dr. Hicks the Loch Maree series); (*b*) more variable bedded gneisses (the Loch Shiel series of the same); (*c*) mica-schists, quartz-schists, friable gneisses (Gairloch and Ben Fyn series of the same); and (*d*) the very flaggy series of schists (the Glen Docherty series of the same). The last, in his view, may possibly be a series of *remanié* beds of Palæozoic age overlying the limestone, but I incline to consider it (though at present I will not venture to speak positively) as representing a yet newer Archæan group—as in the case of the *schistes lustrées* of the Alps. How far it is possible to separate these is at present, as in the Alps, difficult to pronounce, but if there were an unconformity or overlap of the newer upon the older series some of the stratigraphical difficulties would certainly disappear.

In accordance with this view (so far as the above-mentioned district is concerned), the Archæan rocks are regarded as having been thrown into great folds (with a general NW. to SE. strike) by earth-movements prior to the Cambrian times; the crowns of the dome-like masses were worn away by denudation, and on these were deposited the Torridon sandstone and other Palæozoic rocks. At the end of this period of sedimentation came an epoch of mountain-making, the direction of pressure being from NW. to SE. (roughly, at right angles to the former), and newer and older beds were folded together, and inversions or faults with overthrust were produced on a gigantic scale. We may add that in its general characters this Hebridean series presents resemblances to the rocks in the Malvernian region, and to the granitoid rocks of Anglesey and Carnarvonshire, and is very like (so far as I know them from specimens) to the Lower Laurentians of North America (including Greenland). It also resembles the coarse gneisses of the Channel Islands, and of several districts in Europe, including the Ur-gneiss, or protogine of the Alpine chain (in which, however, the felspar is usually whitish instead of pinkish, but the difference, conspicuous to the eye, is of little real moment); in fact, the lithological and petrological characters of these Hebridean gneisses are those of the 'Fundamental gneisses' all the world over—that I know anything about.

The Torridon sandstone is so obviously to a large extent made out of the débris of the Hebridean (though materials of newer date may sometimes be observed) that it is needless to go into much detail: it may be described briefly as an indurated quartz-felspar grit, varying from coarse (even conglomerate or breccia) to moderately fine (grains about 0·1 inch diameter); sometimes in small hand specimens it might readily be mistaken for a rather fine-grained granite. The 'quartzite' varies from a hard grit to an extremely consolidated quartzite that breaks with a subconchoidal fracture, in which the individual grains seem completely 'fused together.' The colour of the latter varies from a pure white to greyish or yellowish or reddish tints—one quartzite being a rich liver colour; under the microscope the more compact kinds are seen to be almost wholly formed of subangular grains of quartz cemented together by secondary quartz, commonly in crystalline continuity with the original grain. The rock was probably once a sand derived from the quartz constituent of the Hebridean gneisses. The burrows of annelids abound in certain of its beds, and an orthoceras has been found. The limestone varies in lithological character; in some places it is fawn-coloured and dolomitic, in others dark—not unlike any carbonaceous Palæozoic limestone; it has yielded three species of orthoceras, with several other fossils. The lithological characters of the Eastern Gneiss have been already described.

I am compelled, both for want of personal knowledge and of published information on which I can rely, to omit the metamorphic rocks of Ireland from this sketch; but I may add that the presence of Archæan rocks, in at least the north-west, is admitted, and that there is the same difficulty as in Scotland of deciding whether a newer metamorphic series is to be regarded as of Ordovician or of much earlier date.

In concluding this brief sketch I may again state that, as I have intimate acquaintance in the field with most of the districts on which it touches, and have probably examined, if I do not possess, a larger number of microscopic slides from their rocks than any other person, it has been impossible for me to avoid expressing my own opinion as to controversial points; but I believe that the lithological descriptions are in no respect coloured by it, and are as accurate as their brevity admits, so that I hope the reader may be now able to understand clearly upon what evidence so many important rock-masses are transferred from the Cambrian and Ordovician groups to the mysterious Archæan Period.[1]

Postscript, Sept. 1.—It may be of some little interest to mention the resemblances between the above-described British rocks and those which I have seen since I landed in Canada. I should hardly venture upon this, seeing that I can only speak at present from a superficial and comparatively limited knowledge, but that I have had exceptional advantages in being accompanied on my excursions either by Sir W. Dawson, Dr. Selwyn, Dr. Girdwood, or Dr. Harrington, and am already familiar with Archæan rocks in more than one other country.

The Lower Laurentian, or Laurentian proper, wherever I have seen it, closely resembles the older gneissic series of Britain, such as the admitted Archæan rocks of the NW. of Scotland, and the more ancient gneisses of the central Highlands—in general terms the Loch

[1] In November 1884, Dr. A. Geikie announced that the Murchisonian hypothesis had been proved to be untenable.

Maree and Loch Shiel series of Dr. Hicks. Concerning the Upper Laurentian or Norian series I am not yet prepared to offer an opinion. I believe, indeed, that much of it is igneous rock, and so may not avail for purposes of comparison at so great a distance. The other members that I have seen do not recall to my memory any of the Scotch rocks. It is needless to say that the gabbros of Skye are igneous in origin, and much more modern than the norites of the Upper Laurentian.

The Gairloch and Ben Fyn series has a very considerable resemblance to a suite of specimens from the White Mountains shown to me by Dr. Sterry Hunt, and forming the series called by him Montalban. These, so far as I have seen, are not generally well represented in Canada, but I think it very probable that it will be found necessary to remove from the Huronian certain schists now provisionally placed at its base, and regard these as representatives either of the Montalban group (which lithologically is represented by the great zone of Alpine schists at the Val Tremola, St. Gothard) or of the immediately overlying zone of schists (*schistes lustrées*, *Bundner schiefer* in part, &c.), concerning whose age in the Alps such diverse opinions have been entertained. To this group the newer schists of the Highlands are probably related, and some at least of the schists of Anglesey and of the south of England—though it is possible the metamorphic rocks of Cornwall may be older.

Some beautiful reddish felstones shown to me by Dr. Sterry Hunt, members of the Petrosilex group, are singularly like the felstones at the base of the Pebidian of Wales (Arvonian of Dr. Hicks). The great mass of the Canadian Huronian, of which I have now seen many specimens, and examined carefully along a section of not a few miles, corresponds rather closely with the great series of slates, grits, agglomerates, and lavas which immediately underlies the Cambrian—viz., the Pebidian (with the Arvonian of Dr. Hicks). The Huronian is not a highly altered series. I feel certain that the microscope will generally disclose its original constituents. I suspect, then, that in many parts of Canada there is an enormous break between the Laurentian and Huronian, though here and there this may be partially bridged over. Further, if we are to put any trust in lithological character as a test of relative age, I hold it impossible to consider the Huronian older than the Montalban, or to correlate it with the Pietra Verde group of the Alps. I have made no reference to the Taconic group of America, because I have not had the opportunity of studying it either in the museum or in the field.

On the concordance of the Mollusca inhabiting both sides of the North Atlantic and the intermediate Seas. By J. Gwyn Jeffreys, *LL.D., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

During a short but delightful and interesting visit to North America which I made in the summer of 1871, on the invitation of the lamented Professor Agassiz, for the purpose of examining the Mollusca procured by the late Count Pourtales in the Gulf of Mexico, I took the opportunity of inspecting also many other collections of North American Mollusca, and especially that of the late Professor Stimpson at Chicago. The kindness of Professor Spencer Baird enabled me to witness the dredgings which were then carried on along the coast of New England under the charge of the eminent and still living zoologist, Professor Verrill, of Yale College.

The result of these examinations was communicated by me to the British Association at their Brighton Meeting in the following year, under the title of 'The Mollusca of Europe compared with those of Eastern North America.' I estimated the former to consist of about 1,000 species (viz., 200 land and freshwater, and 800 marine), and the latter to consist of about 400 species (viz., 110 land and freshwater, and 290 marine): and I took Mr. Binney's edition of Professor Gould's 'Report on the Invertebrata of Massachusetts,' published in 1870, as the standard of comparison for the American Mollusca. That work gave 401 species, of which I considered 41 to be varieties and the young of other species, leaving 360 apparently distinct species. I reckoned that about 40 species might be added in consequence of the later researches of Professor Verrill and Mr. Whiteaves on the coast of New England and in the Gulf of St. Lawrence. I may here observe, by way of parenthesis, that the relative number of species above mentioned has since been considerably increased, both on the European and American continents, although the proportions may not be very different. I proceeded to identify 173 out of the 360 Massachusetts species as European—viz., land and freshwater 39 (out of 110), and marine 134 (out of 250), the proportion in the former case being 28 per cent., and in the latter nearly 54 per cent.; and I produced a tabulated list in support of my statement. I proposed to account for the distribution of the North American Mollusca which I had thus identified by suggesting that the land and freshwater species might have migrated from Europe to Canada through Northern Asia, and that most of the marine species might have been transported from the arctic seas by the Davis Strait current southwards to Cape Cod, and the remainder from the Mediterranean and eastern coasts of the Atlantic by the Equatorial or some other current in a westerly direction. I renewed my objection to the term 'representative species.'

There were some unavoidable errors in my list, because I had not sufficient means of making the necessary comparison of American and European specimens on the spot, and some allowance must be conceded for the well-known difference of opinion among naturalists with regard to species and varieties; but I conscientiously believe that the above comparative analysis was not far from the mark. All the marine species of Mollusca enumerated in the list were what may be now termed inhabitants of shallow water, in contradistinction to the deep-sea Mollusca which now engage the more special attention of conchologists.

Since that time, Professor Whiteaves in Canada, and Professor Verrill and Mr. Dall in the United States, have in an admirable and complete manner worked out and published the Mollusca which have for many years past been brought to light by means of the deep-sea explorations made on that side of the North Atlantic. On the European side several equally important expeditions, with a similar object, have been also made during the same period by the British, Norwegian, French, and Italian Governments; and the Mollusca thus obtained have been published, or are in course of publication. My own papers in the 'Proceedings of the Zoological Society of London' from 1878 to the present year, on the Mollusca of the *Lightning* and *Porcupine* Expeditions, will show the distribution of many species of such deep-water Mollusca on each side of the North Atlantic, and more will follow. To give some idea of the concordance in this distribution, I will here give a comparative list of 35 nearly all deep-sea species which Professor Verrill most obligingly sent me in September 1882, with my remarks.

European	Names of species	Remarks
E.	Pecten vitreus (Gmel.), Wood. No. 1029; 458 fms.	Pecten vitreus, Chemnitz.
E.	Amussium fenestratum (F), Jeffreys. No. 949; 100 fms.	Amussium fenestratum, Forbes. Sculpture of American specimens finer and closer.
E.	Limæa subovata, Jeffreys. No. 997; 335 fms.	Lima subovata, Jeffreys.
E.	Leda unca, Gould. No. 871; 115 fms.	Leda fragilis, Chemn. Larger than European specimens.
E.	Arca pectunculoides; var. septentrionalis, Sars. No. 958; 310 fms.	Arca pectunculoïdes, Scacchi; var. septentrionalis.
E.	Limopsis minuta (Phil.). No. 895; 238 fms.	Limopsis minuta, Philippi.
E.	Cryptodon obesus, V. No. 918; 45 fms.	Axinus flexuosus, Montagu, var. polygona = C. biplicatus (afterwards sinuatus), Philippi.
E.	Cryptodon ferruginosum, Forbes. No. 947; 312 fms.	Axinus ferruginosus, Forbes.
E.	Loripes lens, V. & S. No. 873; 100 fms.	Loripes lacteus, Linné.
E.	Astarte crenata, Gray, (A. lens. St. var.) No. 898; 300 fms.	Astarte crenata, Gray.
E.	Poromya granulata (Nyst) F. & H. No. 949; 100 fms.	Poromya granulata, Nyst & Westendorff.
E.	Lyonsiella abyssicola, Sars. No. 947; 312 fms.	Pecchiolia abyssicola, M. Sars.
E.	Neæra glacialis, G. O. Sars. No. 894; 365 fms.	Neæra obesa, Lovén; var.
E.	Neæra glacialis, G. O. Sars. No. 998; 302 fms.	Neæra obesa, Lov.; var.
E.	Neæra multicostata, V. & S. No. 1038; 146 fms.	Neæra striata, Jeffr.
E.	Neæra rostrata (Spengler), Lovén. No. 949; 100 fms.	Neæra rostrata, Spengler.
E.	Dentalium occidentale, Stimps. (= D. abyssorum, Sars). No. 1025; 216 fms.	D. striolatum, Stimps.; a strongly marked variety.
E.	Dentalium (slender variety). No. 892; 487 fms.	Young of last species.
E.	Cadulus Pandionis, V. & S. No. 876; 120 fms.	Cadulus Olivi, Scacchi.
E.	Lepetella tubicola, V. & S. No. 894; 365 fms.	Also Norwegian and Western coasts of Africa.
E.	Margarita regalis, V. & S. No. 892; 487 fms.	Trochus Ottoi, Philippi.
	Calliostoma Bairdii, V. & S. No. 867; 64 fms.	Allied to Trochus zizyphinus, L., but unknown to me as European.
E.	Cingula Jan-Mayeni (Friele). No. 894; 365 fms.	Rissoa Jan-Mayeni, Fr., Spitzbergen, Jan Mayen I., and Greenland. Sculpture variable.
E.	Scalaria Dalliana, V. & S. No. 949; 100 fms.	Scalaria clathratula, Turton.
E.	Turbonilla Rathbunii, V. & S. No. 995; 358 fms.	Apparently a large form of Odostomia rufa, Ph.

European	Names of species	Remarks
E.	Turbonilla Bushiana, Verrill. No. 892; 487 fms.	Odostomia magnifica, Seguenza.
E.	Eulimella Smithii, Verrill. No. 947; 312 fms.	Odostomia unifasciata, Forbes (as Eulima).
E.	Eulima intermedia, Cantraine. No. 949; 100 fms.	Eulima intermedia, Cantr.
E.	Cerithiella Whiteavesii, Verrill. No. 997; 335 fms.	Allied to Cerithium metula, Lov. Perhaps my C. gracilis.
	Sipho pubescens, Verrill. No. 939; 258 fms.	Allied to Fusus Sabini, Gray, but unknown to me as European.
	Sipho cœlatus, V. & S. No. 997; 335 fms.	A species of Fusus, unknown to me as European.
	Pleurotomella Agassizii, V. & S. No. 894; 365 fms., and 947; 327 fms.	A species of Pleurotoma allied to P. tumida, Jeffr.; but unknown to me as European.
E.	Anachis costulata (Cantr.). No. 894; 365 fms.	Columbella haliæeti, Jeff. Cantraine's species of Fusus is a Pleurotoma.
E.	Astyris diaphana, Verrill. No. 876; 120 fms.	Columbella Holbölli, Möller = C. rosacea, Gould; var.
	Astyris pura, Verrill. No. 892; 487 fms.	Unknown to me as European. A species of Columbella.
E.	Ringicula nitida, Verrill. No. 947; 312 fms.	Ringicula leptochila, Brugnone.
E.	Scaphander punctostriatus (Migh.). Ad. No. 1025; 216 fms.	Scaphander punctostriatus, Migh. & Ad. = S. librarius, Lov.

Of the above-named 35 species, 30 are known to inhabit also the European seas, being a much larger percentage than in the case of those inland and shallow-water species which I enumerated in my list of 1872.

But it is not only in the Mollusca that we find such uniformity between the submarine fauna on both sides of the North Atlantic. An excellent paper by my friend, Mr. Herbert Carpenter, 'On the Crinoidea of the North Atlantic between Gibraltar and the Faroe Islands,' which has been published this year in the 'Proceedings of the Royal Society of Edinburgh,' shows that many species as well as genera of that group of the Echinodermata are common to the European and American seas.

The distribution of deep-sea animals must be accounted for in a different way from that which takes place among land animals and those which inhabit shallow water. Most if not all of the deep-sea animals in their embryonic state swim or move freely, and are wafted by marine currents in different directions, so as to traverse gradually and in course of time vast tracts of the sea bottom; and this process is continually repeated. Depth is no obstacle to this intermigration. There is no doubt that a current or movement of the water, although it may be excessively slow, exists everywhere at or near the bottom. Otherwise the sea might stagnate and perhaps become lifeless, which we know is not the case. In the *Porcupine* expedition of 1870 I dredged off the coast of Portugal, in 994 fathoms, a mass of shells and other organisms, mostly dead, which evidently had been deposited there by the action of some tidal or other marine current. This was at a distance of twenty or thirty miles from the shore. An account of this dredging will be found in the 'Proceedings of the Royal Society' for that year.

Judging from an examination of the Mollusca procured by the *Challenger* expedition, I am not disposed to admit the uniformity of the Mollusca which inhabit the deep-sea areas of the Atlantic and Pacific oceans throughout the globe.

I hope that these notes, although short and imperfect, may be the means of eliciting the opinions of those naturalists who take an interest in the important question of the extent and mode of distribution of marine animals. I regret exceedingly that other engagements will prevent my personally taking part in the discussion.

P.S.—Since writing the above I have received, through the kindness of Professor Verrill, his 'Second Catalogue of Mollusca recently added to the Fauna of the New England Coast, and the adjacent parts of the Atlantic, consisting mostly of deep-sea species, with notes on others previously recorded.' This catalogue was published in the 'Transactions of the Connecticut Academy' for April, May and June, 1884. Twenty-seven European species (most of which were described by me) have now been recognised by Verrill as also inhabiting the American side of the North Atlantic, and probably some more of the species in his Catalogue, as well as many of those in my own papers, may have to be ultimately placed in the same category.

On the Characteristics of the North American Flora. *By* Professor ASA GRAY.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

WHEN the British Association, with much painstaking, honours and gratifies the cultivators of science on this side of the ocean by meeting on American soil, it is but seemly that a corresponding member for the third of a century should endeavour to manifest his interest in the occasion and to render some service, if he can, to his fellow-naturalists in Section D. I would attempt to do so by pointing out, in a general way, some of the characteristic features of the vegetation of the country which they have come to visit,—a country of 'magnificent distances,' but of which some vistas may be had by those who can use the facilities which are offered for enjoying them. Even to those who cannot command the time for distant excursions, and to some who may know little or nothing of botany, the sketch which I offer may not be altogether uninteresting. But I naturally address myself to the botanists of the Association, to those who, having crossed the wide Atlantic, are now invited to proceed westward over an almost equal breadth of land; some, indeed, have already journeyed to the Pacific coast, and have returned; and not a few, it is hoped, may accept the invitation to Philadelphia, where a warm welcome awaits them—warmth of hospitality, rather than of summer temperature, let us hope; but Philadelphia is proverbial for both. There opportunities may be afforded for a passing acquaintance with the botany of the Atlantic border of the United States, in company with the botanists of the American Association, who are expected to muster in full force.

What may be asked of me, then, is to portray certain outlines of the vegetation of the United States and the Canadian Dominion, as contrasted with that of Europe: perhaps also to touch upon the causes or anterior conditions to which much of the actual differences between the two floras may be ascribed. For, indeed, however interesting or curious the facts of the case may be in themselves, they become far more instructive when we attain to some clear conception of the dependent relation of the present vegetation to a preceding state of things, out of which it has come.

As to the Atlantic border on which we stand, probably the first impression made upon the botanist or other observer coming from Great Britain to New England or Canadian shores, will be the similarity of what he here finds with what he left behind. Among the trees the white birch and the chestnut will be identified, if not as exactly the same, yet with only slight differences—differences which may be said to be no more essential or profound than those in accent and intonation between the British speech and that of the 'Americans.' The differences between the beeches and larches of the two countries are a little more accentuated; and still more those of the hornbeams, elms, and the nearest resembling oaks. And so of several other trees. Only as you proceed westward and southward will the differences overpower the similarities, which still are met with.

In the fields and along open roadsides the likeness seems to be greater. But much of this likeness is the unconscious work of man, rather than of Nature, the reason of which is not far to seek. This was a region of forest, upon which the aborigines, although they here and there opened patches of land for cultivation, had made no permanent encroachment. Not very much of the herbaceous or other low undergrowth of this forest could bear exposure to the fervid summer's sun; and the change was too abrupt for adaptive modification. The plains and prairies of the great Mississippi Valley were then too remote for their vegetation to compete for the vacancy which was made here when forest was changed to grain-fields and then to meadow and pasture. And so the vacancy came to be filled in a notable measure by agrestial plants from Europe, the seeds of which came in seed-grain, in the coats and fleece and in the imported fodder of cattle and sheep, and in the various but not always apparent ways in which agricultural and commercial people unwittingly convey the plants and animals of one country to another. So, while an agricultural people displaced the aborigines which the forests sheltered and nourished, the herbs, purposely or accidentally brought with them, took possession of the clearings, and prevailed more or less over the native and rightful heirs to the soil,—not enough to supplant them, indeed, but enough to impart a certain adventitious Old World aspect to the fields and other open grounds, as well as to the precincts of habitations. In spring-time you would have seen the fields of this district yellow with European buttercups and dandelions, then whitened with the ox-eye daisy, and at midsummer brightened by the cerulean blue of chicory. I can hardly name any native herbs which *in the fields and at the season* can vie with these intruders in floral show. The common barberry of the Old World is an early denizen of New England. The tall mullein, of a wholly alien race, shoots up in every pasture and new clearing, accompanied by the common thistle, while another imported thistle, called in the States 'the Canada thistle,' has become a veritable nuisance, at which much legislation has been levelled in vain.

According to tradition the wayside plantain was called by the

American Indian 'White-Man's foot,' from its springing up wherever that foot had been planted. But there is some reason for suspecting that the Indian's ancestors brought it to this continent. Moreover there is another reason for surmising that this long-accepted tradition is factitious. For there was already in the country a native plantain, so like *Plantago major* that the botanists have only of late distinguished it. (I acknowledge my share in the oversight.) Possibly, although the botanists were at fault, the aborigines may have known the difference. The cows are said to know it. For a brother botanist of long experience tells me that, where the two grow together, cows freely feed upon the undoubtedly native species, and leave the naturalized one untouched.

It has been maintained that the ruderal and agrestial Old World plants and weeds of cultivation displace the indigenous ones of newly-settled countries in virtue of a strength which they have developed through survival in the struggle of ages, under the severe competition incident to their former migrations. And it does seem that most of the pertinacious weeds of the Old World which have been given to us may not be indigenous even to Europe, at least to Western Europe, but belong to campestrine or unwooded regions farther east; and that, following the movements of pastoral and agricultural people, they may have played somewhat the same part in the once forest-clad Western Europe that they have been playing here. But it is unnecessary to build much upon the possibly fallacious idea of increased strength gained by competition. Opportunity may count for more than exceptional vigour; and the cases in which foreign plants have shown such superiority are mainly those in which a forest-destroying people have brought upon newly-bared soil the seeds of an open-ground vegetation.

The one marked exception that I know of, the case of recent and abundant influx of this class of Old World plants into a naturally treeless region, supports the same conclusion. Our associate, Mr. John Ball, has recently called attention to it. The pampas of south-eastern South America beyond the Rio Colorado, lying between the same parallels of latitude in the South as Montreal and Philadelphia in the North, and with climate and probably soils fit to sustain a varied vegetation, and even a fair proportion of forest, are not only treeless, but excessively poor in their herbaceous flora. The district has had no trees since its comparatively recent elevation from the sea. As Mr. Darwin long ago intimated: 'Trees are absent not because they cannot grow and thrive, but because the only country from which they could have been derived—tropical and sub-tropical South America—could not supply species to suit the soil and climate.' And as to the herbaceous and fruitescent species, to continue the extract from Mr. Ball's instructive paper recently published in the Linnean Society's Journal, 'in a district raised from the sea during the latest geological period, and bounded on the west by a great mountain range mainly clothed with an alpine flora requiring the protection of snow in winter, and on the north by a warm-temperate region whose flora is mainly of modified sub-tropical origin—the only plants that could occupy the newly-formed region were the comparatively few which, though developed under very different conditions, were sufficiently tolerant of change to adapt themselves to the new environment. The flora is poor, not because the land cannot support a richer one, but because the only regions from which a large population could be derived are inhabited by races unfit for emigration.'

Singularly enough, this deficiency of herbaceous plants is being supplied from Europe, and the incomers are spreading with great rapidity; for lack of other forest material even apple-trees are running wild and forming extensive groves. Men and cattle are, as usual, the agents of dissemination. But colonizing plants are filling, in this instance, a vacancy which was left by nature, while ours was made by man. We may agree with Mr. Ball in the opinion that the rapidity with which the intrusive plants have spread in this part of South America 'is to be accounted for less by any special fitness of the immigrant species, than by the fact that the ground is to a great extent unoccupied.'

The principle applies here also; and, in general, that it is opportunity rather than specially acquired vigour that has given Old-World weeds an advantage may be inferred from the behaviour of our weeds indigenous to the country, the plants of the unwooded districts—prairies or savannas west and south, which, now that the way is open, are coming in one by one into these eastern parts, extending their area continually, and holding their ground quite as pertinaciously as the immigrant denizens. Almost every year gives new examples of the immigration of campestrine western plants into the Eastern States. They are well up to the spirit of the age; they travel by railway. The seeds are transported, some in the coats of cattle and sheep on the way to market, others in the food which supports them on the journey, and many in a way which you might not suspect, until you consider that these great roads run east and west, that the prevalent winds are from the west, that a freight-train left unguarded was not long ago blown on for more than one hundred miles before it could be stopped, not altogether on down grades, and that the bared and mostly unkempt borders of these railways form capital seed-beds and nursery grounds for such plants.

Returning now from this side-issue, let me advert to another and, I judge, a very pleasant experience which the botanist and the cultivator may have on first visiting the American shores. At almost every step he comes upon old acquaintances, upon shrubs and trees and flowering herbs mostly peculiar to this country, but with which he is familiar in the grounds and gardens of his home. Great Britain is especially hospitable to American trees and shrubs. There those both of the eastern and western sides of our continent flourish side by side. Here they almost wholly refuse such association. But the most familiar and longest-established representatives of our flora (certain western annuals excepted) were drawn from the Atlantic coast. Among them are the virginia creeper or ampelopsis, almost as commonly grown in Europe as here, and which, I think, displays its autumnal crimson as brightly there as along the borders of its native woods where you will everywhere meet with it; the red and sugar maples, which give the notable autumnal glow to our northern woods, but rarely make much show in Europe, perhaps for lack of sharp contrasts between summer and autumn; the ornamental ericaceous shrubs, kalmias azaleas, rhododendrons, and the like, specially called American plants in England, although all the rhododendrons of the finer sort are half Asiatic, the hardy American species having been crossed and recrossed with more elegant but tender Indian species.

As to flowering herbs, somewhat of the delight with which an American first gathers wild primroses and cowslips and foxgloves and daisies in Europe, may be enjoyed by the European botanist when he comes upon our trilliums and sanguinaria, cypripediums and dodecatheon, our species of phlox, coreopsis, &c., so familiar in his gardens; or, when, crossing the continent, he comes upon large tracts of ground yellow with eschscholtzia or blue with nemophilas. But with a sentimental difference; in that primroses, daises and heaths, like nightingales and larks, are inwrought into our common literature and poetry, whereas our native flowers and birds, if not altogether unsung, have attained at the most to only local celebrity.

Turning now from similarities, and from that which interchange has made familiar, to that which is different or peculiar, I suppose that an observant botanist upon a survey of the Atlantic border of North America (which naturally first and mainly attracts our attention) would be impressed by the comparative wealth of this flora in trees and shrubs. Not so much so in the Canadian dominion, at least in its eastern part; but even here the difference will be striking enough on comparing Canada with Great Britain.

The coniferæ, native to the British Islands, are one pine, one juniper, and a yew; those of Canada proper are four or five pines, four firs, a larch, an arbor-vitæ, three junipers, and a yew,—fourteen or fifteen to three. Of amentaceous trees and shrubs, Great Britain counts one oak (in two marked forms), a beech, a hazel, a hornbeam, two birches, an alder, a myrica, eighteen willows, and two poplars,—twenty-eight species in nine genera, and under four natural orders. In Canada there are at least eight oaks, a chestnut, a beech, two hazels, two hornbeams of distinct genera, six birches, two alders, about fourteen willows and five poplars, also a plane tree, two walnuts and four hickories; say forty-eight species, in thirteen genera, and belonging to seven natural orders. The comparison may not be altogether fair; for the British flora is exceptionally poor, even for islands so situated. But if we extend it to Scandinavia, so as to have a continental and an equivalent area, the native coniferæ would be augmented only by one fir, the amentaceæ by several more willows, a poplar, and one or two more birches;—no additional orders nor genera.

If we take in the Atlantic United States, east of the Mississippi, and compare this area with Europe, we should find the species and the types increasing as we proceed southward, but about the same numerical proportion would hold.

But, more interesting than this numerical preponderance—which is practically confined to the trees and shrubs—will be the extra-European types, which, intermixed with familiar old-world forms, give peculiar features to the North American flora,—features discernible in Canada, but more and more prominent as we proceed southward. Still confining our survey to the Atlantic district, that is, without crossing the Mississippi, the following are among the notable points :—

1. Leguminous trees of peculiar types. Europe abounds in leguminous shrubs or under-shrubs, mostly of the Genisteous tribe, which is wanting in all North America, but has no leguminous tree of more pretence than the cercis and laburnum. Our Atlantic forest is distinguished by a cercis of its own, three species of locust, two of them fine trees, and two honey locusts, the beautiful cladrastis, and the stately gymnocladus. Only the cercis has any European relationship. For relatives of the others we must look to the Chino-Japanese region.

2. The great development of the Ericaceæ (taking the order in its widest sense), along with the absence of the ericeous tribe, that is, of the heaths themselves. We possess on this side of the Mississippi thirty

genera and not far from ninety species. All Europe has only seventeen genera and barely fifty species. We have most of the actual European species, excepting their rhododendrons and their heaths,—and even the latter are represented by some scattered patches of calluna, of which it may be still doubtful whether they are chance introductions or sparse and scanty survivals; and besides we have a wealth of peculiar genera and species. Among them the most notable in an ornamental point of view are the rhododendrons, azaleas, kalmias, andromedas, and clethras; in botanical interest, the endemic Monotropeæ, of which there is only one species in Europe, but seven genera in North America, all but one absolutely peculiar; and in edible as well as botanical interest, the unexampled development and diversification of the genus vaccinium (along with the allied American type, gaylussacia) will attract attention. It is interesting to note the rapid falling away of ericaceæ westward in the valley of the Mississippi as the forest thins out.

3. The wealth of this flora in compositæ is a most obvious feature; one especially prominent at this season of the year, when the open grounds are becoming golden with solidago, and the earlier of the autumnal asters are beginning to blossom. The compositæ form the largest order of phænogamous plants in all temperate floras of the northern hemisphere, are well up to the average in Europe, but are nowhere so numerous as in North America, where they form an eighth part of the whole. But the contrast between the compositæ of Europe and Atlantic North America is striking. Europe runs to thistles, to inuloideæ, to anthemideæ, and to cichoriaceæ. It has very few asters and only two solidagos, no sunflowers and hardly anything of that tribe. Our Atlantic flora surpasses all the world in asters and solidagos, as also in sunflowers and their various allies, is rich in eupatoriaceæ, of which Europe has extremely few, and is well supplied with vernoniaceæ and helonioideæ of which she has none; but is scanty in all the groups that predominate in Europe. I may remark that if our larger and most troublesome genera, such as solidago and aster, were treated in our systematic works even in the way that Nyman has treated hieracium in Europe, the species of these two genera (now numbering 78 and 124 respectively) would be at least doubled.

4. Perhaps the most interesting contrast between the flora of Europe and that of the eastern border of North America is in the number of generic and even ordinal types here met with which are wholly absent from Europe. Possibly we may distinguish these into two sets of differing history. One will represent a tropical element, more or less transformed, which has probably acquired or been able to hold its position so far north in virtue of high summer temperature. (In this whole survey the peninsula of Florida is left out of view, regarding its botany as essentially Bahaman and Cuban, with a certain admixture of northern elements.) To the first type I refer such trees and shrubs as asimina, sole representative of the anonaceæ out of the tropics, and reaching even to lat. 42°; chrysobalanus, representing a tropical sub-order; pinckneya representing as far north as Georgia the cinchoneous tribe; the baccharis of our coast reaching even to New England; cyrilla and cliftonia, the former actually West Indian; bumelia, representing the tropical order sapotaceæ; bignonia and tecoma of the bignoniaceæ; forestiera in oleaceæ; persea of the laurineæ; and finally the cactaceæ. Among the herbaceous plants of this set, I will allude only to some of peculiar orders. Among them I

reckon sarracenia (of which the only extra-North American representative is tropical-American), the melastomaceæ, represented by rhexia; passiflora (our species being herbaceous), a few representatives of loasaceæ and turneraceæ, also of hydrophyllaceæ; our two genera of burmanniaceæ; three genera of hæmodoraceæ; tillandsia in bromeliaceæ; two genera of pontederiaceæ; two of commelynaceæ; the outlying mayaca and xyris, and three genera of eriocaulonaceæ. I do not forget that one of our species of eriocaulon occurs on the west coast of Ireland and in Skye, wonderfully out of place, though on this side of the Atlantic it reaches Newfoundland. It may be a survival in the Old World; but it is more probably of chance introduction.

The other set of extra-European types, characteristic of the Atlantic North American flora, is very notable. According to a view which I have much and for a long while insisted on, it may be said to represent a certain portion of the once rather uniform flora of the arctic and less boreal zone, from the late tertiary down to the incoming of the glacial period, and which, brought down to our lower latitudes by the gradual refrigeration, has been preserved here in eastern North America and in the corresponding parts of Asia, but was lost to Europe. I need not recapitulate the evidence upon which this now generally accepted doctrine was founded; and to enumerate the plants which testify in its favour would amount to an enumeration of the greater part of the genera or subordinate groups of plants which distinguish our Atlantic flora from that of Europe. The evidence, in brief, is that the plants in question, or their moderately differentiated representatives, still co-exist in the flora of eastern North America and that of the Chino-Japanese region, the climates and conditions of which are very similar; and that the fossilised representatives of many of them have been brought to light in the late tertiary deposits of the arctic zone wherever explored. In mentioning some of the plants of this category I include the magnolias, although there are no nearly identical species, but there is a seemingly identical liriodendron in China, and the schizandras and illiciums are divided between the two floras; and I put into the list menispermum, of which the only other species is eastern Siberian, and is hardly distinguishable from ours. When you call to mind the series of wholly extra-European types which are identically or approximately represented in the eastern North American and in the eastern Asiatic temperate floras, such as trautvetteria and hydrastis in ranunculaceæ; caulophyllum, diphylleia, jeffersonia and podophyllum in berberideæ; brasenia and nelumbium in nymphæaceæ; stylophorum in papaveraceæ; stuartia and gordonia in ternstromiaceæ; the equivalent species of xanthoxylum, the equivalent and identical species of vitis, and of the poisonous species of rhus (one, if not both, of which you may meet with in every botanical excursion, and which it will be safer not to handle); the horse-chestnuts, here called buckeyes; the negundo, a peculiar off-shoot of the maple tribe; when you consider that almost every one of the peculiar leguminous trees mentioned as characteristic of our flora is represented by a species in China or Manchuria or Japan, and so of some herbaceous leguminosæ; when you remember that the peculiar small order of which calycanthus is the principal type has its other representative in the same region; that the species of philadelphus, or hydrangea, of itea, astilbe, hamamelis, diervilla, triosteum, mitchella, which carpets the ground under evergreen woods, chiogenes creeping over the shaded bogs; epigæa, choicest woodland flower of early spring;

elliottia; shortia (the curious history of which I need not rehearse); styrax of cognate species; nyssa, the Asiatic representatives of which affect a warmer region; gelsemium, which under the name of jessamine is the vernal pride of the southern Atlantic States; pyrularia and buckleya, peculiar santalaceous shrubs; sassafras and benzoines of the laurel family; planera and maclura; pachysandra of the box tribe; the great development of the juglandaceæ (of which the sole representative in Europe probably was brought by man into south-eastern Europe in pre-historic times); our hemlock-spruces, arbor-vitæ, chamæcyparis, taxodium and torreya, with their east Asian counterparts, the roxburghiaceæ, represented by croomia—and I might much further extend and particularise the enumeration—you will have enough to make it clear that the peculiarities of the one flora are the peculiarities of the other, and that the two are in striking contrast with the flora of Europe.

This contrast is susceptible of explanation. I have ventured to regard the two antipodal floras thus compared as the favoured heirs of the ante-glacial high northern flora, or rather as the heirs who have retained most of their inheritance. For inasmuch as the present arctic flora is essentially the same round the world, and the tertiary fossil plants entombed in the strata beneath are also largely identical in all the longitudes, we may well infer that the ancestors of the present northern temperate plants were as widely distributed throughout their northern home. In their enforced migration southward geographical configuration and climatic differences would begin to operate. Perhaps the way into Europe was less open than into the lower latitudes of America and eastern Asia, although there is reason to think that Greenland was joined to Scandinavia. However that be, we know that Europe was fairly well furnished with many of the vegetable types that are now absent, possibly with most of them. Those that have been recognised are mainly trees and shrubs, which somehow take most readily to fossilization, but the herbaceous vegetation probably accompanied the arboreal. At any rate, Europe then possessed torreyas and gingkos, taxodium and glyptostrobus, libocedrus, pines of our five-leaved type, as well as the analogues of other American forms, several species of juglans answering to the American forms, and the now peculiarly American genus carya, oaks of the American types, myricas of the two American types, one or two planer-trees, species of populus answering to our cotton-woods and our balsam-poplar, a sasafras and the analogues of our persea and benzoin, a catalpa, magnolias and a liriodendron, maples answering to ours, and also a negundo, and such peculiarly American leguminous genera as the locust, honey locust, and gymnocladus. To understand how Europe came to lose these elements of her flora, and Atlantic North America to retain them, we must recall the poverty of Europe in native forest trees, to which I have already alluded. A few years ago, in an article on this subject, I drew up a sketch of the relative richness of Europe, Atlantic North America, Pacific North America, and the eastern side of temperate Asia in genera and species of forest trees.[1] In that sketch, as I am now convinced, the European forest elements were somewhat underrated. I allowed only 33 genera and 85 species, while to our Atlantic American forest were assigned 66 genera and 155 species. I find from Nyman's 'Conspectus' that there are trees on the southern and eastern borders of Europe which I had omitted,

[1] *Amer. Journ. Sci.*, III. xvi. 85.

that there are good species which I had reckoned as synonyms, and some that may rise to arboreal height which I had counted as shrubs. But, on the other hand, and for the present purpose, it may be rejoined that the list contained several trees, of as many genera, which were probably carried from Asia into Europe by the hand of man. On Nyman's authority I may put into this category cercis siliquastrum, ceratonia siliqua, diospyros lotus, styrax officinalis, the olive, and even the walnut, the chestnut, and the cypress. However this may be, it seems clear that the native forest flora of Europe is exceptionally poor, and that it has lost many species and types which once belonged to it. We must suppose that the herbaceous flora has suffered in the same way. I have endeavoured to show how this has naturally come about. I cannot state it more concisely than in the terms which I used six years ago.

'I conceive that three things have conspired to this loss of American, or, as we might say, of normal, types sustained by Europe. First, Europe, extending but little south of lat. 40°, is all within the limits of severe glacial action. Second, its mountains trend east and west, from the Pyrenees to the Carpathians and the Caucasus beyond: they had glaciers of their own, which must have begun their work and poured down the northward flanks while the plains were still covered with forest on the retreat from the great ice forces coming from the north. Attacked both on front and rear, much of the forest must have perished then and there.

'Third, across the line of retreat of whatever trees may have flanked the mountain ranges, or were stationed south of them, stretched the Mediterranean, an impassable barrier. . . Escape by the east, and rehabilitation from that quarter until a very late period, was apparently prevented by the prolongation of the Mediterranean to the Caspian, and probably thence to the Siberian Ocean. If we accept the supposition of Nordenskiöld that, anterior to the Glacial period, Europe was "bounded on the south by an ocean extending from the Atlantic over the present deserts of Sahara and Central Asia to the Pacific," all chance of these American types having escaped from and re-entered Europe from the south and east seems excluded. Europe may thus be conceived to have been for a time somewhat in the condition in which Greenland is now. . . . Greenland may be referred to as a country which, having undergone extreme glaciation, bears the marks of it in the extreme poverty of its flora, and in the absence of the plants to which its southern portion, extending six degrees below the arctic circle, might be entitled. It ought to have trees, and it might support them. But since their destruction by glaciation no way has been open for their return. Europe fared much better, but has suffered in its degree in a similar way.'[1]

Turning to this country for a contrast, we find the continent on the eastern side unbroken and open from the arctic circle to the tropic, and the mountains running north and south. The vegetation when pressed on the north by on-coming refrigeration had only to move its southern border southward to enjoy its normal climate over a favourable region of great extent; and, upon the recession of glaciation to the present limit, or in the oscillations which intervened, there was no physical impediment to the adjustment. Then, too, the more southern latitude of this country gave great advantage over Europe. The line of terminal moraines, which

[1] *Amer. Journ. Sci.*, III., l. c., 194.

marks the limit of glaciation, rarely passes the parallel of 40° or 39°. Nor have any violent changes occurred here, as they have on the Pacific side of the continent, within the period under question. So, while Europe was suffering hardship, the lines of our Atlantic American flora were cast in pleasant places, and the goodly heritage remains essentially unimpaired.

The transverse direction and the massiveness of the mountains of Europe, while they have in part determined the comparative poverty of its forest-vegetation, have preserved there a rich and widely distributed Alpine flora. That of Atlantic North America is insignificant. It consists of a few arctic plants, left scattered upon narrow and scattered mountain-tops, or in cool ravines of moderate elevation; the maximum altitude is only about 6,000 feet in lat. 44°, on the White Mountains of New Hampshire, where no winter snow outlasts midsummer. The best Alpine stations are within easy reach of Montreal. But as almost every species is common to Europe, and the mountains are not magnificent, they offer no great attraction to a European botanist.

Farther south, the Appalachian Mountains are higher, between lat. 36° and 34° rising considerably above 6,000 feet; they have botanical attractions of their own, but they have no Alpine plants. A few sub-Alpine species linger on the cool shores of Lake Superior, at a comparatively low level. Perhaps as many are found nearly at the level of the sea on Anticosti, in the Gulf of St. Lawrence, abnormally cooled by the Labrador current.

The chain of great fresh-water lakes, which are discharged by the brimming St. Lawrence, seems to have little effect upon our botany, beyond the bringing down of a few north-western species. But you may note with interest that they harbour sundry maritime species, mementos of the former saltness of these interior seas. Cakile Americana, much like the European sea rocket, Hudsonia tomentosa (a peculiar cistacious genus imitating a heath), lathyrus maritimus, and ammophila arenaria are the principal. Salicornia, glaux, scirpus maritimus, ranunculus cymbalaria, and some others may be associated with them. But these are widely diffused over the saline soil which characterises the plains beyond our wooded region.

I have thought that some general considerations like these might have more interest for the biological section at large than any particular indications of our most interesting plants, and of how and where the botanist might find them. Those who in these busy days can find time to herborise will be in the excellent hands of the Canadian botanists. At Philadelphia their brethren of 'the States' will be assembled to meet their visitors, and the Philadelphians will escort them to their classic ground, the Pine Barrens of New Jersey. To have an idea of this peculiar phytogeographical district, you may suppose a long wedge of the Carolina coast to be thrust up northward quite to New York harbour, bringing into a comparatively cool climate many of the interesting low-country plants of the South, which, at this season, you would not care to seek in their sultry proper home. Years ago, when Pursh and Leconte and Torrey used to visit it, and in my own younger days, it was wholly primitive and unspoiled. Now, when the shore is lined with huge summer hotels, the pitch pines carried off for firewood, the bogs converted into cranberry-grounds, and much of the light sandy or gravelly soil planted with vineyards or converted into melon and sweet-potato patches, I fear it may have lost some of its botanical attractions. But large tracts are still nearly in a state of nature. Drosera filiformis, so unlike any European species, and the beautiful sabbatias, the yellow-fringed orchises, lachnanthes and lophiola, the larger xyrises and eriocaulons, the curious grass amphicarpum with cleistogamous flowers at the root, the showy species of chrysopsis, and many others must still abound. And every botanist will wish to collect schizæa pusilla, rarest, most local, and among the smallest of ferns.

If only the season would allow it, there is a more southern station of special interest,—Wilmington, on the coast of North Carolina. Carnivorous plants have, of late years, excited the greatest interest, both popular and scientific, and here, of all places, carnivorous plants seem to have their most varied development. For this is the only and the very local home of dionæa; here grow almost all the North American species of drosera: here, near by, are most of the species of sarracenia, of the bladder-bearing utricularias,—one of which the President of our section has detected in fish-catching,—and also the largest species of pinguicula.

But at this season a more enjoyable excursion may be made to the southern portion of the Alleghany or Appalachian mountains, which separate the waters of the Atlantic side from those of the Mississippi. These mountains are now easily reached from Philadelphia. In Pennsylvania, where they consist of parallel ridges without peaks or crests, and are of no great height, they are less interesting botanically than in Virginia; but it is in North Carolina and the adjacent borders of Tennessee that they rise to their highest altitude, and take on more picturesque forms. On their sides the Atlantic forest, especially its deciduous-leaved portion, is still to be seen to greatest advantage, nearly in pristine condition, and composed of a greater variety of genera and species than in any other temperate region, excepting Japan. And in their shade are the greatest variety and abundance of shrubs, and a good share of the most peculiar herbaceous genera. This is the special home of our rhododendrons, azaleas, and kalmias; at least here they flourish in greatest number and in most luxuriant growth. Rhododendron maximum (which is found in a scattered way even as far north as the vicinity of Montreal) and kalmia latifolia (both called laurels) even become forest trees in some places; more commonly they are shrubs, forming dense thickets on steep mountain-sides, through which the traveller can make his way only by following old bear-paths, or by keeping strictly on the dividing crests of the leading ridges.

Only on the summits do we find rhododendron catawbiense, parent of so many handsome forms in English grounds, and on the higher wooded slopes the yellow and the flame-coloured azalea calendulacea; on the lower, the pink A. nudiflora and more showy A. arborescens, along with the common and widespread A. viscosa. The latter part of June is the proper time to explore this region, and, if only one portion can be visited, Roan Mountain should be preferred.

On these mountain tops we meet with a curious anomaly in geographical distribution. With rarest exceptions, plants which are common to this country and to Europe extend well northward. But on these summits from southern Virginia to Carolina, yet nowhere else, we find—undoubtedly indigenous and undoubtedly identical with the European species—the lily-of-the-valley.

I have given so much of my time to the botany of the Atlantic border that I can barely touch upon that of the Western regions.

Between the wooded country of the Atlantic side of the continent and that of the Pacific side lies a vast extent of plains which are essentially woodless, except where they are traversed by mountain-chains. The prairies of the Atlantic States bordering the Mississippi and of the Winnipeg country shade off into the drier and gradually more saline plains which, with an even and gradual rise, attain an elevation of 5,000 feet or more where they abut against the Rocky Mountains. Until these are reached (over a space from the Alleghanies westward of about twenty degrees of longitude) the plains are unbroken. To a moderate distance beyond the Mississippi the country must have been in the main naturally wooded. There is rainfall enough for forest on these actual prairies. Trees grow fairly well when planted; they are coming up spontaneously under present opportunities; and there is reason for thinking that all the prairies east of the Mississippi, and of the Missouri up to Minnesota, have been either greatly extended or were even made treeless under Indian occupation and annual burnings. These prairies are flowery with a good number of characteristic plants, many of them evidently derived from the plains farther west. At this season, the predominant vegetation is of compositæ, especially of asters and solidagos, and of sunflowers, silphiums, and other helianthoid compositæ.

The drier and barer plains beyond, clothed with the short buffalo-grasses, probably never bore trees in their present state, except as now some cottonwoods (*i.e.*, poplars) on the margins of the long rivers which traverse them in their course from the Rocky Mountains to the Mississippi. Westward, the plains grow more and more saline; and wormwoods and chenopodiaceæ of various sorts form the dominant vegetation, some of them *sui generis* or at least peculiar to the country, others identical or congeneric with those of the steppes of northern Asia. Along with this common campestrine vegetation, there is a large infusion of peculiar American types, which I suppose came from the southward, and to which I will again refer.

Then come the Rocky Mountains, traversing the whole continent from north to south; their flanks wooded, but not richly so, chiefly with pines and firs of very few species, and with a single ubiquitous poplar, their higher crests bearing a well-developed Alpine flora. This is the arctic flora prolonged southward upon the mountains of sufficient elevation, with a certain admixture in the lower latitudes of types pertaining to the lower vicinity.

There are almost 200 Alpine phænogamous species now known on the Rocky Mountains; fully three-quarters of which are Arctic, including Alaskan and Greenlandian; and about half of them are known in Europe. Several others are North Asian but not European. Even in that northern portion of the Rocky Mountains which the Association is invited to visit, several Alpine species novel to European botany may be met with; and farther south the peculiar forms increase. On the other hand, it is interesting to note how many old-world species extend their range southward even to lat. 36° or 35°.

I have not seen the Rocky Mountains in the Dominion; but I apprehend that the aspect and character of the forest is Canadian, is mainly coniferous, and composed of very few species. Oaks and other cupuliferous trees, which give character to the Atlantic forest, are entirely wanting, until the southern confines of the region are reached in Colorado and New Mexico, and there they are few and small. In these southern parts there is a lesser amount of forest, but a much greater diversity of genera and species, of which the most notable are the pines of the Mexican plateau type.

The Rocky Mountains and the coast ranges on the Pacific side so nearly approach in British America that their forests merge, and the eastern types are gradually replaced by the more peculiar western. But in the United States a broad, arid and treeless, and even truly desert, region is interposed. This has its greatest breadth and is best known where it is traversed by the Central Pacific Railroad. It is an immense plain between the Rocky Mountains and the Sierra Nevada, largely a basin with no outlet to the sea, covered with sage-brush (*i.e.*, peculiar species of artemisia) and other sub-saline vegetation, all of greyish hue; traversed, mostly north and south, by chains of mountains, which seem to be more bare than the plains, but which hold in their recesses a considerable amount of forest and of other vegetation, mostly of Rocky Mountain types.

Desolate and desert as this region appears, it is far from uninteresting to the botanist; but I must not stop to show how. Yet even the ardent botanist feels a sense of relief and exultation when, as he reaches the Sierra Nevada, he passes abruptly into perhaps the noblest coniferous forest in the world, a forest which stretches along this range and its northern continuation, and along the less elevated ranges which border the Pacific coast, from the southern part of California to Alaska.

So much has been said about this forest, about the two gigantic trees which have made it famous, and its pines and firs which are hardly less wonderful, and which in Oregon and British Columbia, descending into the plains, yield far more timber to the acre than can be found anywhere else, and I have myself discoursed upon the subject so largely on former occasions, that I may cut short all discourse upon the Pacific coast flora and the questions it brings up.

I note only these points. Although this flora is richer than that of the Atlantic in coniferæ (having almost twice as many species), richer indeed than any other except that of eastern Asia, it is very meagre in deciduous trees. It has a fair number of oaks, indeed, and it has a flowering dogwood, even more showy than that which brightens our eastern woodlands in spring. But, altogether it possesses only one-quarter of the number of species of deciduous trees that the Atlantic forest has; it is even much poorer than Europe in this respect. It is destitute not only of the characteristic trees of the Atlantic side, such as liriodendron, magnolia, asimina, nyssa, catalpa, sassafras, carya, and the arboreous leguminosæ (cercis excepted), but it also wants most of the genera which are common throughout all the other northern-temperate floras, having no lindens, elms, mulberries, celtis, beech, chestnut, hornbeam, and few and small ashes and maples. The shrubbery and herbaceous vegetation, although rich and varied, is largely peculiar, especially at the south. At the north we find a fair number of species identical with the eastern; but it is interesting to remark that this region, interposed between the N.E. Asiatic and the N.E. American, and with coast approximate to the former, has few of those peculiar genera which, as I have insisted, witness to a most remarkable connection between two floras so widely sundered geographically. Some of these types, indeed, occur in the intermediate region, rendering the general absence the more noteworthy. And certain peculiar types are represented in single identical species on the coasts of Oregon and Japan, &c. (such as lysichiton, fatsia, glehnia); yet there is less community between these floras than might be expected from their geographical proximity at the north. Of course the high northern flora is not here in view.

Now, if, as I have maintained, the eastern side of North America and the eastern side of Northern Asia are the favoured heirs of the old boreal flora, and if I have plausibly explained how Europe lost so much of its portion of a common inheritance, it only remains to consider how the western side of North America lost so much more. For that the missing types once existed there, as well as in Europe, has already been indicated in the few fossil explorations that have been made. They have brought to light magnolias, elms, beeches, chestnut, a liquidambar, &c. And living witnesses remain in the two sequoias of California, whose ancestors, along with taxodium, which is similarly preserved on the Atlantic side, appear to have formed no small part of the miocene flora of the Arctic regions.

Several causes may have conspired in the destruction;—climatic differences between the two sides of the continent, such as must early have been established (and we know that a difference no greater than the present would be effective); geographical configuration, probably confining the migration to and fro to a long and narrow tract, little wider, perhaps, than that to which it is now restricted; the tremendous outpouring of lava and volcanic ashes just anterior to the glacial period, by which a large part of the region was thickly covered; and, at length, competition from the Mexican plateau vegetation,—a vegetation beyond the reach of general glacial movement from the north, and climatically well adapted to the south-western portion of the United States.

It is now becoming obvious that the Mexican plateau vegetation is the proximate source of most of the peculiar elements of the Californian flora, as also of the southern Rocky Mountain region and of the Great Basin between; and that these plants from the south have competed with those from the north on the eastward plains and prairies. It is from this source that are derived not only our cacteæ but our mimoseæ, our daleas and petalostemons, our numerous and varied onagraceæ, our loasaceæ, a large part of our compositæ, especially the eupatoriaceæ, helianthoideæ, helenioideæ, and mutisiaceæ, which are so characteristic of the country, the asclepiadeæ, the very numerous polemoniaceæ, hydrophyllaceæ, eriogoneæ, and the like.

I had formerly recognised this element in our North American flora; but I have only recently come to apprehend its full significance. With increasing knowledge we may in a good measure discriminate between the descendants of the ancient northern flora, and those which come from the highlands of the south-west.

On the Theory of the Steam-Engine.

By Professor ROBERT H. THURSTON.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE following paper is intended to present, in the briefest possible form, an outline of the growth of the theory of the steam-engine, from its first and most primitive form to its most recent and most thoroughly practical development in application. It is not proposed to make this sketch in any sense complete, and it is hardly expected that it can be critically accurate. It may, however, prove interesting, and may be of real service, it is hoped, as presenting a distinct outline of what will, when more completely worked up, prove to be an exceedingly interesting and important detail of the history of applied science.

A complete history of the development of the theory of the steam-engine would include, first, the history of the mechanical theory of heat; secondly, the history of the science of thermodynamics, which has been the outgrowth of that theory; thirdly, the history of the application of the science of heat transformation to the case of the steam-engine; and fourthly, an account of the completion of the theory of the steam and other heat-engines by the introduction of the theory of losses by the more or less avoidable forms of waste, as distinguished from those necessary and unavoidable wastes indicated by the pure theory of thermodynamics. The first and second of these divisions are treated of in works on thermodynamics, and in treatises on physics. The third division is briefly considered, and usually very incompletely, in treatises on the steam-engine; while the last is of too recent development to be the subject of complete treatment, as yet, in any existing works. The principal object of the present paper is simply to collect into a condensed form, and in proper relations, these several branches of the subject, leaving for another time and place that more full and complete account which might, did opportunity offer, be prepared to-day.

The 'Mechanical Theory of Heat,' as is now well understood, existed, as a speculation, from the days of the earliest philosophies. The contest which raged with such intensity, and sometimes acrimony, among speculative men of science during the last century was merely a repetition of struggles of which we find evidences at intervals throughout the whole period of recorded history. The closing period of this, which proved to be an important, revolution in science marked the beginning of the nineteenth century. It was inaugurated by the introduction of experimental investigation directed toward the crucial point of the question at issue. It terminated, about the middle of the century, with the acceptance of the general results of such experiment by every scientific man of acknowledged standing on either side the Atlantic. The doctrine that heat was material, and its transfer a real movement of substance from the source to the receiver of heat, was thus finally completely superseded by the theory, now become an ascertained truth, that heat is a form of energy, and its transformation a change in the location and method of molecular vibration. The dynamical theory of heat was first given a solid basis by the experiments of Count Rumford (Benjamin Thompson), in 1796–7, of which an account was given in a paper read by Rumford before the Royal Society of Great Britain in 1798, by the experiments of Sir Humphry Davy in 1798–9, and by the later and more precise determination of the value of the mechanical equivalent of heat, by Joule, in 1843, and subsequently.

The science of thermodynamics has for its essential basis the established fact of the dynamical nature of heat, and the fact of the quantivalence of two forms of energy—heat and mechanical motion, molecular energy and mass energy. Resting, as it does, on fundamental, experimentally-determined principles, it could have no existence, until during the early part of the present century these phenomena and these truths were well investigated and firmly established. Immediately upon the settlement of the controversy relating to the nature of heat, it became possible to commence the construction of the science which, asserting the mechanical theory of heat as its fundamental fact, and the conservation and quantivalence of the two forms of energy as its fundamental principle, led to the determination of the method and extent of the transformation of the one into the other during any prescribed series of physical changes.

It is not within the province of this paper to examine the claims made for rival philosophers in the debate over the matter of priority of discovery of the mutual relations of the phenomena and principles of the new science. It is sufficiently evident that the revelation of the facts of the case led many minds to study the subject, and led to its nearly contemporaneous development in several countries. The first period of the development of the science was occupied almost exclusively by the exposition of the dynamical theory of heat, which lies at the bottom of the whole. This strikingly interesting and obviously important subject so absorbed the attention and occupied the thoughts of physicists that they seem hardly to have attempted to look beyond it, as a rule, and hence failed, at first, to see into what a magnificent department of the theoretical and experimental investigation they were called. Mohr, in 1837; Seguin, in 1839; Mayer, of Heilbronn, in 1842; and Colding, in 1843, each took a step into a field, the limits of which and the importance of which they could at that time hardly have imagined. Mayer certainly had a very clear conception of the bearing of the new theory of heat upon dynamics, and exhibited remarkable insight into the far-reaching principles of the new science. He collated the facts more exactly determined later by Joule and others with the principle of the conservation of energy, and applied the rudiments of a science thus constructed to the calculation of the quantity of carbon and expenditure of heat which are unavoidably needed by a mountain climber, doing a given quantity of work, in the elevation of his own body to a specified height. The work of Mayer may be taken as representing the first step in the production of a science of thermodynamics, and in the deduction of the consequences of the fact which had, until his time, so seldom engaged the attention of men of science. It was only about the middle of the century that it began to be plainly seen that there existed such a science, and that the dynamic equivalence of heat, and energy in the mechanical form, was but a single fact, which must be taken in connection with the general principles of the persistence of energy, and applied in all cases of performance of work by expenditure of heat through the action of elastic bodies.

The development of the science of thermodynamics into available and satisfactory form was effected mainly by Professors Rankine and Clausius, working independently but contemporaneously from 1849. Clausius developed the general theory with beautiful clearness and conciseness of mathematical method and work, and succeeded in constructing a complete system, almost equal in extent and exactness to the geometrical system of Euclid. Rankine, producing the same results, in part, by his wonderfully condensed method of treatment, turned his attention more closely to the application of the theory to the case of the steam and other heat-engines, giving finally, in his 'Prime Movers' (1859), a concise yet full exposition of the correct theory of those motors, so far as it is possible to do so by purely thermodynamic treatment. He was unaware, apparently, as were all the scientific men of his time, of the extent to which the conclusions reached by such treatment of the case are modified, in real engines, by the interference of other physical principles than those taken cognisance of by his science. Sir William Thomson, partly independently, and partly working with Joule, has added much valuable work to that done by Clausius and Rankine. In the hands of these great men the science took form, and has now assumed its place among the most important of all branches of physical science.

The theory of the steam-engine, like every other scientific system, rests upon a foundation of facts ascertained by experiment, and of principles determined by the careful study of the laws relating to those facts, and controlling phenomena, properly classed together by that science. Like every other element entering into the composition of a scientific system, this theory has been developed subsequently to the establishment of its fundamental facts, and the history of progress in the art to which it relates shows that the art has led the science from the first. The theory of the steam-engine includes all the phenomena and all the principles involved in the production of power, by means of the steam-engine, from the heat-energy derived from the chemical combination of a combustible with the oxygen of the air acting as a supporter of combustion. The complete theory therefore includes the theory of combustion; the consideration of the methods of development and transfer, and of losses of heat in the steam boiler; the examination of the methods of transfer of heat-energy from boiler to engine, and of waste of heat in this transfer; and, finally, the development of mechanical energy in the engine, and its application, beyond the engine, to the machinery of transmission, with an investigation of the nature and method of waste in this last transformation. It is, however, only the last of these divisions of the subject that it is here proposed to consider. The remaining portion of this paper will be devoted to the tracing of the growth of the theory of the steam-engine, simply as a mechanical instrument for transformation of the one form of energy into the other—of the molecular energy of heat motion, as stored in the vapour of water, into mass energy, mechanical energy, as applied to the driving of mechanism. The theory thus limited includes a study of the thermodynamic phenomena, as the principal and essential operations involved in the performance of work by the engine; it further includes the consideration of the other physical processes which attend this main function of the engine, and which, inevitably and unavoidably, so far as is to-day known, concur in the production of a waste of energy.

Of all the heat sent forward by the steam boiler to the engine, a certain part, definite in amount and easily calculated when the power developed is known, is expended by transformation into mechanical energy; another part, equally definite and easily calculated, also, is expended as the necessarily-occurring waste which must take place in all such transformations, at usual temperatures of reception and rejection of heat; still another portion is lost by conduction and radiation to surrounding bodies; and, finally, a part, often very large in comparison with even the first and principal of these quantities, is wasted by transfer within the engine, from the induction to the eduction side, from 'steam to exhaust,' by a singular and interesting process, without conversion into useful effect. The science of thermodynamics only takes cognisance of the first, which is sometimes one of the smallest of these expenditures. The science of the general physics of heat takes cognisance of the others.

The science of the phenomena of the steam-engine must, like every other branch of applied science, be considered as the product of two distinct processes of development: the one is what may be called the experimental development of the subject, the other is the purely theoretical progress of the science. So far as the useful application of principles to the perfection of the machine is concerned, the latter has always, as is usually the case elsewhere, been in advance of the former in its deduction of general principles; while, as invariably, the former has kept far in advance, in the working out of practically useful results, and in the determination of the exact facts where questions of economic importance have arisen. It is proposed here to follow the history of the experimental development of the principles controlling the efficiency of the engine, and modifying the conclusions derived by the application of the science of heat transformation, after first tracing the progress of the development of that science. The gradual formation of the pure theory of the steam-engine will be traced, and the limitations of that theory will naturally come up for consideration afterward.

The germ of a science of the steam-engine may be found in the work of Sadi Carnot, published just sixty years ago. Although familiar with the then doubted mechanical theory of heat, he was not sufficiently well convinced of its correctness, apparently, to make it the basis of his work, but assumed, throughout his '*Réflexions sur la Puissance Motrice du Feu*,' the theory of substantial caloric. Nevertheless, in his development of the theory of heat-engines, he enunciated some essential principles, and thus laid the foundation for a theory of the steam-engine which was given correct form, in all its details, as soon as the dynamical theory was taken for its foundation principle.

Carnot asserts that 'the motive power of heat is independent of the means taken to develop it; its amount is determined simply by the temperature of the bodies between which the heat is transferred. Wherever there exists a difference of temperature, there may be a development of power. The maximum amount of power obtainable by the use of steam is the maximum obtainable by any means whatever. High-pressure engines derive their advantage over low-pressure engines simply from their power of making useful a greater range of temperature.' He made use of the device known as the 'Carnot Cycle,' exhibiting the successive expansions and compressions of the working fluid in heat-engines, in the process of change of volume and temperature, while following the series of changes which gives the means of transformation of heat into power with final restoration of the fluid to its initial condition, showing that such a complete cycle must be traversed in order to determine what proportion of the heat energy available can be utilised by conversion into mechanical energy. This is one of the most essential of all the principles comprehended in the modern science. This 'Carnot Cycle' was afterward represented graphically by Clapeyron.

Carnot shows that the maximum possible efficiency of fluid is attained, in heat-engines, by expanding the working fluid from the maximum attainable temperature and pressure down to the minimum temperature and pressure that can be permanently maintained on the side of condensation or rejection, *i.e.*, if we assume expansion according to the hyperbolic law, by adopting as the ratio of expansion the quotient of maximum pressure divided by back pressure. He further shows that the expansion, to give maximum efficiency, should be perfectly adiabatic. These principles have been recognised as correct by all authorities from the time of Carnot to the present time, and have been not infrequently brought forward as new by minor later writers unfamiliar with the literature of the subject. Introducing into the work of Carnot the dynamical relation of heat and work, a relation, as shown by other writings, well understood if not advocated publicly by him, the theory of the steam-engine becomes well defined and substantially accurate. The Count de Pambour, writing in 1835, and later, takes up the problem of maximum efficiency of the steam-engine, shows the distinction to be drawn between the efficiency of fluid and efficiency of machine, and determines the value of the ratio of expansion for maximum efficiency of engine. He makes this ratio equal to the quotient of maximum initial pressure divided by the sum of the useless internal resistances of the engine, including back pressure and friction, and reduced to equivalent pressure per unit of area of piston. This result has been generally accepted, although sometimes questioned, and has been demonstrated anew, in apparent ignorance of the fact of its prior publication by De Pambour, and by more than one later writer. De Pambour, applying his methods to the locomotive particularly, solved the problem, since distinctly known by his name, Given the quantity of steam furnished by the boiler in the unit of time, and the measure of resistance to the motion of the engine: to determine the speed attainable.

Professor Thomas Tate, writing his 'Mechanical Philosophy,' in 1853, gives the principle stated above a broader enunciation, thus: 'The pressure of the steam, at the end of the stroke, is equal to the sum of the resistances of the unloaded engine, whatever may be the law expressing the relation of volume and pressure of steam.'

Professor Clausius, as has been already stated, applied the modern theory of the steam-engine to the solution of the various problems which arise in the practice of the engineer, so far as they can be solved by the principles of thermodynamics. His papers on this subject were printed in 1856. The Count de Pambour had taken a purely mechanical mode of treatment, basing his calculations of the work done in the cylinder of the steam-engine upon the hypothesis of Watt, that the weight of steam acting in the engine remained constant during expansion, and that the same assumption was applicable to the expanding mass contained in engine and boiler during the period of admission. He had constructed empirical formulas, published in his work on the theory of the steam-engine, in 1844, for the relation of volume and pressure during expansion, and had based his determinations of the quantity of work done, and of expenditure of steam in the engine, upon this set of assumptions and formulas, considering the steam to remain in its initial condition of dry and saturated vapour, or of moist vapour as the case may be, from the beginning to the end of the stroke. Errors were thus introduced, which, although not important in comparison with those often occurring when the result of purely thermodynamic and in so far correct treatment was compared with the actual case, were, nevertheless, sufficiently great to become noticeable when the true theory of heat-engines became known and correctly applied. Clausius proved that, in the expansion of dry and saturated steam doing work in the engine, condensation must take place to a certain extent, and that consequently the weight of steam in the cylinder must be somewhat reduced by the process of expansion beyond the point of 'cut-off.' During the period of compression, also, the reverse effect must occur, and the compressed mass must become superheated, if initially dry. He showed that the amount of work actually done in a non-conducting working cylinder must be sensibly different from that estimated by the method of De Pambour. Taking advantage of the re-determination of the constants in Regnault's equations effected by Moritz, Clausius obtains numerical results in the application of the true theory, and deduces the amount of work done in the steam-engine under various conditions such as are met with in practice. He shows how the action of the engine may be made that of the Carnot Cycle, and determines the effect of variation of the temperature of the 'prime' steam. The investigation is, in the main, purely theoretical: no application is made to the cases met with in real work, and the comparison of the results of the application of the new theory to practice in steam engineering is left for others.

The work of Clausius is, throughout, perfectly logical, and beautifully simple and concise, and his application of the theory to the steam-engine amounts to a complete reconstruction of the work of Carnot and his followers upon a correct basis. He develops with mathematical exactness of method and work the fundamental principles of the science of thermodynamics, constructs the 'fundamental equations,' the so-called 'general equations of thermodynamics,' and, in the course of his work, proves the fact of the partial condensation of saturated steam, when permitted to expand, doing work against resistance.

Professor Rankine began his work upon the theory of the transformation of heat into mechanical energy at about the same time with Clausius (1849), and published his first important deduction, the form of the general equation of thermodynamics, nearly simultaneously, but a little earlier. He gave much attention to the then incomplete work of development of applied thermodynamics, and produced, not only the whole theory of the science, but very extended papers, including solutions of practical problems in the application of the science to heat-engines. Stating with singular brevity and clearness the main principles, and developing the general equations in substantially the same form, but by less-easily-followed processes than his contemporary, he proceeded at once to their application. He determines the thermodynamic functions for air and other gases, exhibits the theory of the hot-air engine, as applied to the more important and typical forms, deduces expressions for their efficiency, and estimates the amount of heat demanded and of fuel consumed in their operation, assuming no other expenditure of heat than that required in an engine free from losses by conduction and radiation. He next, in a similar manner, applies the theory to the steam-engine, proves the fact of the condensation of steam during the period of expansion, estimates the amount of heat, fuel, and steam expended, and the quantity of work done, and determines thus the efficiency of the engine. He makes a special case of the engine using superheated steam, as well as that of the 'jacketed' engine, considers the superheated steam-engine, and the binary vapour-engine, and reconstructs De Pambour's problem. Applying the theory of the steam-engine to a considerable number of cases, differing in the steam pressure and in the ratio of expansion adopted, and including both condensing and non-condensing engines, he constructs a table exhibiting the efficiency of the steam, and the probable consumption of fuel (assuming a somewhat low efficiency of boiler), which table represents the limit of efficiency under the assumed conditions, a limit which may be approached as the conditions of practice approximate to those of the ideal cases taken, but which can never be reached.

As Rankine was not aware of the often enormous difference produced in the performance of the steam-engine by the extra thermodynamic phenomena involved in its operation, he does not indicate the fact that the results of his calculations must be taken with the qualification just stated above, and his figures are still sometimes supposed to represent those of actual performance. The fact is, however, that the consumption of steam and of fuel in actual practice always considerably exceeds those obtained by the solution of the thermodynamic problem, and, often, as already stated, exceeds that quantity by a very large amount.

Since the time of Rankine's and Clausius' investigations, the thermodynamic theory of the steam-engine has received no important modifications, and the work of later engineers, and of physicists working upon the general subject, has been confined to the study, experimental or other, of the limitations set to the application of this theory by the influence of other physical phenomena.

Rankine's work included the construction of a remarkably exact, though hypothetical, equation expressing the relation of temperatures and pressures of vapours, based upon his theory of 'molecular vortices,' a comparison of the efficiencies of air and steam-engines working between the same limits of temperature, and an exceedingly beautiful method of graphically determining the most economical size of steam-engine, from the commercial point of view, the quantity of power required being given, and all expenses being calculable. He defined and outlined the science of 'energetics,' established the beginnings of a system of graphical thermodynamics, including the representation of the action of steam in the compound engine. He studied the action of explosive gas-engines, and calculated the explosive energy of liquids heated under pressure. Besides all this, Rankine performed an enormous amount of work in mathematical physics, in hydrodynamics, in hydromechanics, in the theory of naval architecture, and in the application of mechanics to general engineering. Several important text-books, a large volume on ship-building, and other works, with an unknown number of papers, published and unpublished, form a monument to the power and industry of this wonderful man and remarkable genius, that may be looked upon as perhaps the greatest wonder of the intellectual world.

The thermodynamic theory of the steam-engine stands, to-day, substantially as it was left by Clausius and Rankine at the close of their work in this field, in the decade 1850 to 1860. Many treatises have been published, some of them by men of exceptional ability; but all have followed the general line first drawn by these masters, and have only now and then found some minor point to develope. Rankine's 'Steam-engine and other Prime Movers,' written a quarter of a century ago, is still a standard work on the theory of the heat-engines, and is still used as a text-book in engineering schools in this country and Europe.

The limitations of the thermodynamic theory of the heat-engines, and of its application in the design and operation of such engines, were first discovered by James Watt a hundred years ago and more. They were systematically and experimentally investigated by Isherwood in 1855 to 1865, were observed and correctly interpreted by Clark in 1855 and earlier, and were revealed again by the experiments of Hirn, and by those of Emery and many other recent investigators on both sides of the Atlantic. These limitations are due to the fact that losses occur in the operation of steam-engines which are not taken into account by the hitherto accepted theory of the engine, and have no place in the thermodynamic treatment of the case.

It is generally assumed, in the usual theory of the engine, that the expansion of the working fluid takes place in a cylinder having walls impermeable to heat, and in which no losses by conduction or radiation, or by leakage, can occur. Of those losses which actually take place in the real engine, that due to leakage may be prevented, or, if occurring, can be checked; but it is impossible, so far as is now known, to secure a working cylinder of perfectly non-conducting material. The consequence is that, since the steam or other working fluid enters at a high temperature and is discharged at a comparatively low temperature, the surfaces of cylinder, cylinder heads, and piston are at one instant charged with heat of high temperature, and at the next moment, exposed to lower temperatures, are drained of their surplus heat, which heat is then rejected from the cylinder and wasted. Thus, at each stroke, the metal surfaces, exposed to the action of the expanding substance, alternately absorb heat from it, and surrender that heat to the 'exhaust.' In the case of the gas-engines, this waste is rendered enormously greater by the action of the water-jacket, which is there needed to keep the cylinder down to a safe temperature, and which takes away, in the circulating stream of cooling water, an immense amount—usually about one-half—of the heat received from the burning gas. In the steam-engine, the loss by the method here referred to is rarely less than one-fourth in unjacketed cylinders, and is often more than equal to the whole quantity of heat transformed into mechanical energy. The amount of this loss increases with wet steam, and is diminished by any expedient, as steam-jacketing or superheating, which prevents the introduction or the production of moisture in the midst of the mass of steam in the cylinder. As the range of temperature worked through in the engine increases as the quantity of steam worked per stroke diminishes, and as the time allowed for transfer of heat to and from the sides and ends of the cylinder and the piston is increased, the magnitude of this loss increases. Hence the use of high steam, of a high ratio of expansion, and of low piston speed tend to increase the amount of this waste; while low steam, a low ratio of expansion, and high engine speed, tend to diminish it. These physical phenomena are therefore no less important in their influence upon the behaviour of the engine, and upon its efficiency, and are no less essential elements for consideration in the general theory of the engine, than those taken into account in the purely thermodynamic theory.

James Watt, as above stated, discovered this cause of the limitation of the efficiency of the steam-engine. He not only discovered the fact of the existence of this method of waste, but experimentally determined its amount in the first engine ever placed in his hands. It was in 1763 that he was called upon to repair the little model of the Newcomen engine, then and still in the cabinets of the University of Glasgow. Making a new boiler, he set up the machine and began his experiments. He found, to his surprise, that the little steam-cylinder demanded four times its own volume at every stroke, thus wasting, as he says, three-fourths of the steam supplied, and requiring four times as much 'injection water' as should suffice to condense a cylinder full of steam. It was in the course of this investigation that he discovered the existence of so-called 'latent heat.' All of Watt's first inventions were directed toward the reduction of this immense waste. He proposed to himself the problem of keeping the cylinder 'as hot as the steam that entered it;' he solved this problem by the invention of the separate condenser and the steam-jacket, and thus the discovery of the limitation of the thermodynamic theory here noted was the source of Watt's fame and fortune.

John Smeaton, a distinguished contemporary of Watt, and perhaps the most distinguished engineer of his time, not only seems to have been well aware of this defect of the steam-engine, but also was possibly even in advance of Watt in attempting to remedy it. He built a large number of Newcomen engines between 1765 and 1780, in some if not many of which he attempted to check loss by this now familiar 'cylinder-condensation' in engines, some of which were five and six feet in diameter of cylinder by lining pistons and heads with wood. This practice may not be practicable with the temperatures now usual; but no attempt has been made, so far as is known to the writer, to follow Smeaton in his thoroughly philosophical plan of improvement. Cylinder-condensation remains to-day, as in the time of Smeaton and Watt, the chief source of waste in all well-designed and well-constructed heat-engines.

It is a curious fact, and one of great interest as illustrating the gulf formerly separating the philosopher studying the steam-engine and working out its theory from the practitioner engaged in its construction and operation in the earlier days of engineering, that, notwithstanding the fact that this waste was familiar to all intelligent engineers, from the time of the invention of the modern steam-engine, and was recorded in all treatises on engine construction and management, the writers on the theory of the machine have apparently never been aware that it gives rise to the production, in the working cylinder, of a large amount of water mingled with the steam. In fact, it has often been assumed by engineers themselves that this water is always due to 'priming' at the boiler. Even Rankine, writing in 1849-50, while correctly describing the phenomenon of cylinder-condensation, made the mistake of attributing the presence of the water in steam-cylinders to the fact of condensation of dry steam doing work by expansion, apparently not having noted the fact that this would only account for a very insignificant proportion of the moisture actually present in the average steam-engine. He considers incomplete expansion the principal source of loss, as do usually other writers on thermodynamics.

Thomas Tredgold, writing in 1827, who, but little later than Carnot, puts the limit to economical expansion at the point subsequently indicated and more fully demonstrated by De Pambour, exaggerates the losses due to the practical conditions, but evidently does perceive their nature and general effect. He also shows that under the conditions assumed the losses may be reduced to a minimum, so far as being dependent upon the form of the cylinder, by making the stroke twice the diameter.

The limit of efficiency in heat-engines, as has been seen, is thermodynamically determined by the limit of complete expansion. So well is this understood, and so generally is this assumed to represent the practical limit, by writers unfamiliar with the operation of the steam-engine, that every treatise on the subject is largely devoted to the examination of the amount of the loss due to what is always known as 'incomplete expansion'—expansion terminating at a pressure higher than the back pressure in the cylinder. The causes of the practical limitation of the ratio of expansion to a very much lower value than those which maximum efficiency of fluid would seem to demand have not been usually considered either with care or with intelligence by writers thoroughly familiar with the dynamical treatment, apart from the modifying conditions here under consideration.

Watt, and probably his contemporaries and successors, for many years supposed that the irregularity of motion due to the variable pressure occurring with high expansion was the limiting condition, and does not at first seem to have realised that the cylinder-condensation discovered by him had any economical bearing upon the ratio of expansion at maximum efficiency. It undoubtedly is the fact that this irregularity was the first limiting condition with the large, cumbrous, long-stroked, and slow-moving engines of his time. Every accepted authority from that day to the present has assumed, tacitly, that this method of waste has no influence upon the value of that ratio, if we except one or two writers who were practitioners rather than scientific authorities.

Mr. D. K. Clark, publishing his 'Railway Machinery,' in 1855, was the first to discuss this subject with knowledge, and with a clear understanding of the effects of condensation in the cylinder of the steam-engine upon its maximum efficiency. Cornish engines, from the beginning, had been restricted in their ratio of expansion to about one-fourth as a maximum, Watt himself adopting a 'cut-off' at from one-half to two-thirds. Hornblower, with his compound engine competing with the single cylinder-engines of Watt, had struck upon this rock, and had been beaten in economy by the latter, although using much greater ratios of expansion; but Clark, a half century and more later, was, nevertheless, the first to perceive precisely where the obstacle lay, and to state explicitly that the fact that increasing expansion leads to increasing losses by cylinder-condensation, the losses increasing in a much higher ratio than the gain, is the practical obstruction in our progress toward greater economy.

Clark, after a long and arduous series of trials of locomotive engines, and prolonged experiment looking to the measurement of the magnitude of the waste produced as above described, concludes: 'The magnitude of the loss is so great as to defeat all such attempts at economy of fuel and steam by expansive working, and it affords a sufficient explanation of the fact, in engineering practice, that expansive working has been found to be expensive working, and that, in many cases, an absolutely greater quantity of fuel has been consumed in extended expansion working, while less power has been developed.' He states that high speed reduces the effect of this cause of loss, and indicates other methods of checking it. He states that ' the less the period of admission relative to the whole stroke, the greater the quantity of free water existing in the cylinder.' His experiments, revealing these facts, were, in some cases, made prior to 1852. But the men handling the engines had observed this effect even before Clark; he states that they rarely voluntarily adopted ' a suppression of above 30 per cent.,' as they found the loss by condensation greater than the gain by expansion. Describing the method of this loss, this author goes on to say that ' to prevent entirely the condensation of steam worked expansively, the cylinder must not only be simply protected by the non-conductor—it must be maintained by independent external means, at the initial temperature of the steam.' He thus reiterates the principle expressed by Watt three-quarters of a century before, and applies it to the newly-stated case.

The same author, writing in 1877, says: ' The only obstacle to the working of steam advantageously to a high degree of expansion in one cylinder, in general practice, is the condensation to which it is subjected, when it is admitted into the cylinder at the beginning of the stroke, by the less hot surfaces of the cylinder and piston, the proportion of which is increased so that the economy of steam by expansive working ceases to increase when the period of admission is reduced down to a certain fraction of the stroke, and that, on the contrary, the efficiency of the steam is diminished as the period of admission is reduced below that fraction.' The magnitude of this influence may be understood from the fact that the distinguished engineer Loftus Perkins, using steam of 300 pounds' pressure, and attaining the highest economy known up to his time, found his engine to consume 1·62 pounds of fuel per hour per horse-power; while this figure is now reached by engines using steam at one-third that pressure and expanding about the same amount, and sometimes less.

Mr. Humphrys, writing a little later than Clark, shows the consumption of fuel to increase seriously as the ratio of expansion is increased beyond the very low figure which constituted the limit in marine engines of his time.

Mr. B. F. Isherwood, a chief engineer in the United States Navy, and later chief of the Bureau of Steam Engineering, seems to have been the first to have attempted to determine, by systematic experiment, the law of variation of the amount of cylinder-condensation with variation of the ratio of expansion in unjacketed cylinders. Experimenting on board the U.S.S. Michigan, he found that the consumption of fuel and of steam was greater when the expansion was carried beyond about one-half stroke than when restricted to lower ratios. He determined the quantity of steam used, and the amount condensed, at expansions ranging from full stroke to a cut-off at one-tenth. His results permit the determination of the method of variation, with practically satisfactory accuracy, for the engine upon which the investigation was made, and for others of its class. It was the first of a number of such investigations made by the same hand, and these to-day constitute the principal part of our data in this direction. The writer, studying these results, found that the cylinder-condensation varied sensibly as the square root of the ratio of expansion, and this is apparently true for other forms and proportions of engine. The amount of such condensation usually lies between one-tenth and one-fifth the square root of that ratio, if estimated as a fraction of the quantity of steam demanded by a similar engine having a non-conducting cylinder.

The state of the prevalent opinion on this subject, at the time of this work of Clark and of Isherwood, is well expressed by the distinguished German engineer, Dr. Albans, who, writing about 1840, says of the choice of best ratio of expansion: ‘Practical considerations form the best guide, and these are often left entirely out of view by mathematicians. Many theoretical calculations have been made to determine the point, but they appear contradictory and unsatisfactory.’ Renwick, in 1848, makes the ratio of initial divided by back pressure the proper ratio of expansion, but correctly describes the effect of the steam-jacket, and suggests that it may have peculiar value in expansive working, and that the steam may receive heat from a cylinder thus kept at the temperature of the ‘prime’ steam. John Bourne, the earliest of now acknowledged authorities on the management and construction of the steam-engine, pointed out, at a very early date, the fact of a restricted economic expansion. Rankine recognised no such restriction as is here under consideration, considered the ratio of expansion at maximum efficiency to be the same as that stated by Carnot and by other early writers, and only perceived its limitation by commercial considerations, a method of limitation of great importance, but often of less practical effect than is the waste by condensation. In his ‘Life of Elder’ (1871), however, he indicates the existence of a limit in practice, and places the figure at that previously given by Isherwood, for unjacketed engines. By this latter date, the subject had become so familiar to engineers that a writer in ‘London Engineering,’ in 1874, contemns writers who had neglected to observe this limitation of efficiency as indulging in ‘mediæval twaddle.’

A few writers on thermodynamics finally came to understand the fact that such a limitation of applied theory existed. M. G. A. Hirn, who, better than probably any authority of his time or earlier, combined a knowledge of the scientific principles involved with practical experience and experimental knowledge, in his treatise on thermodynamics (1876), concludes: ‘*Qu'il est absolument impossible d'édifier* a priori *une théorie de la machine à vapeur d'eau douce d'un charactère scientifique et exact*,’ in consequence of the operation of the causes here detailed. While working up his experiment upon the performance of engines, comparing the volume of steam used with that of the cylinder, he had always found a great excess, and had, at first, attributed it to the leakage of steam past the piston; but a suggestion of M. Leloutre set him upon the right track, and he came to the same conclusion as had Watt so many years before. He explains that errors of 30, or even up to 70 per cent. may arise from the neglect of the consideration of this loss. Combes had perceived the importance of this matter, and De Freminville suggested the now familiar expedient of compression, on the return stroke as nearly as possible to boiler pressure, as a good way to correct the evil. The matter is now well understood by contemporary writers, and it has become fully agreed, among theoretical writers as well as among practitioners, that the benefit of extended expansion in real engines can only be approximated to that predicted by the theory of the ideal engine, by special arrangements having for their object the reduction of cylinder waste, such as superheating, ‘steam-jacketing,’ and ‘compounding.’

Professor Cotterill has given more attention to this subject than any writer up to the present time. He devotes a considerable amount of space to the study of the method of absorption and surrender of heat by the metal surfaces enclosing the steam, constructs diagrams which beautifully illustrate this action, and solves the problems studied by him with equal precision and elegance of method. He summarises the experimental work done to the date of writing, and very fully and clearly exhibits the mode of transfer of heat past the piston without transformation into work. Professor Cotterill's treatise on steam, ‘considered as a heat-engine,’ is invaluable to the engineer.

Thus the theory of the steam-engine stands to-day incomplete, but on the verge of completion, needing only a little well-directed experimental work to supply the doubtful elements. Even these are becoming determined. Isherwood gives facts showing waste to be proportional, very nearly, if not exactly, to the square root of the ratio of expansion; and Escher, of Zurich, has shown the loss to be also proportional to the square root of the time of exposure, or, in other words, to the reciprocal of the square root of the speed of rotation, and it only remains to determine the method of variation of loss with variation of range of temperature to give the whole of the necessary material for the construction of a working theory which will enable the engineer to estimate, in advance of construction, the economic performance of his machine. There will undoubtedly be much more to be done in constructing an exact theory involving all the physical changes occurring in the working of the heat-engines familiar to us; but it will yet be done, and probably very soon. It is the hope of the writer that experiments made under his direction recently may furnish the needed data, as the result of the first systematic research directed to that end; but if this should prove not to be the fact, it cannot be long before direct investigation will secure all essential knowledge. When this is the case, the remarks of those distinguished physicists and engineers, Hallauer and his great teacher Hirn, will be no longer well based upon apparent fact.

Says Hirn, in his memorable discussion with Zeuner, in regard to this subject: ‘*Ma conviction reste aujourd'hui ce qu'elle était il y a vingt ans, une théorie proprement dite de la machine à vapeur est impossible; la théorie expérimentale, établie sur le moteur lui-même et dans toutes les formes où il a été essayé, en mécanique appliquée, peut seule conduire à des résultats rigoureux.*’

At present, it seems only possible, in the absence of a complete experimental examination, to do more than to base the determination of the ratio of maximum efficiency upon such experience as is familiar to engineers. Mr. C. E. Emery considers that, for common unjacketed engines it is practically safe to take the ratio for maximum duty at a figure expressed by an empirical formula proposed by him: $r = (p + 37) \div 22$. The writer has usually taken it, in estimates, as not far from one-half the square root of the boiler pressure expressed, as before, in pounds on the square inch. These points of cut-off are reduced still further by the fact that, commercially, it is better to reduce the size of engine at the expense of efficiency, as the cost of fuel and of similarly variable expenses increase. This is, however, a matter for the treatment of which space cannot here be taken. Rankine has devised a convenient method of solving such problems, involving this condition, as may arise in practice, where cylinder-condensation may be neglected, and the writer has found a method of adapting it to ordinary practice. The subject will ultimately form, properly, a final division of the complete theory of the steam-engine.

Chronologically considered, it is seen that the history of the growth of the theory of the steam-engine divides itself distinctly into three periods, the first extending up to the middle of the present century, and mainly distinguished by the attempts of Carnot and of Clapeyron to formulate a physical theory of the thermodynamics of the machine; the second beginning with the date of the work of Rankine and Clausius, who constructed a correct thermodynamic theory; and the third beginning a generation later, and marked by the introduction, into the general theory, of the physics of the conduction and transfer of that heat which play no part in the useful transformation of energy. The first period may be said to include, also, the inauguration of experimental investigation, and the discovery of the nature and extent of avoidable wastes, and attempts at their amelioration by James Watt and by John Smeaton. The second period is marked by the attempt, on the part of a number of engineers, to determine the method and magnitude of these wastes by more thorough and systematic investigation, and the exact enunciation of the law governing the necessary rejection of heat, as revealed by the science of thermodynamics. The third period is opening with promise of a complete, and practically applicable, investigation of all the methods of loss of energy in the engine, and of the determination, by both theoretical and experimental research, of all the data needed for the construction of a working theory.

M. Hirn has recognised these three periods, and has proposed to call the second the 'theoretical,' and the third the 'experimental' stage. The writer would prefer to make the nomenclature somewhat more accordant with what has seemed to him to be the true method of development of the subject. It has been seen that the experimental stage really began with the investigations of Watt, in the first period, and that the work of experimentation was continued through the second into the present—the last—period. It is also evident that the theoretical stage, if it can be properly said that such a period may be marked off in the history of the theory of the steam-engine, actually extends into the present epoch, since the work of the engineer and the physicist of to-day consists in the application of the science of heat-transfer and heat-transformation, together, to the engine; during the second period the theory included only the thermodynamics of the engine; while the third period is about to incorporate the theory of conduction and radiation into the general theory, with the already established theory of heat-transformation. The writer would therefore make the classification of these successive stages in the progress here described, thus:—

(1.) Primary period.—That of incomplete investigation, and of earliest systematic, but inaccurate, theory.

(2.) Secondary period.—That of the establishment of a correct thermodynamic theory, the *theory of the ideal engine.*

(3.) Tertiary period.—That of the production of the complete theory of the engine, of the true *theory of the real engine.*

The work of developing this theory is still incomplete. It remains to be determined, by experiment, precisely what are the laws of transfer of heat between metal and vapour, in the engine cylinder, and to apply these laws in the theory of the machine. Cotterill has shown how heat penetrates and traverses the metal, and Grashof has indicated the existence of an intermediate and approximately constant temperature, between the temperatures of the initial steam and of the exhaust, and both have given us some new methods. The writer, while pointing out the nature of the true 'curve of efficiency' of the steam-engine, which he was so fortunate as to discover, has shown how it may be made useful in the solution of practical and of theoretical problems involved in the applied theory of heat-engines, and many able minds are now engaged upon the theory. There can be little doubt that it will soon become satisfactorily complete.

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Improvements in Coast Signals; with Supplementary Remarks on the New Eddystone Lighthouse. By Sir JAMES N. DOUGLASS, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATES IV. and V.]

THE successful development of the maritime commerce of any country must always be very largely dependent on the perfection of its system of coast signals for the guidance of the mariner. Therefore, when we reflect on the important progress made by the Dominion of Canada, occupying, as she now does, the fourth position of the maritime countries of the world, the present occasion of the visit of the British Association to Montreal would appear to be a fitting time for the consideration of recent and future advancement in the development of coast signals.

The installation of the fog-whistle by Daboll at Beaver Tail Point, Rhode Island, in 1851, and the installation of the electric light by Holmes at the South Foreland, in 1858, were two of the most important steps in the progress of coast signals. Since these dates light and sound coast signals have so developed that it is now found to be possible, at any coast signal station, to render trustworthy service to the mariner by one or other of these agents in all the varying conditions of the atmosphere—1st, by providing a reliable and efficient signal; 2nd, by giving it such a clearly distinctive character as to enable the mariner to determine accurately his geographical position.

The light of the four concentric wick oil lamps for the dioptric lights of the first order of Fresnel had an intensity of 230 English candle units. The electric arc light, first practically produced by Holmes, and experimentally installed at the South Foreland in 1858, had an intensity of about 700 candle units.

Compact flame luminaries are now being produced from mineral and other oils, and coal gas, by improved burners, as shown on the drawing No. 1, having an intensity of 1,500 to 2,000 candle units. With the 'Wigham' gas-burners, consuming rich cannel gas, an intensity of nearly 3,000 candles has been reached; but the flames from these burners have been found to be so wanting in focal compactness, and consequently so much loss is incurred with their application to optical apparatus of the dimensions convenient for service in coast lighthouses of the first class, that the intensity of the resultant beam is not found to exceed that of the more compact flame of lower intensity and consumption of oil or gas. With the electric light an intensity of 50,000 candle units is now found to be practically and reliably available for the focus of an optical apparatus for coast lighting, so that, with regard to intensity and consequent penetrative power, this luminary is found to outstrip all competitors.

With regard to economy, and doubtless for a very wide and general application, mineral oil has the advantage of all its rivals up to the maximum intensity at which flame luminaries are practicable. It has also the further advantage over electricity or gas in its ready application at any coast signal station, however isolated, and in many cases where the other luminaries referred to would be impracticable. A very elaborate and ex-


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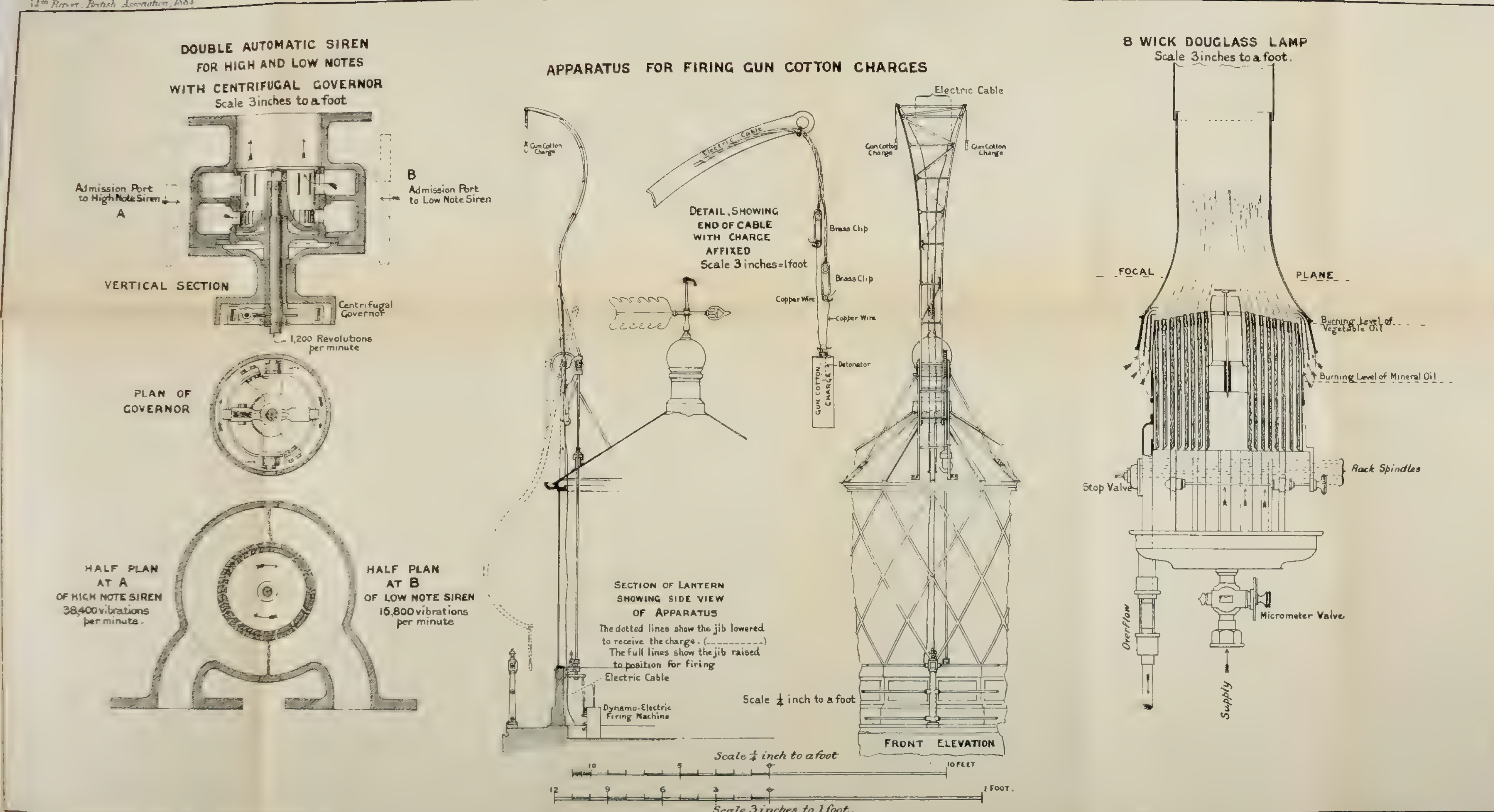


Illustrating Sir James Douglass's Paper 'On Improvements in Coast Signals.'

haustive series of experiments is now being carried out by the Trinity House at the South Foreland with mineral oil, coal and oil gas, and electric arc luminaries, for the purpose of determining the exact relative efficiency and economy of the three illuminants for coast lighting. The results of this important investigation are looked forward to with great interest, as marking an important epoch in the progress of coast lighting.

It is evident that the responsibility for reliable individuality in coast signals increases with the development of trade along any line of coast, more especially since light and sound signals are compulsorily carried by all vessels, whether steam or sailing.

A system of occulting coast signal lights was proposed by the late Charles Babbage, F.R.S., in 1851, but, unfortunately, the system excluded the most powerful and efficient of the existing lights, viz., the revolving or flashing class, whose intensity averages about five times that of the fixed light, and thus Babbage's proposal lay nearly dormant for many years. The subject was brought before the British Association by Sir William Thomson, LL.D., F.R.S., at the Brighton meeting in 1872, when he drew the attention of the Association to the extreme importance of ready identification of lights at sea, and proposed the use of flashing lights, their flashes being of longer or shorter duration; the short and long flashes representing the dot and dash of the Morse alphabet as used in telegraphy.

Until very recently the distinctive characters of coast signal lights consisted of the following—viz., fixed white, fixed red, revolving white, revolving red, revolving alternate white and red. The revolving lights showed a flash at periods of 10 seconds, 20 seconds, 30 seconds, 1 minute, 2 minutes, 3 minutes, and 4 minutes. There were also intermittent or occulting lights having an eclipse at periods of $\frac{1}{2}$ minute, 1 minute, or 2 minutes. It is now generally conceded that fixed lights are no longer to be considered as trustworthy coast signals, owing to their liability to confusion with other lights, both ashore and afloat. It is also generally conceded that the period of a coast signal light should not exceed half a minute; further, that time should not form an element in the determination of the distinctive character of a coast signal. On the coast of England the Trinity House are converting as rapidly as practicable all fixed lights to occulting, where local dangers are required to be covered with a red sector or sectors of danger light. In cases where this local mapping out of dangers is not required, flashing lights, in consequence of their higher intensity, are being adopted.

The electric arc light is eminently efficient for the occulting class of lights with red sectors, owing to the very sharp and perfectly defined lines of demarcation that are capable of being produced between the sectors with a luminary so small and compact at the focus of the optical apparatus.

The French Commission des Phares have lately had under consideration a complete system of electric light and sound signals for the coast of France. They have agreed to abolish as far as possible fixed lights, and they have determined that time shall not be considered an element in the identification of flashing lights. The following code of flashing lights, having periods of about ten seconds, proposed by M. Allard, late Inspector-General of the French Lighthouses, has been adopted for the proposed electric lights when substituted for the existing oil lights, viz.,

Single flashing.

Double flashing.

Triple flashing.

Quadruple flashing.

Double flashing—1 white and 1 red.

Triple flashing—2 white and 1 red.

Quadruple flashing—3 white and 1 red.

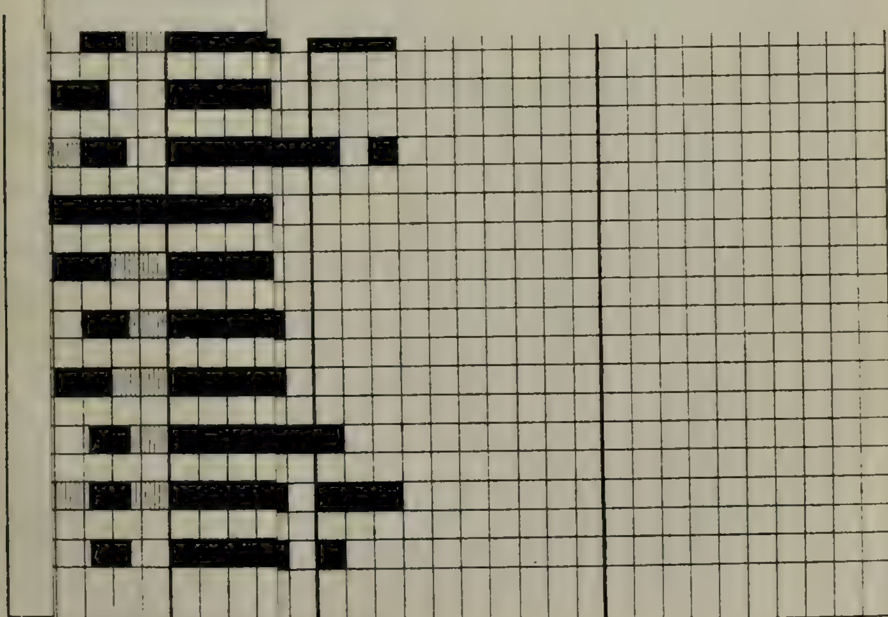
Quintuple flashing—4 white and 1 red.

It would appear to be doubtful whether so limited a code would be found to be sufficient for efficiently covering any important extent of coast, and especially where opposite coasts and mid-channel shoals are required to be lighted.

For the most efficient lighting of a coast, the revolving, or more properly named flashing, class of lights demand the first consideration, on account of their superior intensity and penetrative power as compared with the fixed or occulting class. The fact of being able to obtain from three to seven times the intensity of light with the same expenditure of the illuminating material is of itself a very important consideration, even when judged on its economic merits; but, when considered in its aspect of relative efficiency for the benefit of the mariner, it is impossible to over-estimate its real value, although hitherto its importance does not appear to have been fairly recognised. The number of coast signals throughout the world is about 4,900. Of these about 80 per cent. are fixed lights, 19 per cent. only are flashing lights, and 1 per cent. only are occulting lights. On the extensive sea coasts of the Dominion of Canada there are about 371 coast light signals: of these about 78 per cent. are fixed lights, 20 per cent. flashing lights, and 2 per cent. occulting lights. With regard to the signal lights on the coast of England under the control of the Trinity House, if we except the double fixed lights used as leading lights and for distinction, the fixed lights represent only 16 per cent., while the flashing lights represent 64 per cent. and the occulting lights 20 per cent. of the whole. It is probable that in the course of another year there will not remain a single fixed light in the service of the Trinity House.

On Plate V. are shown two alphabetical codes of flashing lights, nearly all of which can be produced by existing forms of optical apparatus, which is an important consideration. It will be observed that short and long flashes are adopted in the first code, and white and red flashes in the second code. The signals A, M, O, R, and T, in the first code, and the signals A, T, and U in the second code, have been adopted by the Trinity House. With these signals a period of half a minute has been adopted, as shown on the diagram, and this period is found to be generally satisfactory to the mariner. It has the important advantage over shorter periods of a greater intensity of the flashes accumulated during the longer eclipse; and it is to be remembered that the optical apparatus of large coast lights should not be rotated faster than is absolutely necessary, for two reasons: first, to avoid unnecessary wear and tear; and second, to reduce as far as practicable the labour required of the light-keeper in winding up the driving clockwork, which, with some of the largest apparatus, forms the heaviest portion of his duty.

It is an important requirement of any coast signal that the flash or group of flashes given in quick succession occupy not less than 6 to 10 seconds, to enable a mariner, on first sighting the light, to determine on the instant his correct position by a compass bearing. In the proposed codes the mean duration of the groups of flashes is about 10 seconds. It



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Paper 'On

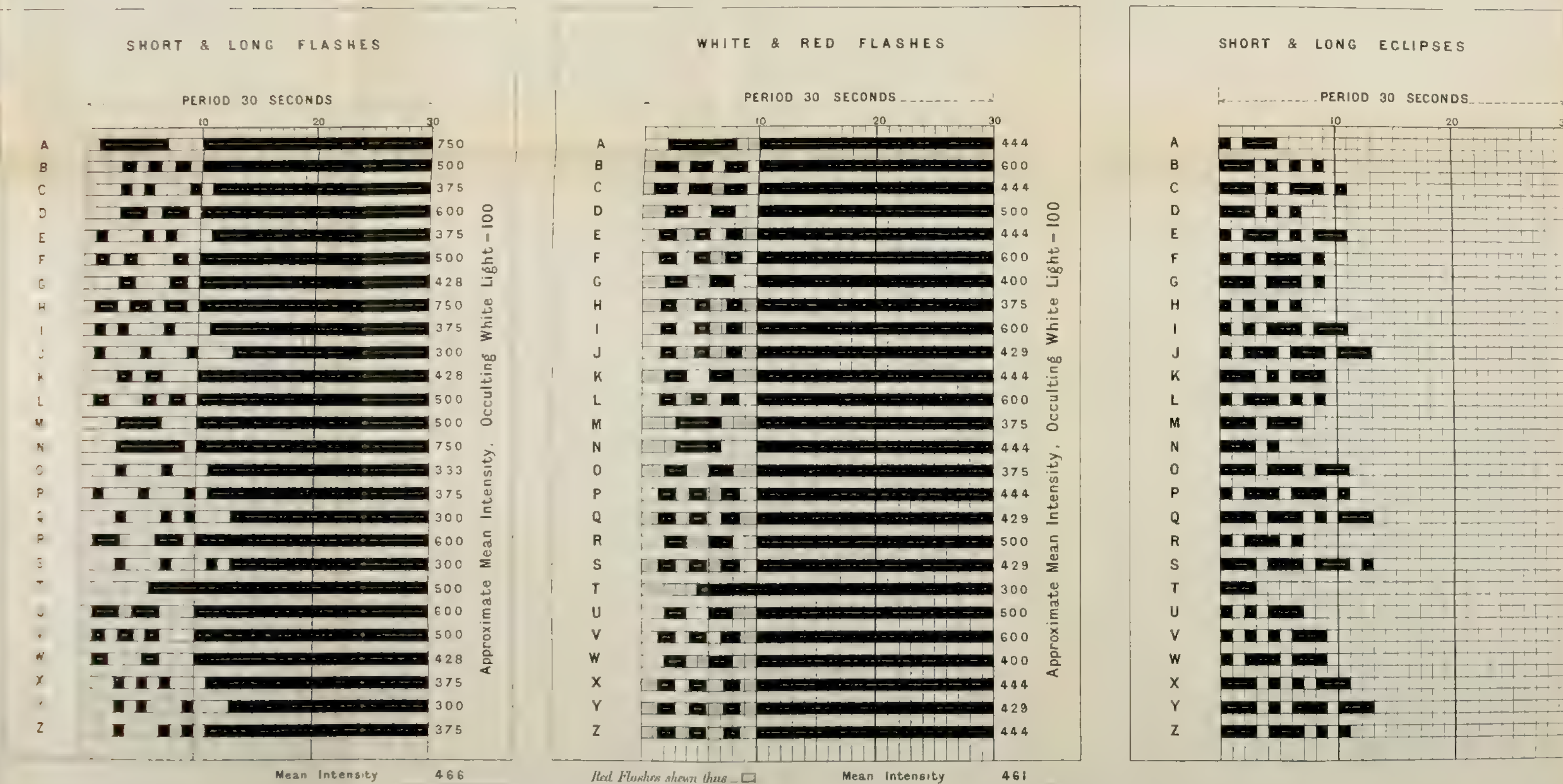
THOs KELL & SON, LITH. 40, KING ST COVENT GARDEN

Distinctive Characters for Coast Signals

Plate V

LIGHT SIGNALS

FLASHING SERIES — OCCULTING SERIES



Illustrating Sir James Douglass's Paper 'On Improvements in Coast Signals.'

will be observed, on comparing the two codes, that their general efficiency with regard to intensity is nearly equal. With the short and long flashing code a waste of light is obviously incurred with the long flashes, which, for rendering them clearly distinctive from the short flashes, are necessarily three times the length of the latter. With the white and red flashing code a loss is also incurred in colouring the red flashes, which are required to have the same penetrative power as the white flashes. This loss is found to be 50 per cent. nearly of the initial intensity. It is found that, with the short and long flashing code on a thickly lighted coast, the distinctions are not sufficiently trustworthy; but, by interposing portions of the white and red code, this difficulty is removed. In the occulting series it will be observed that short and long eclipses are substituted for the short and long flashes of the flashing series, and that the same period of half a minute is proposed. Very fortunately the occulting light is exactly the reverse in appearance of the flashing light. The occulting light is really a fixed light with short eclipses at regular periods, and the flashing light is a flash, or group of flashes, followed by a long eclipse at regular periods. It is, therefore, possible to place occulting lights in close proximity to flashing lights without risk of confusion.

Of all the various sound signals now in use for the guidance of the mariner during fog, viz., bells, gongs, guns, whistles, trumpets, sirens, and sounds produced by explosions of gun-cotton, the sounds produced by the siren and by explosions of gun-cotton have been found to be the most efficient for first-class fog signals; therefore these signals have recently received the greatest care and attention in their development. The siren doubtless ranks first, chiefly on account of the facility it affords for giving sounds of any desired intensity, pitch, or duration; while the explosive sound is always of nearly the same pitch, and its duration is so short as to render it liable to be unheard in consequence, rather than from lack, of power.

The same necessity exists with sound coast signals as with light coast signals for clear and trustworthy distinctive characters; and it is evident that time as an element of distinctiveness should be avoided, and for the following reasons; first, the blast, or group of blasts, or explosions, of a coast fog signal should occupy the same time as the flash or group of flashes of a coast light signal, say 8 to 10 seconds, to enable the mariner on hearing the signal to determine instantly his position by a compass bearing of the sound, which, fortunately, can be accomplished with sufficient accuracy.

It is not considered desirable that the periods of a coast fog signal be so short as those of a coast light signal; indeed, it would appear preferable that sound signals be given more as cautionary aids to navigators. First, in consequence of the uncertainty which necessarily attends the effective range of any sound; and secondly, the necessity for navigators to proceed with the utmost care during fog, to avoid collision with other vessels. Periods of 1, 2, 3, 4, and 5 minutes have been adopted for the siren, and periods of 5, 10, and 15 minutes have been adopted for the explosive signal. The signal of 2 minutes' periods for the siren would appear to fulfil very fairly the required conditions for maximum efficiency. With siren signals sounding one blast of 6 seconds, or groups of two, three, four, or five blasts of 6 seconds collectively every two minutes, we have 6 seconds of blast to 114 seconds of silence, or as 1 to 19; such a signal has, therefore, twenty times

SOUND SIGNALS.

HIGH AND LOW BLASTS.					
A	H	L			
B	L	H	H	H	
C	L	H	L	H	
D	L	H	H		
E	H	L	H	L	
F	H	H	L	H	
G	L	L	H		
H	H	H	H	H	L
I	H	H	L	L	
J	H	L	L	L	
K	L	H	L		
L	H	L	H	H	
M	L	L	H	H	H
N	L	H			
O	L	L	L	H	H
P	H	L	L	H	
Q	L	L	H	L	
R	H	L	H		
S	L	L	L	H	
T	L	H	H	H	
U	H	H	L		
V	H	H	H	L	
W	H	L	L		
X	L	H	H	L	
Y	L	H	L	L	
Z	L	L	H	H	

the intensity in its blasts compared with that of a similar apparatus if sounded continuously. This matter of accumulative intensity is a consideration of very great importance in determining the periods of a siren fog signal in relation to its efficiency for the service of the mariner.

It is evident that, if we adopt a 2 minutes' period for siren coast signal blasts, the number of distinctive characters would be limited to about five, viz.:—

One blast every 2 minutes.
Two „ „ „
Three „ „ „
Four „ „ „
Five „ „ „

If, for the purpose of extending the above code, short and long blasts be adopted, a serious loss of power must be incurred with the long blasts; further, it is found to be very desirable to differentiate the sounds of coast sound signals as completely as possible from the sounds of the whistles and horn signals of steam and sailing vessels; therefore, the question of establishing a code of siren coast blasts composed of notes of high and low pitch has lately received the careful consideration of the Trinity House, and, so far, promises to be very successful. The system has the advantage of the same alphabetical letter or number being appropriated to the light and the sound signal at each station, which is found to be advantageous in aiding the memory of the mariner. I have shown on the previous page a complete alphabetical code of distinctive characters for coast signals, which can thus be adopted, each signal being composed of a combination of high and low notes. The signals A, G, K, N, R, and U have been already adopted by the Trinity House. After a series of exhaustive experimental trials, a high note of 670 vibrations per second and a low note of 290 vibrations per second have been adopted. A slight inferiority in the audibility of the high note, as compared with that of the low note, is found to exist where they both start with the same initial power; but this defect is remedied by increasing the area of the ports of the high-note siren about 20 per cent. On Plate IV. is shown one of the most recent cylindrical first-class sirens in the service of the Trinity House for sounding a high and a low note. The walls of the cylindrical siren chamber, and the corresponding chamber in which it revolves, have two oblique rows of ports, one above the other. The lower row, for the low note, contains fourteen ports, and the upper row, for the high note, contains thirty-two ports. The siren is surrounded by an annular chamber which is divided by a horizontal partition, so that the compressed air or steam for sounding the instrument can be admitted separately to the high or low note ports. On the spindle of the siren, at the lower part, is fitted a centrifugal governor, which is readily adjustable for any required speed of the instrument. It will thus be seen that, by any simple automatic arrangement for the admission of compressed air or steam to the upper or lower ports, any desired distinctive character can be given to the signal.[1]

[1] To Mr. G. H. Slight, Superintendent of the Trinity House workshops, is due the cylindrical form of the instrument, and the adjustable centrifugal governor by which the speed is controlled. The improvement of the instrument in rendering it automatic in its action, instead of being driven by a belt and pulley, was patented in 1875 by Holmes, the inventor of the first magneto-electric machine adopted for lighthouses.

Notwithstanding the short duration of the sound of explosive signals, they are rendering valuable service to the mariner in cases where the siren, or any other powerful form of sound signal, could not be applied, for want of space. The rapidity of combustion, and consequent loud report of charges of gun-cotton, compared with equal charges of gunpowder, together with the safety in storage of the former, have led the Trinity House to adopt gun-cotton largely for coast fog signals; and at the suggestion of the late Admiral Sir Richard Collinson, K.C.B., Deputy Master of the Trinity House, rockets are employed for carrying one or more charges of gun-cotton up to a height of 800 to 1,000 feet, and then causing them to explode. These rockets are most usefully employed at stations where obstacles to the sound-waves occur in the seaward arc over which they are required to be sent. The sound thus elevated has been found to surmount such difficulties most successfully. Gun-cotton has also been found to provide a very efficient coast fog signal at isolated stations on rocks or shoals where previously, from want of space, nothing better than a bell could be applied. On Plate IV. is shown, for this form of signal, the apparatus which I have lately designed, and which is now adopted by the Trinity House. To the roof of the lighthouse lantern is attached a light wrought-iron crane, the jib of which is promptly raised and lowered by a worm-wheel and pinion, worked by a hand-wheel inside the lantern. When the jib is depressed the lower end reaches near the gallery outside the lantern, where the light-keeper suspends the charge or charges of gun-cotton with their detonators already attached to the electric cable or cables, which are carried from the end of the jib to a small dynamo-electric firing machine placed inside the lantern. After suspending the charge or charges, the light-keeper returns to the lantern, when he raises the jib to the upper position, where the charge or charges are fired nearly vertically over the glazing of the lantern, and thus without causing any fracture of the glass.

The New Eddystone Lighthouse.

In a paper contributed to the British Association at the Plymouth meeting in 1877 on the Eddystone Lighthouse, I explained the necessity for erecting a successor to the justly celebrated model of Smeaton, in consequence of the portion of the gneiss rock on which it was founded having been seriously undermined and shaken, also owing to the light being frequently eclipsed by each heavy wave during stormy weather, thus impairing and altering its distinctive character. I now propose to supplement my remarks on 'Improvements in Coast Signals' by a brief reference to the new lighthouse. To the diagrams of the new structure shown I have added diagrams to the same scale of Smeaton's lighthouse, and the two that preceded it, viz., that of Winstanley, erected in 1696, and destroyed by a storm in 1703; the other of Rudyerd, commenced in 1706, lighted in 1708, and destroyed by fire in 1755.

The new tower at the Eddystone is a concave elliptic frustrum standing on a cylindrical base 44 feet in diameter by 22 feet high; the generating curve of the frustrum has a semi-transverse axis of 173 feet, and a semi-conjugate axis of 37 feet. The mean focal plane of the light is 133 feet above high water, having a nautical range of $17\frac{1}{2}$ miles. The tower consists of 2,171 stones, containing 62,133 cubic feet, or 4,668 tons of granite. All the stones are dovetailed together both horizontally and vertically, as shown, on a system suggested by the late Mr. Nicholas Douglass, C.E., for the Hanois Lighthouse near the island of Guernsey. From experiments which have been made upon blocks of hard granite put together in this manner with Portland cement, it has been found that the work is so homogeneous as to be as nearly as possible equal to solid granite. The system also affords great protection to both horizontal and vertical joints against the wash of the sea and general safety to the work when first set, thus greatly facilitating the execution of such an exposed sea structure. Each stone of the foundation courses is sunk to a depth of not less than one foot below the surrounding surface of the rock, and is further secured to the rock by two yellow metal bolts. The tower contains nine rooms, which are fitted up for the accommodation of the light-keepers and the stores necessary for the service of the light. The rooms are rendered as far as possible fire-proof, the floors being of granite, the stairs and partitions of iron, and the external doors, windows, and shutters of gun-metal. The two oil rooms are capable of storing 4,300 gallons of oil, and the water tanks have a capacity of 4,700 gallons. The lantern is of the cylindrical helically framed type now generally adopted by the Trinity House. The distinctive character of the light adopted for this station, to replace the old fixed light, is white, double-flashing at half-minute periods, showing two successive flashes, each of about 3½ seconds' duration, divided by an eclipse of about 3 seconds, the second flash being followed by an eclipse of about 20 seconds. The optical apparatus consists of two superposed tiers of lenses, twelve in each tier. The section of these lenses, which are of the first-order dimensions, having a common focus at a distance of 920 millimetres, was designed by Dr. John Hopkinson, C.E., F.R.S., in 1880, for the Anvil Point Lighthouse. Each lens subtends a horizontal angle at its focus of 30 degrees, and a vertical angle of 92 degrees. This increased vertical angle, which is the largest yet adopted for coast illumination, has been obtained by the adoption of heavy flint-glass for the six highest and for the three lowest rings of each lens panel. The relative efficiency of this section of lens and that of the old section is 88 to 70 nearly, and its power is only about 12 per cent. less than that of the complete section of a Fresnel first-order apparatus, composed of lenses combined with totally reflecting prisms above and below them. The focal light is produced by two six-wick 'Douglass' oil-burners, one being placed in the common focus of each tier of lenses. With a clear atmosphere, and the Plymouth Breakwater light, ten miles distant, clearly visible, the lower burner only is worked, and at its minimum intensity of about 450 candle units, giving an intensity of the flashes of the optical apparatus of about 37,000 candles; but, whenever the atmosphere is so thick as to impair the visibility of the Breakwater light, the full power of the two burners is put in action, with an aggregate intensity in the flashes of the optical apparatus of about 159,000 candle units. This intensity is about twenty-three times greater than that of the fixed dioptric light latterly exhibited from Smeaton's tower, and about 3,280 times the intensity of the light originally exhibited in the same tower from tallow candles. The Eddystone furnishes complete evidence of the recent progress in lighthouse illumination, and of the great value of perfect optical apparatus for the utilisation of the illuminant for the benefit of the mariner. The original chandelier light in Smeaton's lighthouse was unaided by optical apparatus, the intensity of the aggregate light of its twenty-four tallow candles was about sixty-seven candle units, and its cost per hour at the current price of tallow candles would be nearly identical with the average cost per hour of the present light, which is about 2,380 times its intensity.

The first landing at the rock was made in July 1878. Around the foundation of the tower a strong coffer-dam of brick and quick-setting Roman cement was built, as favourable opportunities of smooth water and low tides occurred. The water was removed from this dam at each tide by steam pumps worked on board the twin screw tender.

The work of cutting out the foundations was much facilitated by the use of rock drills driven by compressed air supplied from the tender. For landing stone the tender was moored at about 30 fathoms from the rock, and the stones, averaging $2\frac{1}{2}$ tons each, were landed by her machinery. Thus every stone in the building, together with the required cement, sand, water, &c., was landed and hoisted to the summit of the work at single hoists. This is probably the first application of floating machinery to the actual erection of an exposed structure at sea. On August 19, 1879, the foundation stone was laid by His Royal Highness the Duke of Edinburgh, Master of the Trinity House, who was accompanied by His Royal Highness the Prince of Wales, an Elder Brother of the Trinity House. On June 1, 1881, the last stone of the tower was laid by His Royal Highness the Master, and on May 18, 1882, His Royal Highness completed the undertaking by lighting the lamps and formally opening the lighthouse. The work was thus accomplished within four years of its commencement and one year under the time estimated. The author's estimate for the lighthouse was 78,000*l.* Tenders for executing the work were obtained by the Trinity House from six eminent contracting firms experienced in the construction of sea structures; but, as the lowest offer was considerably in excess of the approved estimate, the Trinity House determined on carrying out the work, as in previous similar cases, by their own engineering staff. The lighthouse was thus completed at a cost of 59,255*l.*, being $23\frac{1}{2}$ per cent. below the estimate. The low cost was mainly due to the successful operation of the various special mechanical appliances introduced for saving manual labour and facilitating the progress of the work. On the completion of the new lighthouse, the lantern and upper part of Smeaton's tower, comprising the four rooms, were carefully taken down and removed to Plymouth, where, by the public-spirited community of that town, the hope I ventured to express at the Plymouth meeting of the British Association is being realised. The lighthouse is being re-erected on a suitable site on Plymouth Hoe as a beacon for the further benefit of the mariner; and there, it is to be hoped, it will ever remain as a monument to the genius of Smeaton.

[The diagrams illustrative of the lighthouse have not been engraved.]

On American Permanent Way.

By JOSEPH M. WILSON, *A.M.*, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATES VI.—VIII.]

THE word 'American' covers a very wide field, including not only Canada and the United States, but the whole continent: a vast extent of country, with all its varying conditions of climate, of constructive material, and of railway requirements.

When, therefore, American Permanent Way comes to be considered, the subject must necessarily involve a considerable variety of constructions, depending upon location and other conditions. Thus the form of construction required for a railroad in the Northern United States or in Canada, built to resist the severe winters of these latitudes, might be unnecessarily expensive for the mild climate of the south; also roads with heavy traffic require a more solid and substantial construction than those having only a light service; then, again, the materials of construction available in places geographically far apart are often very different, and the engineer must adapt himself to circumstances, using what materials he can best obtain at a reasonable cost.

Permanent Way, or railway superstructure, as it is sometimes called, is that portion of railway which directly receives the weight of the moving trains, and transmits it to the road-bed below. It comprises the rails, the cross-ties or sleepers to which these are attached, and the distributing material in which the ties or sleepers are bedded. The object of the permanent way, no matter how constructed, is in all cases the same —to provide a way for the running equipment of the road to move upon, and to so transmit and distribute the weight from this to the substructure, that the latter, which is usually a soft material, as earth, may be able to sustain the load without settlement.

American Permanent Way only differs from that of other countries in the adaptation of the materials available for the construction of the work, taking into consideration their relative abundance and value, and displaying, perhaps, some of the aptness for which Americans have a reputation.

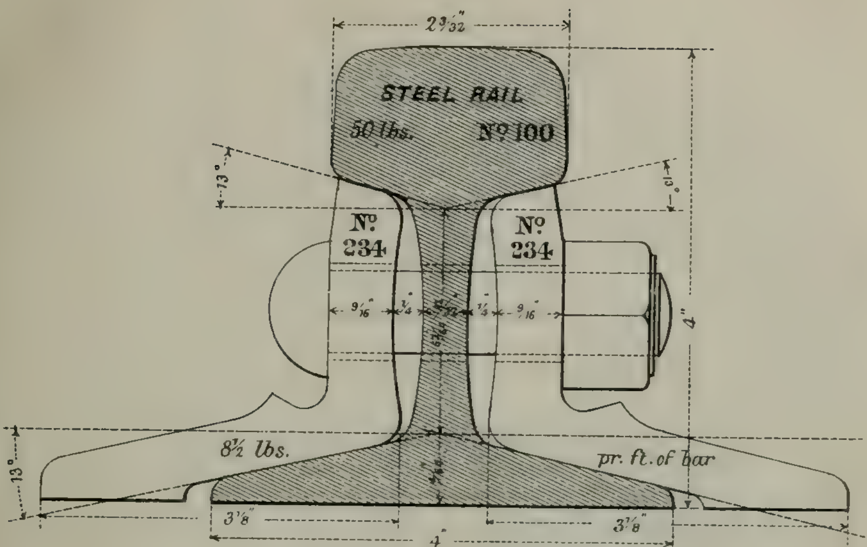
It is necessary for a first-class perfect track to have good surface, good drainage, true line, accurate gauge, and tight joints.

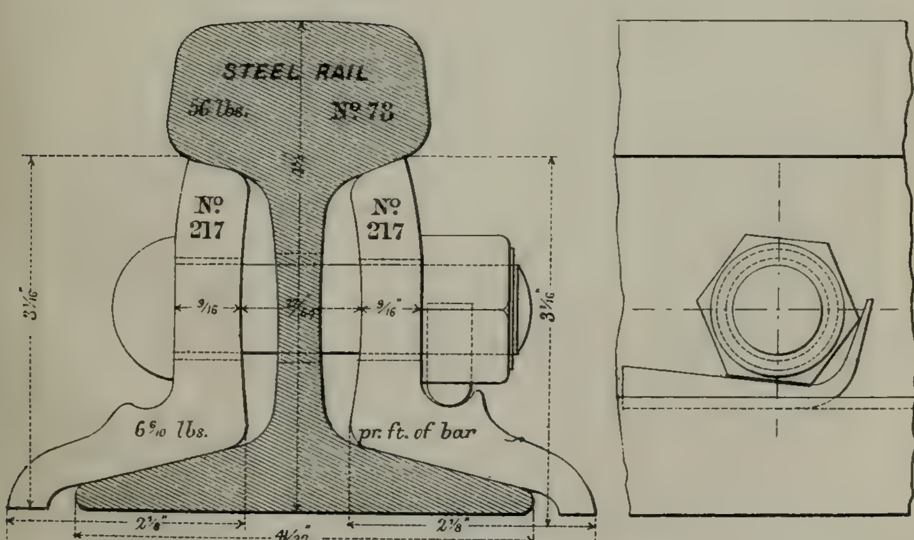
Rails have been made of wood, iron, and steel. Wood is so soft a substance, and so perishable, that it can only be employed for very light and temporary service, such as is sometimes required in lumber regions. It has been so employed, and may be considered as essentially 'American.' Iron and steel are the materials used throughout the world for railway service proper, and the cost of steel in late years has so nearly approached that of iron, that with its vastly superior qualities it is rapidly driving iron out of use; in fact, the use of iron may already be said to be of the past. The shape and weight of the rail is governed by several conditions. Its section must be so formed at the top as to properly carry the wheels of the moving load with the least amount of wear, and at the bottom so that it may be securely attached to the supports upon which it rests, at the same time transmitting the load effectively to them. It must be designed with the greatest possible economy in weight, to carry with safety its load between the points of support, acting as a continuous girder of a span equal to the distance of the points of support apart, or rather twice that distance, so that in case any one should fail or give way, the rail would still be able to carry over the increased span with safety. Theory therefore points to a deep rail having a comparatively thin web, with upper and lower flanges, the upper flange being rounded to the proper shape to receive the wheels of the moving load, allowing sufficient width of bearing surface to prevent crushing under the action of the wheels, but not more than necessary, as the friction would otherwise be increased; and the lower flange shaped to adapt it to the mode of support adopted. In England, where iron chairs of peculiar kind are used to carry the rail, the lower flange is made of a similar form to the upper, while on the Continent of Europe and in America the lower flange is made flat to rest on a timber tie or sleeper. The width of this flange should be such that the load will not cause the rail to sink into the timber. The web of the rail must be sufficiently thick to give stiffness sideways, and prevent the load bending the top of the rail over and crushing it. The section of the rail is made symmetrical about a vertical axis, allowing of reversal, if desired, when the inner edge has become seriously worn by the wheels.

As to the proper depth and weight of the rail, it will readily be seen that this depends upon the distance that the supports are placed apart and the load carried. The loads carried on first-class American railways are no lighter than those carried on European railways. Class K engine, as used on the Pennsylvania Railroad, has a total weight in working order of 92,700 pounds, distributed on a wheel base of 22 feet $7\frac{1}{2}$ inches, and a weight on the first pair of drivers of 33,600 pounds. Class L engine, on same road, has a total weight of 124,100 pounds, on a wheel base of 31 feet 4 inches, with a load on the main pair of drivers of 32,500 pounds. Class M engine has a total weight of 87,500 pounds, on a wheel base of only 10 feet 8 inches, and a weight on the first pair of drivers of 33,400 pounds. But in Europe, where timber is expensive, the ties or sleepers are placed farther apart than they are in America, and therefore heavier rails are required. So long as timber is cheap in this country light rails will be used, but there is a tendency on some lines to heavier rails.

In assuming the proper load to be used in calculating the proportions and weight of rail, it is not sufficient to take the static weight from the heaviest wheel, but an amount must be added to this on account of the load being a live or moving load, and also for impact, the tendency of a rapidly moving train, particularly with the driving wheels of the engine, being to pound down as it were upon the track, making sudden applications of heavy loads. The percentages of addition thus required to the dead load cannot be determined theoretically, but must be assumed more or less empirically, depending upon the results of practical experience. The rails, when fastened firmly to their supports, must also possess sufficient lateral stiffness to resist all deflection sideways from the swinging motion of the train, centrifugal force on curves, &c.

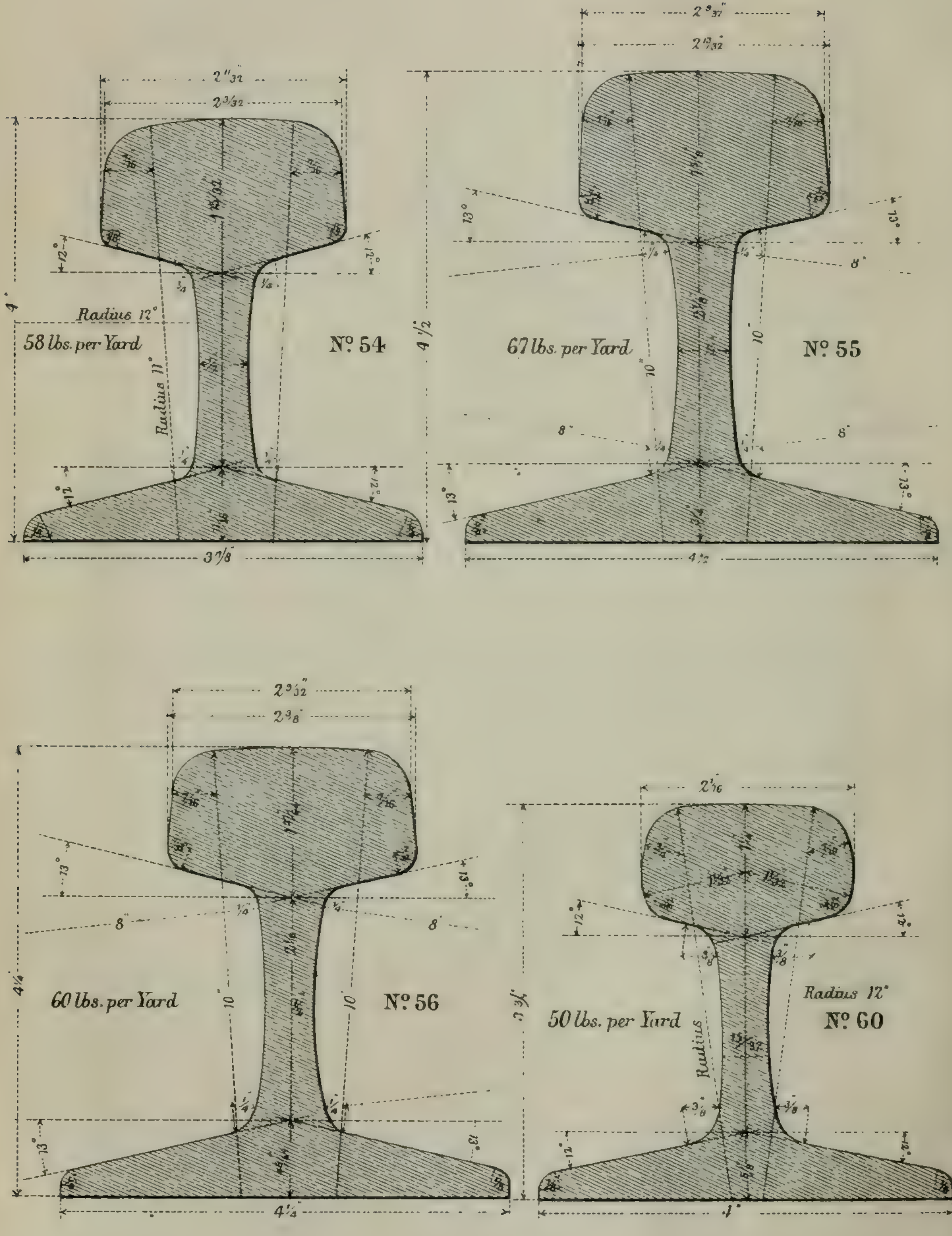
The author is indebted to the courtesy of the Cambria Iron Company, Johnstown, Penn., for the standard sections of steel rails shown on Plates





CAMBRIA PATENTED RAIL JOINT.

Illustrating Mr. J. M. Wilson's Paper 'on American Permanent Way.'



Illustrating Mr. J. M. Wilson's Paper 'on American Permanent Way.'

VI. and VII., as adopted and in use on a number of American roads. These will represent pretty fairly the general practice throughout the country. In comparing these it must be borne in mind that the service on some lines is not so severe as on others; also that the same railroad company uses lighter sections on its branch lines than on its main stem, on account of the difference in service. Sections that are quite suitable in one case are not so in others.

The numbers by which the several sections are designated are those of the Cambria Iron Company. Where the roads using any section are noted, and the date is given, it simply means that this section was rolled for that railroad at that date. It does not follow that the railroad in question may not have changed its section at some other mill since then; but this is a matter that could not be ascertained, and its probability is not very great.

The Grand Trunk Railway of Canada uses the Sandberg pattern of T rail, weight 65 pounds per yard.

The Chicago and North-Western Railway Company are using 30-feet rails, the weight on main lines since 1882 being 65 pounds per yard, on less important lines 60 pounds per yard, and some 56 and 50 pound rails on branches.

The material of which rails are formed requires great care in selection. It must be sufficiently strong to sustain as a girder, tough to avoid all brittleness and danger of breaking under sudden shocks, and at the same time compact in texture and having hardness in the top to resist wearing action under service. With iron rails it is sought to arrange for these qualities in the packing or building up of the masses of iron from which the rails are rolled, taking advantage of the well-known principle that the different parts of the mass keep their same relative positions in the section of the bar when rolled out as in the original pile. Harder material is put in the top of the pile, and softer in the bottom. Steel rails, however, are rolled from solid ingots, and as a consequence they are of a homogeneous texture throughout. They do not split like iron rails, which sometimes shows the result of imperfect welding between the separate pieces of which the original pile from which the rail was rolled was formed.

Rails are rolled to a certain maximum length, 30 feet being the usual standard on American roads; but there is always a certain proportion of shorter rails allowed, which however must conform to regular specified lengths, these being generally arranged to conform to the standard spacings of the cross-ties.

The following specification of the Pennsylvania Railroad Company for steel rails, adopted January 27, 1879, may be regarded as a standard for first-class manufacture:—

'As it is the desire of the Pennsylvania Railroad Company to have on the roads under their control none but first-class tracks in every respect, and as the rails laid down on these tracks form an important part in the achievement of this result, the Pennsylvania Railroad Company have found it necessary to make certain demands in regard to the manufacture of their steel rails, with which the different rolling mills and rail inspectors will be required to comply:—

'1. The steel used for rails shall be in accordance with the "pneumatic" or "the open hearth" process, and contain not less than thirty nor more than fifty one-hundredths of one per cent. of carbon.

'2. The result of the carbon test of each charge, of which the

Pennsylvania Railroad Company is to receive rails, and of which an official record is kept at each mill, is to be exhibited to the rail inspector.

'3. A test bar, three quarters of an inch wide, and about ten inches long, is to be taken from a web of rail made from each charge.

'4. The number of the charge and place and year of manufacture shall be marked in plain figures and letters on the side of the web of each rail.

'5. The sections of the rails rolled shall correspond with the respective templates issued by the Pennsylvania Railroad Company, showing the shape and dimensions of the different rails adopted as their standard.

'6. The space between the web of the rails and template representing the splice-bar shall not be less than one quarter of an inch, nor more than three-eighths of an inch.

'7. The weight of rails shall be kept as near to the standard weights as can be demanded after complying with section No. 5.

'8. Circular holes one inch in diameter shall be drilled through the web in the centre thereof, at equal distances from the upper surface of the flange and lower surface of the head, and three and fifteen-sixteenths inches from the end of the rail to the centre of the first hole, and of five inches from the centre of the first hole to the centre of the second hole.

'9. The lengths of rails at sixty degrees Fahrenheit shall be kept within one quarter of an inch of the standard lengths, which are thirty feet, twenty-seven and one-half and twenty-five feet. That not more than ten per cent. of the shorter lengths, nor more than five per cent. of No. 2 rails, will be accepted on any one contract.

'10. The rough edges produced at the ends of the rails by the saw shall be well trimmed off and filed.

'11. All rails are to be straightened in order to insure a perfectly straight track.

'12. The causes for temporary rejection of the rails are—

'(1) Crooked rails.

'(2) Imperfect ends (which, after being cut off, would give a perfect rail of one of the standard short lengths).

'(3) Missing test reports.

'(4) A variation of more than one quarter of an inch from the standard lengths.

'13. The causes for the permanent rejection of a rail, as a No. 1 rail, are—

'(1) A bad test report, showing a deficiency or excess of carbon.

'(2) The presence of a flaw of one quarter of an inch in depth in any part of the rail.

'(3) A greater variation between the rail and splice-bar than is allowed in paragraph No. 6.

'(4) The presence of such other imperfections as may involve a possibility of the rail breaking in the track.'

In the construction of a railroad, the rails should be accurately laid to line and level stakes as given by the engineer. On straight lines the two rails of a track must be laid to the same level, but on curves the outer rail is elevated according to the degree of curvature, the elevation commencing at each end back of the point of curvature, by a distance also depending upon the sharpness of the curve, and increasing to the curve itself, around which the full elevation is carried uniformly. The amount of elevation varies on different roads, and indeed on the branches and main stem of the same road, depending upon the velocity at which trains are intended to be run. If one rides at a rapid rate over a road adapted in this respect for slow speed, he will soon discover the want of elevation to the curves. John B. Henck, an American civil engineer of great reputation for his 'Field-book for Railroad Engineers,' published many years ago, gives the following table for elevation of the outer rail on curves, based on the question of centrifugal force tending to throw the car against the outer rail, and the elevation of the same above the inner one to counteract it. Practical use of this table has demonstrated its correctness. M in the table represents the speed of train in miles per hour, and the elevation is given in decimals of a foot for the degree of curvature and the speed of train M.

ELEVATION OF OUTER RAIL ON CURVES.

John B. Henck, A.M., C.E.

Degree	M=15	M=20	M=25	M=30	M=40	M=50
1°	·012	·022	·034	·049	·088	·137
2	·025	·044	·068	·099	·175	·274
3	·037	·066	·103	·148	·263	·411
4	·049	·088	·137	·197	·351	·548
5	·062	·110	·171	·247	·438	·688
6	·074	·131	·205	·296	·526	·822
7	·086	·153	·240	·345	·613	·958
8	·099	·175	·274	·394	·701	1·095
9	·111	·197	·308	·443	·788	1·232
10	·123	·219	·342	·493	·876	1·368

Of course some of these figures are merely theoretical, and out of the question practically. No one would expect to go around a ten-degree curve at 50 miles per hour, but would reduce speed.

The Atlantic and Pacific Railroad Company elevate the curve one half-inch per degree up to a ten-degree curve which has an elevation of 5 inches, and all sharper curves are kept at this same elevation. This corresponds very nearly with Henck's table for thirty miles per hour. The elevation of outer rail is run off, on to straight track, a distance of 10 feet per degree of curvature. Thus for a two-degree curve the distance on the tangent is 20 feet, and for a ten-degree curve it is 100 feet. There may be cases where reverse curves come close together, and this rule cannot be strictly carried out; but an endeavour is always made in such cases, if possible, to secure at least 50 feet of level track on a tangent. Where two curves in the same direction are connected by a tangent less than 100 feet long, the elevation is carried through from curve to curve without reduction; and if the tangent exceeds 100 feet the regular inclinations are made from each curve until they meet, or until level track is reached. These illustrations will serve to show the variations in practice with different roads. The rules for elevation of course do not apply in yard tracks. All rails for curves should be bent to the proper curvature before being laid on the ties.

Several different standards of gauge of track have been used on American roads: 6 feet, 5 feet, 4 feet $8\frac{1}{2}$ inches or 4 feet 9 inches (a modification adopted for compromise cars), also the various narrow gauges, from 2 feet 6 inches to 3 feet 6 inches. There is a considerable tendency towards a uniform gauge of 4 feet $8\frac{1}{2}$ or 9 inches, and there have been several noted changes on long lines from 6 feet gauge to 4 feet $8\frac{1}{2}$ inches, the operation being performed in an almost incredibly short interval of time.

Rails are connected together by joints, and the more closely a joint approximates to a continuous rail, the nearer it reaches perfection. Some years ago the joints were placed on the supports, but they proved too rigid, the ends of the rails being hammered or battered down under service, and it was found best to place them between the supports. The use of double fish-plates has now become almost universal. These fish-plates or splices are made to hug up well between the top and bottom flanges of the rail, and in their best form are generally about 24 inches in length, with a wide angular flange spreading out over the lower flange of the rail. Two splices are used at each joint, one on each side of the rails, and they are connected together through the webs of the rails by four bolts which draw them up tightly together, rigidly binding the rails into line and surface. These bolts have semi-spherical heads, allowing as little obstruction as possible, and they should be arranged so that they cannot turn in the holes; the nuts, which are always placed on the outside of the track, being provided with some approved mechanical device to prevent turning and consequently loosening of the bolts. A spiral washer, as shown in the illustration of standard track Pennsylvania Railroad, answers very well, and the arrangement used by the Cambria Iron Company (see Plate VI.) is also good. An allowance must always be made in a joint between the ends of the rails, for expansion. The maximum amount will vary probably somewhat with the climate, being dependent upon the difference between the extremes of temperature at different times of the year, and the space actually allowed in the process of track-laying is of course different at different seasons. In latitude 40 degrees it is customary to give 5-16ths of an inch in winter and 1-16th of an inch in summer. Iron shims of the requisite thickness should be used to separate the rails in laying. The best practice places the joint of one line of rails opposite the centre of the rail on the other line of the same track. This arrangement tends to break up any tendency to a regular jolting or jumping of the cars as they pass over the joints, an effect that increases by the regular repetition, and is very disagreeable on roads laid with the joints opposite. Plate VI. shows another form of rail-fastenings, for which the author is also indebted to the Cambria Iron Company.

Supports of iron for the rails have been adopted with success, where timber is very scarce or is liable to rapid decay, as in India or other tropical countries. In temperate climates, however, timber is used almost universally, creosoting or some other preservative process being sometimes employed, particularly in Europe, to increase its longevity. There is a prevalent opinion that timber, on account of its elasticity, is essential for supports in order to make a good road; but this does not seem to be borne out in fact, as iron has been used quite successfully where its expense has not been an objection. In America timber is still abundant, and many years may elapse before other material is used to any extent; but the time *will* come when something else must take its place, and far-seeing railroad men are already looking forward to the wrought-iron or steel cross-tie of the future. Notwithstanding the experience of Europe, it is a question whether preservatives are of much use for wooden ties in America. On roads where there is heavy service, the material often wears out before decaying; the harder kinds of wood, which are the best for service, do not absorb a preservative solution as readily as the softer and inferior kinds, which latter wear out very rapidly, and the cost of using a preservative would only be a useless expense.

On roads with very light traffic, operated by horse-power, as street railways, longitudinal timbers placed under the rails have been generally used as supports, those for the same track being tied across at intervals to preserve the gauge of track. This arrangement, however, will not answer for locomotive traffic; and even for street railways, as already intimated by the author, it is being abandoned, a form of rail being adopted that will admit of the use of cross ties. A longitudinal sleeper is very apt to split with the spikes which must be driven into it at frequent intervals in its length to hold the rail, water gets into these cracks, softening and decaying the timber, and there is a great tendency in the rail to sink into the wood, the supporting power being lost. Timber will always bear a load best resting across the grain, even when in first-class condition; the cross-tie system also offers great advantages in renewals over the longitudinal stringer system, vastly increasing facilities of replacing material without delay or interruption of traffic. Even on bridges where longitudinal stringers have been used for years, on account of advantages obtained in the details of construction of the floor system, they are now being abandoned and a cross-tie system adopted. The *rationale* of the present almost universal method of timber cross-tie supports is therefore readily seen.

These ties are placed at frequent intervals, sufficient to properly support the rails, the latter being securely spiked to them, and the ties, in addition to giving the proper support, tie the rails together to gauge, and by their hold in the ballast below, keep the whole track in line. Hence the American word '*cross-tie*,' at once descriptive and appropriate. The cross-tie should, if possible, be of what is technically termed 'hard wood,' and of all woods in America the best for this purpose is white oak. This is the case at least in the temperate zone. There may be some woods in the tropics, unknown to the author, that are better.

The more bearing surface the rail has on the tie, and the more surface the tie has on the ballasting material below it, the better and more stable the track. Hence the ties should be flattened on the upper and lower sides, and a minimum width of flat surface should be specified, less than which will not be allowed. The sides of the ties are only barked and left rounding. Sawed ties are sometimes used cut square on all sides, but hewn ties are by far the best, less liable to decay, and giving a better shape with the rounded sides. The length of the tie should be sufficient to give ample allowance outside of each rail and all the requisite bearing surface on the ballast below. Hard-wood ties not only carry the rails better than soft wood, but they will also hold the spikes two or three times as firmly. In soft wood the spike bruises and breaks the fibres, while in hard wood it tends to compress and push them back on themselves, increasing the pressure against the sides of the spike and holding it tighter. The great scarcity of hard woods in some sections necessitates, however, the use of softer and inferior material—hemlock, spruce, the various kinds of pine, &c.—and hemlock in particular is used in large quantities, being very abundantly distributed over the country, notwithstanding that it is one of the poorest woods for the purpose, and liable to very rapid and deceptive decay, the interior going first, leaving only a hollow shell of good timber outside.

In Canada, tamarac and cedar are also used for ties. Tamarac can only be obtained in certain districts. It is a timber somewhat resembling larch, is higher priced than hemlock, but lasts longer. Cedar and locust are both good woods in lasting properties, but are softer than desirable, particularly the former.

Uniformity in the size of cross-ties is important, especially in cold latitudes, as in the spring of the year large ties hold the frost much longer than the smaller ones, and irregularity in line and surface of road occur under service.

The spikes which are used to secure the rails to the cross-ties should not be less than 5 inches in length, better $5\frac{1}{2}$ inches, should be square in section $\frac{9}{16}$ of an inch each side, and should have a flat head projecting to one side to catch the flange of the rail. The lower end of the spike should be flat- or chisel-pointed in a direction to cut across the grain of the tie, and not to split it. The spikes should be sound, smooth, well-shaped, and of double-refined iron, bending cold at least ninety degrees without sign of fracture. The length of spike necessitates the depth of cross-ties being at least 6 to 7 inches, and they should also be of this size to perform their other requirements. They should have not less than 8 inches across their flatted surface, and ought to be at least 8 or, better, $8\frac{1}{2}$ feet long for a 4 feet $8\frac{1}{2}$ inches or 4 feet 9 inches gauge.

Some years ago the regular distance for laying cross-ties was 2 feet 6 inches centre to centre, and this may still be the custom on some of the lighter roads, but those with heavier surface are now laying them much closer. They are usually placed 18 inches to centres under joints, and 2 feet to centres at other places, making for a 30-feet rail 2,640 ties to the mile of single track. Circumstances may, however, justify the engineer increasing the distance. The question is governed by the width of tie, the allowable carrying length of rail, and the space required between the ties to provide for proper tamping of ballast around them.

A true track requires, of course, that the ties should be laid to a uniform top surface. If the tie is twisted it should be made true on top by adzing, to give an even bearing to the rail for the whole width, but under no circumstances should a tie be notched. This only allows water to enter the pores and decay the timber, besides being a disfigurement to the track. The ends of the ties should be lined up parallel with the rail on one side, always the outside for double track, the ties should be well rammed into the ballast or bearing material below them, and they must have a solid bearing for their whole length. The rails must be spiked on the inside and outside at each tie, on straight lines as well as on curves, and the spikes must be driven so as to keep the ties at right angles to the rails. There are therefore four spikes to each tie. Those on opposite sides of the same rail should not be placed in line, as it increases the tendency of the tie to split; and this rule should be carried out also at splices, the two spike notches in each splice being made unsymmetrical with the centre of splice so as to insure this result. Special ties are required under switches and crossings, according to the standard diagrams of the special road for which they are intended.

The ordinary life of a tie is from five to ten years, depending upon location, drainage, service, &c. White oak ties only last on the main line of the Pennsylvania Railroad from five to six years on an average, but they might have nearly double that life on a road with less and lighter traffic. Hemlock and spruce, in favourable locations, will last from three to five years, and cedar eight to ten years, but the latter being so soft a wood will only stand light service on easy grades. Timber will last much longer in a severe climate where it is frozen up uniformly for many months in the year, than it will in a temperate climate, exposed to alternate freezing and thawing.

The following is the standard specification of the Pennsylvania Railroad for cross-ties as adopted January 1, 1879:—

'1. All ties must be made of green or living timber, of good quality, and free from decayed knots or other unsound parts. White oak and rock oak will be the only kinds of timber admitted.

'2. Ties must be eight and a half feet long, seven inches thick, and not less than seven inches wide; to be hewn on two sides with straight faces, of an even thickness, sawed off square at each end, and stripped of the bark.

'3. No variation will be allowed in the length and thickness given above.

'4. No sawed or split ties will be received.

'5. They must be delivered on the line of the railroad, stacked up in neat square stacks of fifty each, with alternate layers crossing each other, on ground which is as high or higher than the grade of the road, and in such position as to admit of being counted and inspected.

'6. Ties delivered at suitable and convenient places, will be inspected, and bills made for all received and accepted to the fifteenth of each month. The payments will be made on or about the fifteenth of succeeding month.'

The number of ties used for each 30-feet rail are—for main running tracks, sixteen ties; for branch roads and third tracks on main lines used exclusively for freight trains, fourteen ties; and for sidings and tracks used for standing cars only, not exceeding twelve ties.

The Grand Trunk Railway of Canada uses ties 8 inches flatted face, by 6 inches thick and 8 feet long, 2,640 to the mile. The material is white oak, hemlock, or tamarac, the former now becoming very scarce. White oak lasts ten to twelve years, and the other woods about six years.

The Atlantic and Pacific Railroad (western division) uses ties 8 inches by 6 inches by 8 feet long, mostly native pine, but on heavy grades and curves oak ties are used; number to the mile, 2,816.

The Cincinnati Southern Railway specifies ties 'of either white, post, burr, or chestnut oak, or other timber approved by the engineer, cut from sound live timber, free from rotten or loose knots, worm-holes, dry rot, wind-shakes, or other imperfections affecting the strength and durability of the wood. All bark must be removed. They must be 8 feet in length, not less than 6 or more than 6½ inches in thickness; one-fourth the number must measure not less than ten inches face for the entire length of the tie, and the remainder not less than 8 inches; the faces must be parallel, not winding, smooth, free from deep score-marks and splinters. Ties must be cut square at the ends, and be straight in all directions. Not more than one inch of sap will be allowed on the face of sawed ties. 2,640 ties are used to the mile of single track.'

The standard hard-wood ties of the Chicago and North-Western Railway have the following order of value: white oak, burr oak, red elm, cherry, black ash, and butternut. They are 8 feet in length, and 6 by 8 inches section if sawed, or 6 inches thick with 6 inches face if hewn.

The soft wood ties are cedar and hemlock, and have 7 inches depth by 7 inches face; 3,000 ties are used to the mile.

The Chicago, Burlington, and Quincy Railroad uses oak ties entirely on main line, but cedar on some of the branches, the sizes being the same as for oak. The specifications for oak ties require all to be hewn from sound live white, burr, or post oak, 8 feet long when squared at the ends, not less than 6 inches nor more than 7 inches thick, at least 85 per cent. to have not less than 8 inches face, and none less than 7 inches face. 3,000 ties are used to the mile on main line, and down to 2,640 on the branches.

The cross-ties are bedded in what is termed ballast. The embankment or cutting of the road is finished to a certain width, depending upon the question of single or double track, and the class of road that is being built. In cuttings sufficient width must always be allowed for good drainage ditches on each side, and on embankments enough width to rightly sustain the ballast and ties. The road-bed should then be sloped from the central portion to the sides to drain off properly. Embankments on single track are made from 14 to 16 feet wide at top, and 24 to 28 feet on double track. Cuttings on single track are from 16 to 21 feet wide, and on double track 26 to 32 feet. It may be necessary in some cuttings, depending upon the nature of the material and its liability to wash down on the track, to have very wide ditches, and these exceptional cases must be provided for. The road-bed being properly prepared, the ballast is laid upon it. This ballast is either broken stone, gravel, sand, burnt clay, cinders, shells, refuse coal-siftings from the mines, &c., or simply earth, the latter being really no ballast at all, but merely the ties bedded in the earth, properly rammed, and surfaced with the right slope for drainage between the ties. The question of material for ballast depends altogether on what can be obtained at a reasonable price; and if inferior material is used, of course so much the less perfect the road is.

The ballast acts as an elastic bed, receiving the load from the moving train and spreading it out over a broad surface, and also serves as a drain to carry off the water from rain or snow to the ditches, and not allow it to freeze around the ties in winter, or to form wet holes in the road-bed, into which the ties and ballast will work and sink. First-class ballast material should be clean, hard, and always of such consistency as will allow of the passage of water through it. The best ballast is a hard durable stone, not liable to decomposition or disintegration under the action of the weather, such as limestone or trap, when broken into angular fragments not larger than will pass through a two and a half inch ring. The amount placed under the ties is very variable, the question, unfortunately, not always being how much is best, but how much can the railroad company afford to use. For the best, or a first-class track, there should not be less than 12 inches, although many roads which are considered as high-class do not use over 9 inches.

On the Cincinnati Southern Railway portions of the road through clay formation have twelve inches of ballast under the ties; other parts, where the grading is light, have only six inches, and the engineer's estimates were made for the whole line on an average of nine inches for main track and six inches for sidings. (See Report of December 1877, since which there may have been some modification in the standard.) The ballast on this line is specified of gravel or broken stone; the gravel to be clean, free from clay or boulders larger than two and a half inches in any direction, and it must not contain more than one-third of sand; the broken stone to be of good durable and hard limestone or sandstone approved by the engineer, and not larger than two and a half inches in any direction.

The Chicago and North-Western Railway Company uses, as standard, one foot of ballast under ties, either gravel or broken stone.

The Atlantic and Pacific Railroad Company (western division) uses gravel, stone, or earth ballast.

The Chicago, Burlington, and Quincy Railroad Company has been for some time experimenting with burnt clay for ballast, having had two miles of this in use for two years, and it contemplates putting in about fifteen miles additional this season. Where the road is not ballasted, it is surfaced up with the soil, filling in between rails about two inches above the tie, sloping each side so as to clear the bottom of the rail, and running down to the bottom of the tie at the ends. The company possesses some excellent gravel beds in Illinois, has about 425 miles of its road ballasted with gravel in that state, and about 50 miles with broken stone. In Iowa, however, where the supply is deficient, it has only about 150 miles with gravel ballast and the same amount with broken stone. It is in Iowa that the burnt clay ballast will be used.

The Pennsylvania Railroad Company specifies that there must be a uniform depth of at least twelve inches of clean broken stone or gravel under the ties. The ballast must be filled up evenly between, but not above, the top of the ties, and also between the main tracks and sidings where stone ballast is used. In filling up between the tracks, coarse large stones must be placed in the bottom in order to provide for drainage; but care should be taken to keep the coarse stone away from the ends of the ties. At the outer ends of the ties the ballast must be sloped off evenly to the sub-grade. When stone is used it must be broken evenly, and not larger than a cube that will pass through a two and a half inch ring.

The Grand Trunk Railway Company of Canada uses gravel for ballast, from pits, taking the best the country affords, putting about six inches in depth under the ties, and filling in between the latter to their surface.

For good drainage the ditches must be ample, well made, with proper grades, and kept well cleaned out. The Pennsylvania Railroad Company has been sodding a great many of the slopes of its cuttings to prevent the material from washing into the ditches, and the result has been very successful, saving the cost of maintenance and at the same time improving the appearance of the road. It has also had a number of gutters made with a concrete of Portland cement two inches thick laid on stone ballast four inches thick, having a granolithic top of one inch, and cut into flags of six feet long. These have given general satisfaction, and the use of them is being extended at various points. In its instructions to road-foremen the Pennsylvania Railroad Company specifies for ditches, 'that the cross section at the highest point must be of the width and depth as shown on the standard drawing, and graded parallel with the track, so as to pass water freely during heavy rains and thoroughly drain the road-bed. The line of the bottom of the ditch must be made parallel with the rails, and well and neatly defined, at a distance of not less than seven feet from the outside rail. All necessary cross drains must be put in at proper intervals. Earth taken from ditches or elsewhere must be dumped over the banks, and not left at or near the ends of the ties, but distributed over the slope. Earth taken out of the ditches in cuts, must not be thrown on the slope. The channels or streams for a considerable distance above the road should be examined, and brush, drift, and other obstructions removed. Ditches, culverts, and box drains should be cleaned of all obstructions, and the outlets and inlets of the same kept open to allow a free flow of water at all times.'

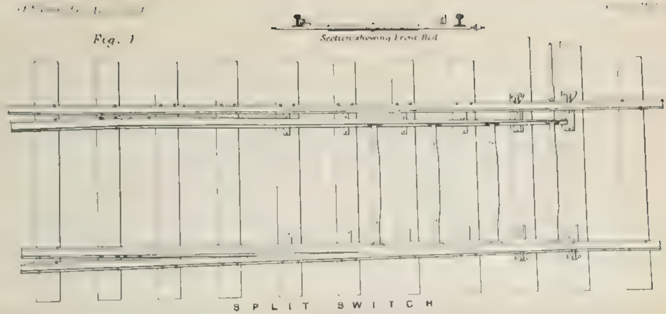
All sidings should be kept in as good order as practicable, but it is not necessary that they be kept up to the standard of main tracks, second-class rails and ties, or partly worn material from the main tracks, being usually used for their construction.

In reference to turn-outs and crossings from one track to another, the general arrangement is very well illustrated by the standards of the Pennsylvania Railroad, also the standard third track connections of the same road. The old-fashioned stub switch is now entirely out of date. It will of course be found on many roads, but now switches of this kind are not being introduced anywhere in first-class work. The term 'switch' is an American word, and indicates any arrangement of movable rails, used for the purpose of transferring a train from one track to another. In the stub switch, where the lines of rails separate, each pair of the four rails are brought as closely together as will just allow the flanges of the wheels to run between them. The last pair of rails of the single track are then connected together to gauge by bars, and have only the rear ends fixed to the ties, the other ends being made so as to swing back and forth horizontally, by means of a lever in front of either pair of the diverging lines, so that a continuous connection can be made with either one or the other. The ends of these movable rails, which are called switch rails, rest on slide plates which receive and partially secure them, limiting their movement, or the 'throw' of the switch, to the distance between the rails of the diverging lines. A small opening or space must always be left between the end of the switch rail and the next rail, to allow not only for expansion and contraction under changes of temperature, but also the creeping of the rails under service, both of which causes tend to close up the space, and hold the switch rails so tightly in place that they cannot be moved and the switch opened. But the want of continuity in the track causes severe shocks and jars to passing trains, not only uncomfortable to passengers, but also battering down the ends of the rails, rapidly destroying them and the ties below, and causing much trouble. In addition to these disadvantages, inherent in the form of switch, it possesses no elements of safety. If placed for the wrong track, a train approaching from the side of the diverging lines must be derailed.

The great advances which have been made in the scientific operating of railroads in this country, and the vastly increased traffic, demanding greater comfort and greater safety, have necessitated some form of switch that would pass trains smoothly and easily, free from the shocks and jars experienced with the old form, easily operated without risk of being locked by changes of temperature or creeping of rails, and, at least on the main tracks, of a switch that even if set wrong would not derail a train. These wants have been met by the split or point switch.

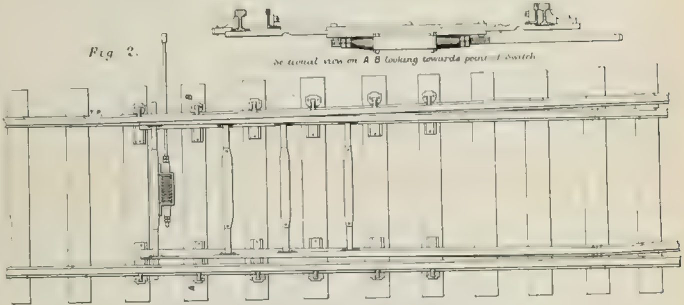
The split switch as made in America is of the same type as has been used almost altogether in Europe, but there may be some differences

Fig. 1



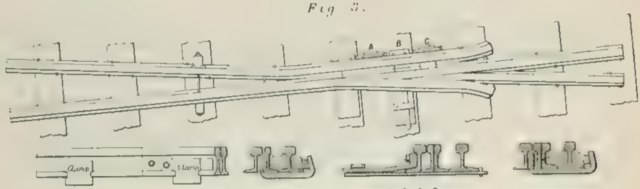
SPLIT SWITCH

Fig. 2.



LORENZ SAFETY SWITCH

Fig. 3.



SPRING RAIL FROGS.
PATENT KEYED PATTERN

Illustrating Mr. J. M. Wilson's Paper on "American Permanent Way" in details, or in the application of the principle. This form of switch consists simply of a movable pair of split or tapering rails, which are fastened to the two inside rails of the four that come together, the outer rails being fixed, and connected and made continuous with the single track from which the divergence takes place. These split rails at the opposite end are free to be shifted sideways and move with each other, being tied together to a certain fixed distance apart by rods, this distance being made so that only one of them can be in contact with a fixed rail at the same time, the other being separated from the fixed rail by a space, called the 'throwing' of the switch, sufficient to pass the flanges of wheels of trains. The free end of the pointed rails is called the 'toe,' and the fixed or pivot end the 'heel' of the switch. At the heel, the fixed distance from the adjoining rail must be enough to pass wheels easily. It is essential that the point when pressed up against the fixed or 'stock' rail, as it is called, should leave no projection that a wheel approaching the switch could run against. For some years it was customary to make the points quite blunt, and to cut a recess into the side of the stock rail for the point to fit into; but as now made, the point rails are tapered down to a thin wedge, and shaped so as to fit very closely to the stock rails resting on them, and having the thin point also tapered for a short distance from the end, so that there will be no risk of the wheels touching the point rails until they reach a thicker part. Nothing has to be done to the stock rails, and no changes of temperature or creeping of rails will affect the point rails. The throw of the switch is usually made about $3\frac{1}{2}$ or 4 inches, to avoid any danger of the open end of the point being struck by the back of a wheel, although less throw would answer. Sometimes short guard rails are used in front of the points to protect them. The two point rails require to be connected together by rods or bars, which should be as low to the surface of the cross-ties as possible, and rigid vertically, while flexible to some extent sideways to allow of self-adjustment.

Split switches are made by a number of firms, each of which usually has some special patent or detail of its own in the style which it builds. Fig. 1, Plate VIII., shows the split switch as made by the Pennsylvania Steel Company, which will very well illustrate the type. The form of connecting bar is also shown. The two arms of the bar are rigidly attached to the webs of the rails, and are secured together in the centre by means of two flat plates, which lay on each side of them, and are riveted together through a separating block. The arms, having only one rivet in each, can adjust themselves between the plates about this rivet as a pivot. The point rails of this Company are made 15 feet long, being one-half of a 30-feet rail. They are planed and tapered down without being heated, and are shaped so as to completely fit the stock rails and to rest on the flanges of the same throughout the whole length of the tapered portion, in such a manner that the point rails receive substantial support if required, although the wheels do not come in contact with them until they have passed the extreme end. The slide plates under the point rails are of wrought iron, quite plain except near the point, where they extend also under the stock rails, and have the ends turned up to hold rail braces.

When a train approaches a split switch by the heel, it is called a 'trailing switch;' but if the toe or point is approached first, then it is called a 'facing switch.' Single point switches are sometimes made, with only one movable point rail, the other being fixed like a frog point; but this is not a good arrangement. If the movable point rail is placed inside the curve diverging from the main line, then, when it is set right for the diverging line, it acts not as an ordinary point rail, but as a guard rail, for which it is not suitable; also, no matter which way the switch is placed, the support to the treads of the wheels is not as much as two point rails give, and the stock rail alongside the fixed point wears out the same as a wing rail in a frog wears out at the frog point. One of the greatest dangers with the split switch—that of loose wheels working in to catch the end of the open point—is doubled in the single point switch, for a loose wheel will catch as easily on the end of a fixed point as on an open point, and when the point in such switches is open, there are two places where there is a liability of trouble. In this connection it would be well to say that split switches should always be made trailing if possible; never facing the travel if it can be avoided. On single track lines, with travel in both directions, it is not feasible to carry out this precaution; but on double track lines the matter should never be overlooked, as it may prevent serious accidents. If a trailing switch be operated by a spring or weight, so that, in case the switch is wrong for an approaching train, the flanges of the wheels advancing from the fixed rail on to the movable point rail can overcome the resistance and move the points into their proper position, thus avoiding a derailing of train, then the switch becomes a self-acting 'safety switch.'

Mr. William Lorenz, who has for a long time been chief engineer of the Philadelphia and Reading Railroad, designed a simple and practicable form of self-acting split switch, with a spring securely holding the points against the stock rail, so that the switch was safe for all trains approaching, facing the switch, at the same time that it was self-acting as a trailing switch. His switch being the type of all of these, his name is deservedly attached to them, and they are known as the 'Lorenz Safety Switch.' Fig. 2, Plate VIII., shows the Pennsylvania Steel Company's improved pattern of this switch. The general arrangement is the same as already described, except as it regards the spring, which is steel, double coiled, and is generally arranged in a yoke on the side of the front connecting bar, where it can be conveniently reached for adjustment. The length of the points is 15 feet, and the throw is 3½ inches, the switch stand throwing 4 inches to give proper compression to the spring. In the original Lorenz pattern the points were usually made much longer, even up to 30 feet.

A shorter pattern of safety switch is made for yard service, the point rails being as short as seven feet six inches, with a flange way at the heel of only two inches.

The Pennsylvania Steel Company also make an automatic switch stand, which, by the combined operation of a weighted lever and gearing, holds the switch with a solid rigid throw, and renders it absolutely safe for all 'facing' trains, at the same time giving a signal indicating the position of the point. It also acts automatically as a safety switch for trains trailing over it from either track. When acting in the latter way, the first pair of wheels over the switch set it right, so that the remaining wheels do not have to open the switch each for themselves, as in the safety switch with springs.

In Wharton's Patent Switch, the great principle is always to preserve an unbroken line in the main tracks, under all circumstances, and to carry a train off on to a siding without any break in the continuity of the rails. This is accomplished in the following manner:—The switch rails and a movable guard rail are connected together, the inner switch rail being shaped like the letter U, and having one side, next the rail, terminating in a point, which, when the switch is set for the side track, laps under the main rail and guides the wheel away from it. The guard rail acts also to draw this wheel away from the main line, so as to insure the point being cleared by the flanges. The result brings the tread of the wheel upon the outer switch rail, which at the end is flush with the main rail, but, gradually rising, lifts the wheel in a distance of about $4\frac{1}{2}$ feet, until it can pass over the top of the main rail. Each end of the longitudinal shaft of the operating machinery has a crank, one connected with the guard rail and the other with the switch rails, and the angles of these are so arranged with reference to each other that while the crank holding the switch is on the dead centre or a little below it, that at the other end is at such a position as to be easily acted on by the movable guard rail. Any lateral pressure, therefore, against the switch when it is in use, tends to hold it in position. If the switch should accidentally be left closed, the first wheels of a train on main line, acting on the guard rail, operate the switch, placing it all right for main track. These switches are rather expensive, but have given great satisfaction where used. Their employment depends upon the question as to whether their increased expense, complication, multiplication of parts, &c., are more than compensated for by their increased efficiency over the simpler safety split switch.

The Wharton Switch Company also manufacture a safety split switch, with the guard rail attachment for throwing it right for main line, by the action of the wheels of a train, when left wrong.

When one rail is crossed by another rail, unless under some such arrangement as the Wharton switch, the rail crossed must have an opening or slit in it to allow the flanges of the wheels to pass through. The arrangement that provides for this is called a 'frog.' The earliest forms of frogs were of cast iron; then they were steel-plated, afterwards cast-steel frogs were used, and several forms of construction have been made of steel plates alternating with layers of wood and rubber to secure elasticity. Frogs were also made of iron rails, such as are used in the tracks, fitted together in various ways; but iron rails wore out so rapidly under service that they were not found satisfactory. When, however, steel rails came into the market, it became entirely practicable to make use of them for frogs, and the result has been that frogs of this kind have superseded everything else. Steel rail frogs possess many advantages over the other varieties. Using the same standard rail as in the track, they become an integral part of it, can be secured with the same splice joints, use the same ties, spikes, &c., and for a perfect realisation of the problem there should be no necessity for cutting away any parts of the ties, or adjustment of them, different from what is required in standard track, and the rails which make the frog should be kept to their full section and have their full resistance to service that they possess in their ordinary location. What is wanted, then, is a simple construction that will bind the rails together in the form required in a solid, permanent manner. The nearer these conditions can be fulfilled the better.

There are two principal kinds of frogs in use, the 'Spring Rail' and the 'Stiff Frog.' Spring rail frogs are sometimes made by riveting the point rails and one side rail to a wrought-iron bed-plate, the two pieces forming the point of the frog being dovetailed together and secured by heavy mortise rivets. The other side rail is loose, being kept in place by a cross-bar passing through a slot in the point and the fast rail, the loose rail being kept close against the point by rubber springs and a rod connecting it with the fast rail some distance beyond the point. There is an objection, however, to the rivetwork and also to the plate underneath, from its accumulating ice, dirt, &c., and interfering with tamping of ties. The best construction is that with keys, the type being illustrated by fig. 3, Plate VIII., showing the pattern made by the Pennsylvania Steel Company. The fixed parts are tied together by two heavy clamps, secured by split keys, and the 'throat' or space between the point and wing rail is maintained by closely fitting iron blocks, which are prevented from moving by rivets and pins through the rails. Spring rail frogs give easy riding, smooth tracks, but some of the best roads do not use them now to any extent, preferring the 'stiff' frog. These also are made in several ways: with riveted plate, with dividing blocks, and bolts, and with keys. The keyed pattern is decidedly the best. These frogs are best with three clamps, but the split keys for fastening are considered preferable to bolts. This form of frog possesses all the elasticity of the rails, just the same as in the regular track, making it very easy riding; the strength of the rails remains as originally, the peculiar modes of fastening have great advantages over bolts or other arrangements, as there is nothing that can interfere with wheel flanges, and the frog rests on the ties in their usual positions, giving ample room for tamping up, &c. First quality steel rails should be used, drilled for the standard splice of the road; the pieces of rail forming the point should be dovetailed by planing cold, and thoroughly secured by heavy rivets; the clamps should be of heavy wrought iron, and the parts within should be secured by bevelled split keys. Solid iron throat-pieces fit the rails perfectly and maintain the throat space. The whole forms about as perfect a frog as can be designed. There is nothing movable about the frog but the keys. These should be examined by the trackmen in their course of duties, and if found loose, driven tight, the split end being spread open to hold them to place.

Where two railroads cross each other on a level—not at all an uncommon thing in this country—expensive crossing frogs are required. Much the same style of work is used in making these frogs as for the ordinary frogs, although the work is more complicated. Where the angle is very acute, they can be made like the keyed stiff frogs, but in other cases it appears difficult to design them without the wrought plate underneath.

The subject-matter of this paper might be extended almost indefinitely, including interlocking switches, signals, the Westinghouse Automatic air system, where compressed air is used as the moving power applied by electricity, &c.; but the author fears he has extended his limits already, and he must come to a conclusion. He would like to say that, on a visit to Europe in 1869, he examined very closely into the interlocking and blocking systems, returning full of ideas on these subjects; but could get no one to bestow a thought upon them. It was agreed that such things would not suit this country at all, that they were not needed, and that the operating of switches and signals through long distances would not succeed in our freezing winter climate. But there has been a revolution since then. The accumulation of business and exigencies of travel have demanded these improvements, and they are now in active use.

In conclusion, the author would dwell upon the importance of keeping a road in a thoroughly clean and neat condition, with every part to proper line and shape. The great value of this cannot be over-estimated. Not only does it produce a good effect on the public, but it inculcates care and attention on the part of the employés, and lessens their liability to neglect of the main essentials. A road superstructure well and continuously kept up is, in the end, at far less expense for maintenance than one which is allowed to get out of order and to run down, until it is absolutely necessary by a strong effort to bring it back into good shape. It is true that there are many lines of road throughout the country in sparsely settled sections, and having a small traffic, which could not afford the expenditure on the permanent way that a main trunk line could do. Such a line may live in hopes of raising its standard at some future time and improving its superstructure; but even now, in its present state, it can keep everything in neat order, and make its work thorough so far as it goes.

The author desires to express his acknowledgments to the various railroad and manufacturing companies who have so kindly furnished him with information and data.

NOTE.—The paper was illustrated by a series of plates, a selection from which only have been reproduced.

Explanation of Plates VI. and VII.

PLATE VI.

Rail No. 234 is in use on the Pennsylvania R. R., 1883, and the Detroit, Bay City, and Alpena R. R., 1883.

PLATE VII.

Rail No. 54 is in use on the

- Louisville and Nashville R. R., 1881.
- Philadelphia, Wilmington, and Baltimore R. R., 1875.
- Western Maryland R. R., 1875.
- Louisville, Cincinnati, and Lexington R. R., 1879.
- Cincinnati, Hamilton, and Dayton R. R., 1879. See 60, No. 59.
- Cleveland, Mt. Vernon, and Columbus R. R., 1879.

Rail No. 55 is in use on the

- Pennsylvania R. R., Main Line, 1883.
- Illinois and St. Louis Bridge Co., 1877.
- Cumberland and Pennsylvania R. R., 1877–79.
- Baltimore and Ohio R. R., 1881. Also 60, No. 56.
- Pittsburgh, Cincinnati, and St. Louis R. R., 1881. Also 60, No. 56.

Rail No. 56 is in use on the

- Pennsylvania R. R. (Leased Lines and Branches), 1883.
- Allegheny Valley R. R., 1879.
- Pittsburgh, Ft. Wayne, and Chicago R. R., 1881.

Rail No. 56—*continued.*

- Pittsburgh, Cincinnati, and St. Louis R. R., 1881.
- Cleveland and Pittsburgh R. R., 1877.
- Terre Haute and Indianapolis R. R., 1878.
- Northern Central Ry. (Pennsylvania), 1877.
- Louisville, Paducah, and South-Western R. R., 1875.
- Bellefonte and Snow Shoe R. R., 1880.
- Dunleth and Dubuque Bridge Co., 1880.
- Erie and Pittsburgh R. R., 1878.
- Summit Branch R. R., 1876.
- Philadelphia and Erie R. R., 1879.
- St. Louis, Alton, and Terre Haute R. R., 1879.
- Toledo and Woodville R. R., 1877.
- West Jersey R. R., 1880.
- Huntingdon and Broad Top R. R., 1879.
- Illinois Central R. R., 1877.
- Springfield Southern R. R., 1881.
- Cumberland and Pennsylvania R. R., 1880.
- St. Louis, Iron Mountain, and Southern R. R., 1881.
- Baltimore and Ohio R. R., 1881.

Rail No. 60 is in use on the

- Baltimore and Potomac R. R., 1876.
- Central Pacific R. R., 1876.
- Squankum and Freehold Marl Co., 1876.
- Chesapeake and Ohio R. R., 1876.
- New York Elevated Ry., 1876.
- Connecticut and Passumpsic Rivers R. R., 1876.

Rail No. 60—*continued.*

- Grand Rapids and Indiana R. R., 1875–80.
- Seabord and Roanoake R. R., 1879.
- Raleigh and Gaston R. R., 1879.
- Eel River R. R., 1877.
- Mineral Range R. R., 1879.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—
Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.L. & E., F.R.A.S.

THURSDAY, AUGUST 28.

The President delivered the following Address:—

Steps towards a Kinetic Theory of Matter.

The now well-known kinetic theory of gases is a step so important in the way of explaining seemingly static properties of matter by motion, that it is scarcely possible to help anticipating in idea the arrival at a complete theory of matter, in which all its properties will be seen to be merely attributes of motion. If we are to look for the origin of this idea, we must go back to Democritus Epicurus and Lucretius. We may then, I believe, without missing a single step, skip 1,800 years. Early last century we find in Malebranche's 'Recherche de la Vérité,' the statement that 'La dureté des corps' depends on 'petits tourbillons.'[1] These words, embedded in a hopeless mass of unintelligible statements of the physical, metaphysical, and theological philosophies of the day, and unsupported by any explanation, elucidation, or illustration throughout the rest of the three volumes, and only marred by any other single sentence or word to be found in the great book, still do express a distinct conception, which forms a most remarkable step towards the kinetic theory of matter. A little later we have Daniel Bernoulli's promulgation of what we now accept as a surest article of scientific faith—the kinetic theory of gases. He, so far as I know, thought only of the Boyle's and Marriot's law of the 'spring of air,' as Boyle called it, without reference to change of temperature or the augmentation of its pressure if not allowed to expand for elevation of temperature, a phenomenon which perhaps he scarcely knew, still less the elevation of temperature produced by compression, and the lowering of temperature by dilatation, and the consequent necessity of waiting for a fraction of a second or a few seconds of time (with apparatus of ordinary experimental magnitude), to see a subsidence from a larger change of pressure, down to the amount of change that verifies Boyle's law. The consideration of these phenomena forty years ago by Joule, in connection with Bernoulli's original conception, formed the foundation of the kinetic theory of gases as we now have it. But what a splendid and useful building has been placed on this foundation by Clausius and Maxwell, and what a beautiful ornament we see on the top of it in the radiometer of Crookes, securely attached to it

[1] 'Preuve de la supposition que j'ay faite: Que la matière subtile ou éthérée est nécessairement composée de PETITS TOURBILLONS; et qu'ils sont les causes naturelles de tous les changements qui arrivent à la matière; ce que je confirme par l'explication des effets les plus généraux de la Physique, tels que sont la dureté des corps, leur fluidité, leur pesanteur, leur légèreté, la lumière et la réfraction et réflexion de ses rayons.'—Malebranche, *Recherche de la Vérité*, 1712.

by the happy discovery of Tait and Dewar,[1] that the length of the free path of the residual molecules of air in a good modern vacuum may amount to several inches. Clausius' and Maxwell's explanations of the diffusion of gases, and of thermal conduction in gases, their charmingly intelligible conclusion that in gases the diffusion of heat is just a little more rapid than the diffusion of molecules, because of the interchange of energy in collisions between molecules,[2] while the chief transference of heat is by actual transport of the molecules themselves; and Maxwell's explanation of the viscosity of gases, with the absolute numerical relations which the work of those two great discoverers found among the three properties of diffusion, thermal conduction, and viscosity; have annexed to the domain of science a vast and ever-growing province.

Rich as it is in practical results, the kinetic theory of gases, as hitherto developed, stops absolutely short at the atom or molecule, and gives not even a suggestion towards explaining the properties in virtue of which the atoms or molecules mutually influence one another. For some guidance towards a deeper and more comprehensive theory of matter, we may look back with advantage to the end of last century and the beginning of this century, and find Rumford's conclusion regarding the heat generated in boring a brass gun: 'It appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner the heat was excited and communicated in these experiments, except it be MOTION,' and Davy's still more suggestive statement: 'The phenomena of repulsion are not dependent on a peculiar elastic fluid for their existence. . . .' 'Heat may be defined a peculiar motion, probably a vibration, of the corpuscles of bodies, tending to separate them. . . .' 'To distinguish this motion from others, and to signify the causes of our sensations of heat, &c., the name *repulsive* motion has been adopted.' Here we have a most important idea. It would be somewhat a bold figure of speech to say the earth and moon are kept apart by a repulsive motion; and yet, after all, what is centrifugal force but a repulsive motion, and may it not be that there is no such thing as repulsion, and that it is solely by inertia that what seems to be repulsion is produced? Two bodies fly together, and, accelerated by mutual attraction, if they do not precisely hit one another, they cannot but separate in virtue of the inertia of their masses. So, after dashing past one another in sharply concave curves round their common centre of gravity, they fly asunder again. A careless onlooker might imagine they had repelled one another, and might not notice the difference between what he actually sees and what he would see if the two bodies had been projected with great velocity towards one another, and either colliding and rebounding, or repelling one another into sharply convex continuous curves, fly asunder again.

Joule, Clausius, and Maxwell, and no doubt Daniel Bernoulli himself, and I believe every one who has hitherto written or done anything very explicit in the kinetic theory of gases, has taken the mutual action of molecules in collision as repulsive. May it not after all be attractive? This idea has never left my mind

[1] *Proc. R. S. E.* March 2, 1874, and July 5, 1875.

[2] On the other hand in liquids, on account of the crowdedness of the molecules, the diffusion of heat must be chiefly by interchange of energies between the molecules, and should be, as experiment proves it is, enormously more rapid than the diffusion of the molecules themselves, and this again ought to be much less rapid than either the material or thermal diffusivities of gases. Thus the diffusivity of common salt through water was found by Fick to be as small as ·0000112 square centimetres per second: nearly 200 times as great as this is the diffusivity of heat through water, which was found by J. T. Bottomley to be about ·002 square centimetres per second. The material diffusivities of gases, according to Loschmidt's experiments, range from ·098 (the interdiffusivity of carbonic acid and nitrous oxide) to ·642 (the interdiffusivity of carbonic oxide and hydrogen); while the thermal diffusivities of gases, calculated according to Clausius' and Maxwell's kinetic theory of gases, are ·089 for carbonic acid, ·16 for common air or other gases of nearly the same density, and 1·12 for hydrogen (all, both material and thermal, being reckoned in square centimetres per second).

since I first read Davy's 'Repulsive Motion,' about thirty-five years ago, but I never made anything of it, at all events have not done so until to-day (June 16, 1884), (if this can be said to be making anything of it), when in endeavouring to prepare the present address I notice that Joule's and my own old experiments[1] on the thermal effect of gases expanding from a high pressure vessel through a porous plug, proves the less dense gas to have greater intrinsic *potential* energy than the denser gas, if we assume the ordinary hypothesis regarding the temperature of a gas, according to which two gases are of equal temperatures[2] when the kinetic energies of their constituent molecules are of equal average amounts per molecule.

Think of the thing thus. Imagine a great multitude of particles enclosed by a boundary which may be pushed inwards in any part all round at pleasure. Now station an engineer corps of Maxwell's army of sorting demons all round the enclosure, with orders to push in the boundary diligently everywhere, when none of the besieged troops are near, and to do nothing when any of them are seen approaching, and until after they have turned again inwards. The result will be that with exactly the same sum of kinetic and potential energies of the same enclosed multitude of particles, the throng has been caused to be denser. Now Joule's and my own old experiments on the efflux of air prove that if the crowd be common air, or oxygen, or nitrogen, or carbonic acid, the temperature is a little higher in the denser than in the rarer condition when the energies are the same. By the hypothesis, equality of temperature between two different gases or two portions of the same gas at different densities means equality of kinetic energies in the same number of molecules of the two. From our observations proving the temperature to be higher, it therefore follows that the potential energy is smaller in the condensed crowd. This—always, however, under protest as to the temperature hypothesis—proves some degree of attraction among the molecules, but it does not prove ultimate attraction between two molecules in collision, or at distances much less than the average mutual distance of nearest neighbours in the multitude. The collisional force might be repulsive, as generally supposed hitherto, and yet attraction might predominate in the whole reckoning of difference between the intrinsic potential energies of the more dense and less dense multitudes. It is, however, remarkable that the explanation of the propagation of sound through gases, and even of the positive fluid pressure of a gas against the sides of the containing vessel, according to the kinetic theory of gases, is quite independent of the question whether the ultimate collisional force is attractive or repulsive. Of course it must be understood that if it is attractive, the particles must be so small that they hardly ever meet—they would have to be infinitely small to *never* meet—that, in fact, they meet so seldom, in comparison with the number of times their courses are turned through large angles by attraction, that the influence of these purely attractive collisions is preponderant over that of the comparatively very rare impacts from actual contact. Thus, after all, the train of speculation suggested by Davy's 'Repulsive Motion' does not allow us to escape from the idea of true repulsion, does not do more than let us say it is of no consequence, nor even say this with truth, because, if there are impacts at all, the nature of the force during the impact, and the effects of the mutual impacts, however rare, cannot be evaded in any attempt to realise a conception of the kinetic theory of gases. And in fact, unless we are satisfied to imagine the atoms of a gas as mathematical points endowed with inertia, and,

[1] Republished in Sir W. Thomson's *Mathematical and Physical Papers*, Vol. I. Article XLIX. p. 381.

[2] That this is a mere hypothesis has been scarcely remarked by the founders themselves, nor by almost any writer on the kinetic theory of gases. No one has yet examined the question: what is the condition as regards average distribution of kinetic energy, which is ultimately fulfilled by two portions of gaseous matter, separated by a thin elastic septum which absolutely prevents interdiffusion of matter, while it allows interchange of kinetic energy by collisions against itself? Indeed I do not know but that the present is the very first statement which has ever been published of this condition of the problem of equal temperatures between two gaseous masses.

as according to Boscovich, endowed with forces of mutual positive and negative attraction, varying according to some definite function of the distance, we cannot avoid the question of impacts, and of vibrations and rotations of the molecules resulting from impacts, and we must look distinctly on each molecule as being either a little elastic solid, or a configuration of motion in a continuous all-pervading liquid. I do not myself see how we can ever permanently rest anywhere short of this last view; but it would be a very pleasant temporary resting-place on the way to it, if we could, as it were, make a mechanical model of a gas out of little pieces of round perfectly elastic solid matter, flying about through the space occupied by the gas, and colliding with one another and against the sides of the containing vessel. This is, in fact, all we have of the kinetic theory of gases up to the present time, and this has done for us, in the hands of Clausius and Maxwell, the great things which constitute our first step towards a molecular theory of matter. Of course from it we should have to go on to find an explanation of the elasticity and all the other properties of the molecules themselves, a subject vastly more complex and difficult than the gaseous properties, for the explanation of which we assume the elastic molecule; but without any explanation of the properties of the molecule itself, with merely the assumption that the molecule has the requisite properties, we might rest happy for awhile in the contemplation of the kinetic theory of gases, and its explanation of the gaseous properties, which is not only stupendously important as a step towards a more thorough-going theory of matter, but is undoubtedly the expression of a perfectly intelligible and definite set of facts in nature. But alas for our mechanical model consisting of the cloud of little elastic solids flying about amongst one another. Though each particle have absolutely perfect elasticity, the end must be pretty much the same as if it were but imperfectly elastic. The average effect of repeated and repeated mutual collisions must be to gradually convert all the translational energy into energy of shriller and shriller vibrations of the molecule. It seems certain that each collision must have something more of energy in vibrations of very finely divided nodal parts than there was of energy of such vibrations before the impact. The more minute this nodal subdivision, the less must be the tendency to give up part of the vibrational energy into the shape of translational energy in the course of a collision, and I think it is rigorously demonstrable that the whole translational energy must ultimately become transformed into vibrational energy of higher and higher nodal subdivisions if each molecule is a continuous elastic solid. Let us, then, leave the kinetic theory of gases for a time with this difficulty unsolved, in the hope that we or others after us may return to it, armed with more knowledge of the properties of matter, and with sharper mathematical weapons to cut through the barrier which at present hides from us any view of the molecule itself, and of the effects other than mere change of translational motion which it experiences in collision.

To explain the elasticity of a gas was the primary object of the kinetic theory of gases. This object is only attainable by the assumption of an elasticity more complex in character, and more difficult of explanation, than the elasticity of gases—the elasticity of a solid. Thus, even if the fatal fault in the theory, to which I have alluded, did not exist, and if we could be perfectly satisfied with the kinetic theory of gases founded on the collisions of elastic solid molecules, there would still be beyond it a grander theory which need not be considered a chimerical object of scientific ambition—to explain the elasticity of solids. But we may be stopped when we commence to look in the direction of such a theory with the cynical question: What do you mean by explaining a property of matter? As to being stopped by any such question, all I can say is that if engineering were to be all and to end all physical science, we should perforce be content with merely finding properties of matter by observation, and using them for practical purposes. But I am sure very few, if any, engineers are practically satisfied with so narrow a view of their noble profession. They must and do patiently observe, and discover by observation, properties of matter, and results of material combinations. But deeper questions are always present, and always fraught with interest to the true engineer, and he will be the last to give weight to any other objection to any attempt to see below the surface of things than the practical question: Is it likely to prove wholly futile? But now, instead of imagining the question: What do you mean by explaining a property of matter? to be put cynically, and letting ourselves be irritated by it, suppose we give to the questioner credit for being sympathetic, and condescend to try and answer his question. We find it not very easy to do so. All the properties of matter are so connected that we can scarcely imagine one *thoroughly explained* without our seeing its relation to all the others, without in fact having the explanation of all; and till we have this we cannot tell what we mean by 'explaining a property,' or 'explaining the properties' of matter. But though this consummation may never be reached by man, the progress of science may be, I believe will be, step by step towards it, on many different roads converging towards it from all sides. The kinetic theory of gases is, as I have said, a true step on one of the roads. On the very distinct road of chemical science, St. Clair Deville arrived at his grand theory of dissociation without the slightest aid from the kinetic theory of gases. The fact that he worked it out solely from chemical observation and experiment, and expounded it to the world without any hypothesis whatever, and seemingly even without consciousness of the beautiful explanation it has in the kinetic theory of gases, secured for it immediately an independent solidity and importance as a chemical theory when he first promulgated it, to which it might even by this time scarcely have attained if it had first been suggested as a probability indicated by the kinetic theory of gases, and been only afterwards confirmed by observation. Now, however, guided by the views which Clausius and Williamson have given us of the continuous interchange of partners between the compound molecules constituting chemical compounds in the gaseous state, we see in Deville's theory of dissociation a point of contact of the most transcendent interest between the chemical and physical lines of scientific progress.

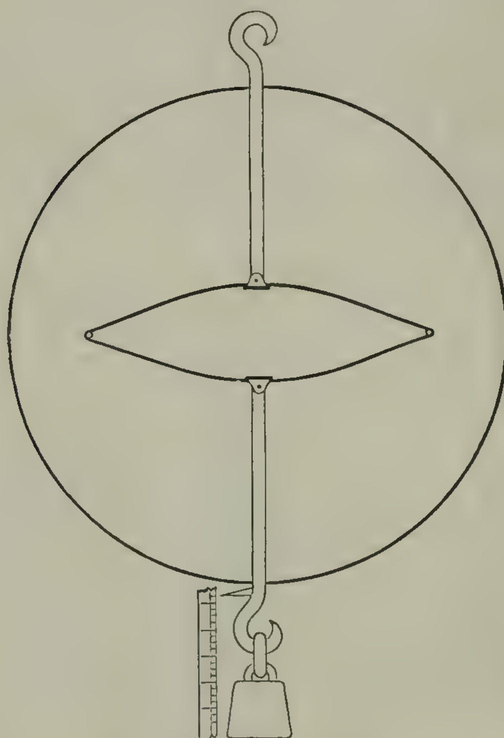
To return to elasticity: if we could make out of matter devoid of elasticity a combined system of relatively moving parts which, in virtue of motion, has the essential characteristics of an elastic body, this would surely be, if not positively a step in the kinetic theory of matter, at least a finger-post pointing a way which we may hope will lead to a kinetic theory of matter. Now this, as I have already shown,[1] we can do in several ways. In the case of the last of the communications referred to, of which only the title has hitherto been published, I showed that, from the mathematical investigation of a gyrostatically dominated combination contained in the passage of Thomson and Tait's 'Natural Philosophy' referred to, it follows that any ideal system of material particles, acting on one another mutually through massless connecting springs, may be perfectly imitated in a model consisting of rigid links jointed together, and having rapidly rotating fly-wheels pivoted on some or on all of the links. The imitation is not confined to cases of equilibrium. It holds also for vibration produced by disturbing the system infinitesimally from a position of stable equilibrium and leaving it to itself. Thus we may make a gyrostatic system such that it is in equilibrium under the influence of certain positive forces applied to different points of this system; all the forces being precisely the same as, and the points of application similarly situated to, those of the stable system with springs. Then, provided proper masses (that is to say, proper amounts and distributions of inertia) be attributed to the links, we may remove the external forces from each system, and the consequent vibration of the points of application of the forces will be identical. Or we may act upon the systems of material points and springs with any given forces for any given time, and leave it to itself, and do the same thing for the gyrostatic system; the consequent motion will be the same in the two cases. If in the one case the springs are made more and more stiff, and in the other case the angular velocities of the fly-wheels are made greater and greater, the periods of the vibrational constituents of

[1] Paper on 'Vortex Atoms,' *Proc. R. S. E.* Feb. 1867; abstract of Lecture before Royal Institution of Great Britain, March 4, 1881, on 'Elasticity viewed as possibly a Mode of Motion;' Thomson and Tait's *Natural Philosophy*, second edition, Part I. §§ 345 $_{\text{viii}}$ to 345 $_{\text{xxvii}}$; 'On Oscillation and Waves in an Adynamic Gyrostatic System' (title only), *Proc. R. S. E.* March 1883.

the motion will become shorter and shorter, and the amplitudes smaller and smaller, and the motions will approach more and more nearly those of two perfectly rigid groups of material points, moving through space and rotating according to the well-known mode of rotation of a rigid body having unequal moments of inertia about its three principal axes. In one case the ideal nearly rigid connection between the particles is produced by massless exceedingly stiff springs; in the other case it is produced by the exceedingly rapid rotation of the fly-wheels in a system which, when the fly-wheels are deprived of their rotation, is perfectly limp.

The drawings (Figs. 1 and 2) before you illustrate two such material systems.[1] The directions of rotation of the fly-wheels in the gyrostatic system (fig. 2) are indicated by directional ellipses, which show in perspective the direction of rotation of the fly-wheel of each gyrostat. The gyrostatic system (fig. 2) might have been constituted of two gyrostatic members, but four are shown for symmetry. The enclosing circle represents in each case in section an enclosing spherical shell to

Fig. 1.



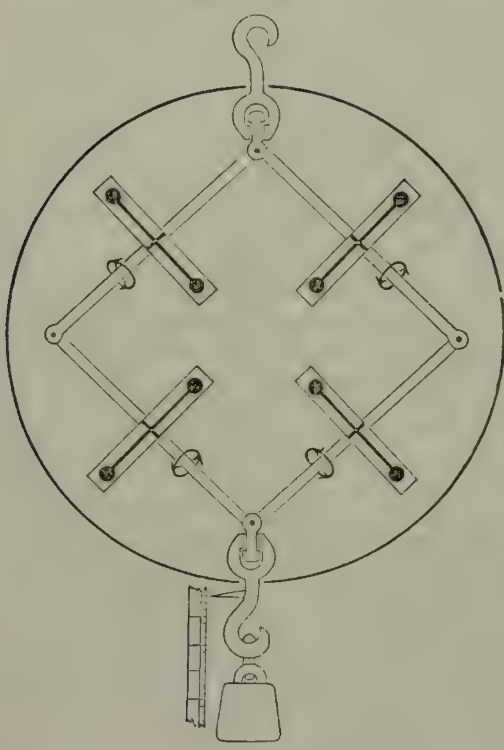
prevent the interior from being seen. In the inside of one there are fly-wheels, in the inside of the other a massless spring. The projecting hooked rods seem as if they are connected by a spring in each case. If we hang any one of the systems up by the hook on one of its projecting rods, and hang a weight to the hook of the other projecting rod, the weight when first put on will oscillate up and down, and will go on doing so for ever if the system be absolutely unfrictional. If we check

[1] In fig. 1 the two hooked rods seen projecting from the sphere are connected by an elastic coach spring. In fig. 2 the hooked rods are connected one to each of two opposite corners of a four-sided jointed frame, each member of which carries a gyrostat so that the axis of rotation of the fly-wheel is in the axis of the member of the frame which bears it. Each of the hooked rods in fig. 2 is connected to the framework through a swivel joint, so that the whole gyrostatic framework may be rotated about the axis of the hooked rods in order to annul the moment of momentum of the framework about this axis due to rotation of the fly-wheels in the gyrostats.

the vibration by hand, the weight will hang down at rest, the pin drawn out to a certain degree; and the distance drawn out will be simply proportional to the weight hung on, as in an ordinary spring balance.

Here, then, out of matter possessing rigidity, but absolutely devoid of elasticity, we have made a perfect model of a spring in the form of a spring balance. Connect millions of millions of particles by pairs of rods such as these of this spring balance, and we have a group of particles constituting an elastic solid; exactly fulfilling the mathematical ideal worked out by Navier, Poisson, and Cauchy, and many other mathematicians who, following their example, have endeavoured to found a theory of the elasticity of solids on mutual attraction and repulsion between a group of material particles. All that can possibly be done by this theory, with its assumption of forces acting according to any assumed law of relation to distance, *is* done by the gyrostatic system. But the gyrostatic system does, besides, what

FIG. 2.



the system of naturally acting material particles cannot do: it constitutes an elastic solid which can have the Faraday magneto-optic rotation of the plane of polarisation of light; supposing the application of our solid to be a model of the luminiferous ether for illustrating the undulatory theory of light. The gyrostatic model spring balance is arranged to have zero moment of momentum as a whole, and therefore to contribute nothing to the Faraday rotation; with this arrangement the model illustrates the luminiferous ether in a field unaffected by magnetic force. But now let there be a different rotational velocity imparted to the jointed square round the axis of the two projecting hooked rods, such as to give a resultant moment of momentum round any given line through the centre of inertia of the system, and let pairs of the hooked rods in the model thus altered, which is no longer a model of a mere spring-balance, be applied as connections between millions of pairs of particles as before: with the lines of resultant moment of momentum all similarly directed. We now have a model elastic solid which will have the property that the direction of vibration in waves of rectilinear vibrations propagated through it shall turn round the line of propagation of the waves; just as Faraday's observation proves to be done by the line of vibration of light in a dense medium between the poles of a powerful magnet. The case of wave front perpendicular to the lines of resultant moment of momentum (that is to say, the direction of propagation being parallel to these lines) corresponds, in our mechanical model, to the case of light travelling in the direction of the lines of force in a magnetic field.

In these illustrations and models we have different portions of ideal rigid matter acting upon one another, by normal pressure at mathematical points of contact—of course no forces of friction are supposed. It is exceedingly interesting to see how thus, with no other postulates than inertia, rigidity, and mutual impenetrability, we can thoroughly model not only an elastic solid, and any combination of elastic solids, but so complex and recondite a phenomenon as the passage of polarized light through a magnetic field. But now, with the view of ultimately discarding the postulate of rigidity from all our materials, let us suppose some to be absolutely destitute of rigidity, and to possess merely inertia and incompressibility, and mutual impenetrability with reference to the still remaining rigid matter. With these postulates we can produce a perfect model of mutual action at a distance between solid particles, fulfilling the condition, so keenly desired by Newton and Faraday, of being explained by continuous action through an intervening medium. The law of the mutual force in our model, however, is not the simple Newtonian law, but the much more complex law of the mutual action between two electromagnets—with this difference, that in the hydrokinetic model in every case the force is opposite in direction to the corresponding force in the electromagnetic analogue. Imagine a solid bored through with a hole and placed in our ideal perfect liquid. For a moment let the hole be stopped by a diaphragm, and let an impulsive pressure be applied for an instant uniformly over the whole membrane, and then instantly let the membrane be dissolved into liquid. This action originates a motion of the liquid relatively to the solid, of a kind to which I have given the name of 'irrotational circulation,' which remains absolutely constant however the solid be moved through the liquid. Thus, at any time the actual motion of the liquid at any point in the neighbourhood of the solid will be the resultant of the motion it would have in virtue of the circulation alone, were the solid at rest, and the motion it would have in virtue of the motion of the solid itself, had there been no circulation established through the aperture. It is interesting and important to remark in passing that the whole kinetic energy of the liquid is the sum of the kinetic energies which it would have in the two cases separately. Now, imagine the whole liquid to be enclosed in an infinitely large rigid containing vessel, and in the liquid, at an infinite distance from any part of the containing vessel, let two perforated solids, with irrotational circulation through each, be placed at rest near one another. The resultant fluid motion due to the two circulations will give rise to fluid pressure on the two bodies, which if unbalanced will cause them to move. The force systems—force-and-torques, or pairs of forces—required to prevent them from moving will be mutual and opposite, and will be the same as, but opposite in direction to, the mutual force systems required to hold at rest two electromagnets fulfilling the following specification. The two electromagnets are to be of the same shape and size as the two bodies, and to be placed in the same relative positions, and to consist of infinitely thin layers of electric currents in the surfaces of solids possessing extreme diamagnetic quality—in other words, infinitely small permeability. The distribution of electric current on each body may be any whatever which fulfils the condition that the total current across any closed line drawn on the surface once through the aperture is equal to $1/4\pi$ of the circulation [1] through the aperture in the hydrokinetic analogue.

It might be imagined that the action at a distance thus provided for by fluid motion could serve as a foundation for a theory of the equilibrium, and the

[1] The integral of tangential component velocity all round any closed curve, passing once through the aperture, is defined as the 'Cyclic constant,' or the 'circulation' ('Vortex Motion,' § 60 (*a*), *Trans. R. S. E.* April 29, 1867). It has the same value for all closed curves passing just once through the aperture, and it remains constant through all time whether the solid body be in motion or at rest.

vibrations, of elastic solids, and the transmission of waves like those of light through an extended quasi-elastic solid medium. But unfortunately for this idea the equilibrium is essentially unstable, both in the case of magnets and, notwithstanding the fact that the forces are oppositely directed, in the hydrokinetic analogue also, when the several movable bodies (two or any greater number) are so placed relatively as to be in equilibrium. If, however, we connect the perforated bodies with circulation through them in the hydrokinetic system, by jointed rigid connecting links, we may arrange for configurations of stable equilibrium. Thus without fly-wheels, but with fluid circulations through apertures, we may make a model spring balance, or a model luminiferous ether, either without or with the rotational quality corresponding to that of the true luminiferous ether in the magnetic fluid—in short, do all by the perforated solids with circulations through them that we saw we could do by means of linked gyrostats. But something that we cannot do by linked gyrostats we can do by the perforated bodies with fluid circulation. We can make a model gas. The mutual action at a distance, repulsive or attractive according to the mutual aspect of the two bodies when passing within collisional distance [1] of one another, suffices to produce the change of direction of motion in collision, which essentially constitutes the foundation of the kinetic theory of gases; and which, as we have seen before, may as well be due to attraction as to repulsion, so far as we know from any investigation hitherto made in this theory.

There remains, however, as we have seen before, the difficulty of providing for the case of actual impacts between the solids; which must be done by giving them massless spring buffers, or, which amounts to the same thing, attributing to them repulsive forces sufficiently powerful at very short distances to absolutely prevent impacts between solid and solid; unless we adopt the equally repugnant idea of infinitely small perforated solids, with infinitely great fluid circulations through them. Were it not for this fundamental difficulty, the hydrokinetic model gas would be exceedingly interesting; and, though we could scarcely adopt it as conceivably a true representation of what gases really are, it might still have some importance as a model configuration of solid and liquid matter, by which without elasticity the elasticity of a true gas might be represented.

But lastly, since the hydrokinetic model gas with perforated solids and fluid circulations through them fails because of the impacts between the solids, let us annul the solids and leave the liquid performing irrotational circulation round vacancy,[2] in the place of the solid cores which we have hitherto supposed; or let us annul the rigidity of the solid cores of the rings, and give them molecular rotation according to Helmholtz's theory of vortex motion. For stability the molecular rotation must be such as to give the same velocity at the boundary of the rotational fluid core as that of the irrotationally circulating liquid in contact with it, because, as I have proved, frictional slip between two portions of liquid in contact is inconsistent with stability. There is a further condition, upon which I cannot enter in detail just now, but which may be understood in a general way when I say that it is a condition of either uniform or of increasing molecular rotation from the surface inwards, analogous to the condition that the density of a liquid, resting for example under the influence of gravity, must either be uniform or must be greater below than above for stability of

[1] According to this view there is no precise distance, or definite condition respecting the distance, between two molecules at which apparently they come to be in collision, or when receding from one another they cease to be in collision. It is convenient, however, in the kinetic theory of gases, to adopt arbitrarily a precise definition of collision, according to which two bodies or particles mutually acting at a distance may be said to be in collision when their mutual action exceeds some definite arbitrarily assigned limit, as, for example, when the radius of curvature of the path of either body is less than a stated fraction (1/100, for instance) of the distance between them.

[2] Investigations respecting coreless vortices will be found in a paper by the author, 'Vibrations of a Columnar Vortex,' *Proc. R. S. E.* March 1, 1880; and a paper by Hicks, recently read before the Royal Society.

equilibrium. All that I have said in favour of the model vortex gas composed of perforated solids with fluid circulations through them holds without modification for the purely hydrokinetic model, composed either of Helmholtz cored vortex rings or of coreless vortices, and we are now troubled with no such difficulty as that of the impacts between solids. Whether, however, when the vortex theory of gases is thoroughly worked out, it will or will not be found to fail in a manner analogous to the failure which I have already pointed out in connection with the kinetic theory of gases composed of little elastic solid molecules, I cannot at present undertake to speak with certainty. It seems to me most probable that the vortex theory cannot fail in any such way, because all I have been able to find out hitherto regarding the vibration of vortices,[1] whether cored or coreless, does not seem to imply the liability of translational or impulsive energies of the individual vortices becoming lost in energy of smaller and smaller vibrations.

As a step towards kinetic theory of matter it is certainly most interesting to remark that in the quasi-elasticity, elasticity looking like that of an india-rubber band, which we see in a vibrating smoke-ring launched from an elliptic aperture, or in two smoke-rings which were circular, but which have become deformed from circularity by mutual collision, we have in reality a virtual elasticity in matter devoid of elasticity, and even devoid of rigidity, the virtual elasticity being due to motion, and generated by the generation of motion.

The following Papers were read:—

1. *On the Action of Lubricants.* *By* Professor OSBORNE REYNOLDS, *F.R.S.*

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2. *On Kinetic Elasticity as illustrating the Mechanical Theory of Heat.* *By* Professor OSBORNE REYNOLDS, *F.R.S.*

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3. *On the Vapour-pressure of a substance in the solid and liquid states at the same temperature.* *By* Professor WILLIAM RAMSAY, *Ph.D.*, *and* SYDNEY YOUNG, *D.Sc.*

Regnault, in the course of his researches on the vapour-pressures of liquids and solids, attempted to ascertain whether the vapour of a substance in the solid state exerted a pressure different from that of the same substance in the liquid state, the temperature being in both cases identical; and from results obtained with acetic acid, water, and other liquids, he concluded that the vapour-pressure in both cases is the same. Professor Kirchhoff, and independently Professor James Thomson, showed that from theoretical considerations the vapour-pressures must be different; and the latter, by comparing formulæ given by Regnault to express the curves representing very numerous observations on the vapour-pressures of ice and water, discovered a want of continuity in the two curves; and he pointed out that the water-steam curve, if prolonged to temperatures below the freezing point of water, was not identical with the ice-steam curve, experimentally determined by Regnault, and that the difference approximated to that indicated by theory.

The authors have experimented with four substances which conclusively prove the justice of Professor Thomson's conclusions, viz., camphor, benzene, acetic acid, and water. With the two first it was proved that the solid-vapour and liquid-vapour curves are not continuous, but would intersect at a temperature close to the melting-point; and with the two latter they were successful in cooling them in the liquid form below their freezing-points without their solidifying, and in accu-

[1] See papers by the author 'On Vortex Motion,' *Trans. R. S. E.* April 1867, and 'Vortex Statics,' *Proc. R. S. E.* December 1875; also a paper by J. J. Thomson, B.A., 'On the Vibrations of a Vortex Ring,' *Trans. R. S.* December 1881, and his valuable book on Vortex Motion (being the Adams prize essay for 1882).

rately measuring the vapour-pressures of solid and liquid. This is particularly well shown by acetic acid: at a temperature of 2·72° the pressures of the vapour in contact with liquid was 4·0 mm., while at 2·86° the pressure of vapour in contact with solid was 2·8 mm. The individual determinations amount to more than a hundred and are perfectly concordant with each other, furnishing two curves which diverge at temperatures below the melting point of the solid acid, 16·4°.

These results were obtained by distilling the substance which was made to coat the bulb of a thermometer under different pressures, and observing the temperatures corresponding to these pressures.

As in the case of ice and water, the differences of pressure were too minute to estimate with great accuracy, the apparatus was modified, so that ice, covering the bulb of one thermometer, and water adhering to cotton wool wrapped round the bulb of another thermometer, were exposed to the same low pressures, these pressures being variable at will, and the differences of temperature shown by the thermometers were noted. Assuming the formula given by Regnault for the vapour-pressure of liquid water to be correct, the theoretical vapour-pressure of ice was calculated and was found to be identical with the authors' experimental results. A series of determinations of the vapour-pressure of ice at very low temperatures was also found to be in accordance with the calculated results.

Experiments made by the usual method of heating the solid placed over mercury in a barometer-tube gave capricious results, even when care was taken to ensure absolute purity and complete exclusion of air.

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4. *On the Law of Total Radiation at High Temperatures.* *By* Professor J. Dewar, *M.A., F.R.S.*

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5. *On Loss of Heat by Radiation and Convection as affected by the dimensions of the cooling body, and on Cooling in Vacuum.* *By* J. T. Bottomley, *M.A., F.R.S.E.*

In the course of a series of experiments on the heating of conductors by the electric current, which were carried on during the past winter, I obtained a considerable number of results which both gave me the means of calculating the *Emissivity* for heat in absolute measure of various surfaces under different circumstances, and also caused me to undertake a number of special experiments on the subject. These experiments are still in progress, and I am making preparation for a more extended and complete series; but a brief notice of some of the results already arrived at may not be without interest to the British Association.

The experiments were made on wires of various sizes, some of them covered and some of them bare, cooling in air at ordinary temperatures, and at normal and also at very much reduced pressures.

The mode of experimenting was as follows:—A current passing through a wire generates heat the amount of which is given by Joule's well-known law:—

$$H = C^2R/J \; ; \quad . \; . \; . \; . \quad (1)$$

where C is the current, R the electric resistance, J Joule's equivalent, and H the quantity of heat generated per unit of time; each being reckoned in C. G. S. units. Let l be the length of the wire, d its diameter, and σ_t the specific resistance of the material at temperature $t°$ (at which temperature let us suppose that the wire, in the given external conditions, is maintained by the current). Then

$$R = \frac{\sigma_t l}{\frac{1}{4}\pi d^2} = \frac{4\sigma_t l}{\pi d^2}$$

Hence from (1)

$$H = \frac{C^2}{J} \cdot \frac{4\sigma_t l}{\pi d^2} \quad . \; . \; . \; . \; . \quad (2)$$

Consider, now, that the wire suspended in the air is losing heat by its surface;

and let us suppose that it neither loses nor gains heat by its ends. Let H′ be the quantity lost by emission from the surface per unit of time. Let e be the emissivity or quantity of heat lost per unit area of the cooling surface, per unit difference of temperatures between the cooling surface and the surroundings, per unit time; and $t°$ being, as has been said, above the temperature of the wire, let $\theta°$ be the temperature of the surroundings. Then:—

$$H' = \pi dl.e.(t-\theta) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

But when the wire has acquired a permanent temperature, with the current flowing through it, there is as much heat being lost at the sides as is being generated by the current. In this case H = H′ and we obtain the expression for e:—

$$e = \frac{4C^2\sigma_t}{J\pi^2 d^3(t-\theta)} \quad . \quad . \quad . \quad . \quad (4)$$

My experiments consist in measuring the strength of the current and the temperature of the wire, the latter being effected by measuring the electric resistance of a known length of the wire while the current is flowing through it, and hence inferring the temperature. These being known, and likewise the temperature of the surroundings, we have all the data for finding e, the emissivity of the surface in absolute measure.

The experiments of Mr. D. Macfarlane giving emissivities in absolute measure are well known, and are of undoubted accuracy. They were communicated to the Royal Society (*Proc. Roy. Soc.*, 1872, p. 93); and the results are quoted in Prof. Everett's 'Units and Physical Constants' (chap. ix. § 137). These experiments were made with a copper globe about 4 centimetres in diameter, suspended in a cylindrical chamber, with top and bottom, about 60 centimetres in diameter and 60 centimetres high. The results may be briefly summed up as follows: Mr. Macfarlane finds an emissivity of about $\frac{1}{4000}$ of the thermal unit C. G. S. per square centimetre per second, per degree of difference of temperatures between cooling body and surroundings for a polished surface, with an excess of temperature of a little more than 60° C; and, for a blackened surface, the same emissivity with an excess of 5° C or under.

Using round wires of small diameter (0·85 millimetre and under), and with the surfaces either brightly polished or in the common dull condition of a wire fresh from the maker, I have found a much larger emissivity than $\frac{1}{4000}$. I have obtained for wires of different sizes different values of e varying from $\frac{1}{2000}$ down to $\frac{1}{400}$, which was obtained with a wire of 0·40 mm. diameter, and with an excess of temperature of 24° C. It seems to be shown by all the experiments I have made that, other things being the same, the smaller the wire the greater the emissivity.

To do away with the part of the emissivity which is due to convection and conduction by the air, I have commenced experiments on loss of heat by small wires in the nearly perfect vacuum afforded by the modern mercurial air-pump. This part of the subject was experimented on long ago by Dulong and Petit, and within the last few years by Winkelmann and by Kundt and Warburg; lastly, and much more perfectly, by Mr. Crookes (*Proc. Roy. Soc.*, vol. xxxi., p. 239), though in no case, I believe, were the emissivities in absolute measure determined. The conclusion come to by all these experimenters is the same, namely, that there is a decrease of emissivity due to lowering of the air pressure, this decrease being very small for a reduction down to one-half, or one-third, of the ordinary atmospheric pressure, but becoming very great as the vacuum approaches completeness. The very interesting experiments of Mr. Crookes seem to show that, even with the high vacuum which he obtained, the effect of the residual gas in carrying off heat from the cooling body was far from being annulled.

The following table shows the emissivity of a copper wire with bright surface half a metre long, 0·40 millimetre in diameter, and sealed into a glass tube about 1·5 centimetre in internal diameter.

TABLE I. (Quoted from a Paper to the Royal Society.)

Current Ampères	Pressure 760mm.		Pressure 380mm.		Pressure 180mm.		Very high Vacuum Pump worked continuously	
	$t-\theta$	e	$t-\theta$	e	$t-\theta$	e	$t-\theta$	e
1	4·7°	$\frac{1}{1822}$	4·5°	$\frac{1}{1784}$	5·5°	$\frac{1}{2176}$	17·0°	$\frac{1}{6443}$
2	22·5	$\frac{1}{2084}$	21·5	$\frac{1}{1996}$	23·5	$\frac{1}{2174}$	68·0	$\frac{1}{5620}$
3	56·0	$\frac{1}{2114}$	58·0	$\frac{1}{2180}$	55·0	$\frac{1}{2082}$	140·0?	*

* The temperature probably much too low. The wire sagged down with heat, and touched the sides of the tube at several points. The result calculated for emissivity from 140° is $e=\frac{1}{4606}$.

The following table may also be found interesting. It shows the emissivity in absolute measure of several materials commonly used as insulating coverings for wires in air of ordinary atmospheric pressure.

TABLE II. (Quoted from a Paper to the Royal Society.)

Specifying Number (B.W.G.) and nature of covering	Length of wire (centimetres)	Resistance of 100 centimetres of wire (B. A. Units)	Diameter of wire (millimetres)	Diameter of covered wire outside measurement	Current (amps.)	$t-\theta$	Emissivity
No. 22 Silk covered . . .	100	·0395	·76	·96	10·0	23·4°	0·001333
No. 26 Cotton covered . .	100	·094	·50	·88	10·0	58·0	0·001385
No. 26 Silk covered . . .	100	·1115	·45	·57	9·8	70·0	0·002020
No. 22 Gutta-percha . . .	100	·0455	·72	1·67	10·0	24·0	0·000854
No. 22 Tinned, Gutta-percha-covered and Double Cotton-covered outside	100	·0132	·73	1·8	10·0	23·0	0·000759

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6. *On a Gyrostatic Working Model of the Magnetic Compass.* *By* Professor Sir WILLIAM THOMSON, *LL.D., F.R.S.*

In my communication to the British Association at Southport,[1] I explained several methods for overcoming the difficulties which had rendered nugatory, I believe, all previous attempts to realise Foucault's beautiful idea of discovering with perfect definiteness the earth's rotational motion by means of the gyroscope. One of these, which I had actually myself put in practice with partially satisfactory results, was a

GYROSTATIC BALANCE FOR MEASURING THE VERTICAL COMPONENT OF THE EARTH'S ROTATION.

It consisted of one of my gyrostats supported on knife edges attached to its containing case, with their line perpendicular to the axis of the interior flywheel and above the centre of gravity of the flywheel and framework by an exceedingly small height,

[1] No report of this communication has, so far as I know, hitherto appeared in print.

when the framework is held with the axis of the flywheel and the line of knife edges both horizontal, and the knife edges downwards in proper position for performing their function. The apparatus, when supported on its knife edges with the flywheel not spinning, may be dealt with as the beam of an ordinary balance. Let now the framework bear two small knife edges, or knife-edged holes, like those of the beam of an ordinary balance, giving bearing points for weights in a line, cutting the line of the knife edges as nearly as possible, and of course (unless there is reason to the contrary in the shape of the framework) approximately perpendicular to this line, and, for convenience of putting on and off weights, hang, as in an ordinary balance, two very light pans by hooks on these edges in the usual way. Now, with the flywheel not running, adjust by weights in the pans if necessary, so that the framework rests in equilibrium in a certain marked position, with the axis of rotation inclined slightly to the horizontal in order that the axis of the flywheel, whether spinning or at rest, may always slip down so as to press on one and not on the other of the two end plates belonging to its two ends. Now, unhook the pans and take away the gyrostat and spin it; replace it on its knife edges, hang on the two pans, and find the weight required to balance it in the marked position with the flywheel now rotating rapidly. This weight, by an obvious formula which was placed before the Section at Southport, gives an accurate measure of the vertical component of the earth's rotation.[1]

Gyrostatic Model of the Dipping Needle.

I also showed at Southport that the gyrostatic balance described above, if modified by fixing the knife edges, with their line passing as accurately as possible through the centre of gravity of the flywheel and framework, and with the faces of the knives so placed that they shall perform their function properly when the axis of the flywheel is parallel to the earth's axis of rotation, and the rotation of the flywheel in the same direction as the earth's, will act just as does an ordinary magnetic dipping needle; but showing latitude instead of dip, and dipping the South end of the axis downwards instead of the end that is towards the North, as does the magnetic dipping needle. Thus, if the bearing of the knife edges be placed East and West, the gyrostat will balance with its axis parallel to the earth's axis, and therefore dipping with its South end downwards in northern latitudes and its North end downwards in southern latitudes. If displaced from this position and left to itself, it will oscillate according to precisely the same law as that by which the magnetic needle oscillates.

If the bearings be turned round in azimuth the position of equilibrium will follow the same law as does that of a magnetic dipping needle similarly dealt with. Thus, if the line of knife edges be North and South, the gyrostat will balance with the axis of the flywheel vertical, and if displaced from this position will oscillate still according to the same law; but with directive couple equal to the sine of the latitude into the directive couple experienced when the line of knife edges is East and West. Thus this piece of apparatus gives us the means of definitely measuring the direction of the earth's rotation, and the angular velocity of the rotation.

These experiments will, I believe, be very easily performed, although I have not myself hitherto found time to try them.

Gyrostatic Model of a Magnetic Compass.

At Southport I showed that a gyrostat supported frictionlessly on a fixed vertical axis, with the axis of the flywheel horizontal or nearly so, will act just as does the magnetic compass, but with reference to 'astronomical North' (that is to

[1] The formula is

$$gw = \frac{1}{a} \mathrm{W}k^2 \omega \gamma \sin l;$$

where w denotes the balancing weight; gw the force of gravity upon it; a the arm on which this force acts; W the weight of the flywheel; k its radius of gyration; ω its angular velocity; γ the earth's angular velocity; and l the latitude of the place.

say, rotational North) instead of 'magnetic North.' I also showed a method of mounting a gyrostat so as to leave it free to turn round a truly vertical axis, impeded by so little of frictional influence as not to prevent the realisation of the idea. The method, however, promised to be somewhat troublesome, and I have since found that the object of producing a gyrostatic model of the magnetic compass may, with a very remarkable dynamical modification, be much more simply attained by merely suspending the gyrostat by a very long fine wire or even by floating it with sufficient stability on a properly planned floater. To investigate the theory of this arrangement let us first suppose a gyrostat with the axis of its flywheel horizontal, to be hung by a very fine wire attached to its framework at a point, as far as can conveniently be arranged for, above the centre of gravity of flywheel and framework, and let the upper end of the wire be attached to a torsion head, capable of being turned round a fixed vertical axis as in a Coulomb's torsion balance. First, for simplicity, let us suppose the earth to be not rotating. The flywheel being set into rapid rotation, let the gyrostat be hung by the wire, and after being steadied as carefully as possible by hand, let it be left to itself. If it be observed to commence turning azimuthally in either direction, check this motion by the torsion head; that is to say, turn the torsion head gently in a direction opposite to the observed azimuthal motion until this motion ceases. Then do nothing to the torsion head, and observe if a reverse azimuthal motion supervenes. If it does, check this motion also by opposing it by torsion, but more gently than before. Go on until when the torsion head is left untouched the gyrostat remains at rest. The process gone through will have been undistinguishable from what would have had to be performed if, instead of the gyrostat with its rotating flywheel, a rigid body of the same weight, but with much greater moment of inertia about the vertical axis, had been in its place. The formula for the augmented moment of inertia is as follows. Denote by—

W, the whole suspended weight of flywheel and framework,

K, the radius of gyration round the vertical through the centre of gravity of the whole mass regarded for a moment as one rigid body,

w, the mass of the flywheel,

k, the radius of gyration of the flywheel,

a, the distance of the point of attachment of the wire above the centre of gravity of flywheel and framework,

g, the force of gravity on unit mass,

ω, the angular velocity of the flywheel; the virtual moment of inertia round a vertical axis is

$$\mathrm{WK}^2\left(1+\frac{w^2k^4\omega^2}{\mathrm{W}^2\mathrm{K}^2ag}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The proof is very easy. Here it is. Denote by—

ϕ, the angle between a fixed vertical plane and the vertical plane containing the axis of the flywheel at any time t,

θ, the angle (supposed to be infinitely small and in the plane of ϕ) at which the line a is inclined to the vertical at time t,

H, the moment of the torque round the vertical axis exerted by the bearing wire on the suspended flywheel and framework.

By the law of generation of moment of momentum round an axis perpendicular to the axis of rotation requisite to turn the axis of rotation with an angular velocity $d\phi/dt$, we have

$$wk^2\omega\frac{d\phi}{dt}=g\mathrm{W}a\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

because $g\mathrm{W}a\theta$ is the moment of the couple in the vertical plane through the axis by which the angular motion $d\phi/dt$ in the horizontal plane is produced. Again, by the same principle of generation of moment of momentum taken in connection with the elementary principle of acceleration of angular velocity, we have

$$wk^2\omega\frac{d\theta}{dt}+\mathrm{WK}^2\frac{d^2\phi}{dt^2}=\mathrm{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Eliminating θ between these equations we find

$$\left(\frac{w^2\,k^4\,\omega^2}{g\mathrm{W}a} + \mathrm{WK}^2\right)\frac{d^2\phi}{dt^2} = \mathrm{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

which proves that the action of H in generating azimuthal motion is the same as it would be if a single rigid body of moment of inertia given by the formula (I), as said above, were substituted for the gyrostat.

Now to realise the gyrostatic model compass: arrange a gyrostat according to the preceding description with a very fine steel bearing wire, not less than 5 or 10 metres long (the longer the better; the loftiest sufficiently sheltered enclosure conveniently available should be chosen for the experiment). Proceed precisely as above to bring the gyrostat to rest by aid of the torsion head, attached to a beam of the roof or other convenient support sharing the earth's actual rotation. Suppose for a moment the locality of the experiment to be either the North or South pole, the operation to be performed to bring the gyrostat to rest will not be discoverably different from what it was, as we first imagined it when the earth was supposed to be not rotating. The only difference will be, that when the gyrostat hangs at rest relatively to the earth, θ will have a very small constant value; so small that the inclination of a to the vertical will be quite imperceptible, unless a were made so exceedingly small that the arrangement should give the result, to discover which was the object of the gyrostatic model balance described above, that is to say, to discover the vertical component of the earth's rotation. In reality we have made a as large as we conveniently can; and its inclination to the vertical will therefore be very small, when the moment of the tension of the wire round a horizontal axis perpendicular to the axis of rotation of the flywheel is just sufficient to cause the axis of the flywheel to turn round with the earth.

Let now the locality be anywhere except at the North or South pole; and now, instead of bringing the gyrostat to rest at random in any position, bring it to rest by successive trials in a position in which, judging by the torsion head and the position of the gyrostat, we see that there is no torsion of the wire. In this position the axis of the gyrostat will be in the North and South line, and, the equilibrium being stable, the direction of rotation of the flywheel must be the same as that of the component rotation of the earth round the North and South horizontal line, unless (which is a case to be avoided in practice) the torsional rigidity of the wire is so great as to convert into stability, the instability which, with zero torsional rigidity, the rotational influence would produce, in respect to the equilibrium of the gyrostat with its axis reversed from the position of gyrostatic stability. It may be remarked, however, that even though the torsional rigidity were so great that there were two stable positions with no twist, the position of gyrostatic unstable equilibrium made stable by torsion would not be that arrived at: the position of stable gyrostatic equilibrium, rendered more stable by torsion, would be the position arrived at, by the natural process of turning the torsion head always in the direction of finding by trial a position of stable equilibrium with the wire untwisted by manipulation of the torsion head.

Now by manipulating the torsion head bring the gyrostat into equilibrium with its axis inclined at any angle ϕ, to that position in which the bearing wire is untwisted; it will be found that the torque required to balance it in any oblique position will be proportional to sin ϕ.

The chief difficulty in realising this description results from the great augmentation of virtual moment of inertia, represented by the formula (1) above. The paper at present communicated to the section contains calculations on this subject, which throw light on many of the practical difficulties hitherto felt in any method of carrying out gyrostatic investigation of the earth's rotation, and which have led the author to fall back upon the method described by him at Southport, of which the essential characteristic is to constrain the frame of the gyrostat in such a manner as to leave it just one degree of freedom to move. The paper concludes with the description of a simplified manner of realising this condition for a gyrostatic compass—that is to say, a gyrostat free to move in a plane either rigorously or very approximately horizontal.

7. *Recent Improvement in Apparatus and Methods for Sounding Ocean Depths. By* Rear-Admiral Daniel Ammen, *U.S. Navy.*

The author, after briefly noticing the advances made by Berryman, Brooke, Sands and others, in deep-sea sounding apparatus, proceeds to the soundings, by Sir W. Thomson, in the Bay of Biscay in 1872, at a depth of 2,700 fathoms. He used pianoforte wire, Birmingham gauge 22, weighing 14½ lbs. to the nautical mile, capable of bearing a strain of 230 lbs. His dynamometer, had three miles in length of this wire been wound upon the drum, would have been still so portable that one man could have carried it with ease.

Early in 1873 the Navy Department was preparing to make extended soundings in the Pacific Ocean. The Chief of Bureau of navigation, charged with the execution of this work, asked the advice and assistance of Sir William Thomson. He was good enough to order wire and such apparatus as his personal experience suggested, and to send carefully prepared instructions for effecting the object in view; in short, he did everything within his power to make the use of his apparatus successful. The substitution of it and its effective manipulation by Captain Belknap, U.S.N., marked an era of progress in deep sounding and in possibilities of obtaining true ocean depths, as truly as did the steamship mark an advance in traversing wide and stormy seas with celerity and certainty. At that time Belknap commanded the 'Tuscarora,' and until the sounding apparatus was sent, had only the fittings that belong to vessels of war. Notwithstanding these disadvantages, the results obtained were eminently satisfactory. For specific information reference may be made to No. 54 of the Hydrographic Office publications, entitled 'Deep-sea Soundings in the North Pacific Ocean,' 1874.

In depths of 2,500 fathoms Belknap found it necessary to make several additional revolutions of the drum by hand, on the sinker striking the bottom, to prevent jerks and strains on the wire which otherwise would have occurred from the rolling of the ship. This necessity was due to the almost instantaneous ceasing of the drum to revolve on the sinker touching the bottom. He reported his soundings at this depth as probably more accurate than many casts in depths of 100 fathoms with an ordinary lead and line. He added: 'I expect to accomplish all the work with it (Sir William Thomson's apparatus) which the Department has assigned me, and if I succeed, no greater compliment could be paid to the genius of the inventor.'

The winding up of miles of wire on a light drum gave a cumulative pressure on the original apparatus in deep soundings, such as to make a continuous system of repair necessary, and finally the substitution of steel drums in the Naval service.

To fully appreciate the advance made through the use of this apparatus, it is necessary to bear in mind the tons of rope required to reach depths of four or five miles, and its rapid deterioration from use, the cumbrous apparatus, the slowness of the process even under the most favourable conditions, and what is of greater import, the uncertainty as to the actual depth sounded, arising in part from the under-currents of the ocean carrying great bights of rope in one or more directions, and in part from the very small proportion the weight of the sinker must bear to the hemp line, but in a more marked degree from the 'stretch' of the rope under tension, and the gradual shortening of it as soon as the sinker reached the bottom.

The report of the Secretary of the Navy for 1874, p. 61, discusses the advantages gained by the use of wire as follows: the small amount of weight and space required for the apparatus; the large weight of the sinker relatively with the weight of the wire necessary, even in sounding the greatest depths, and the very little surface friction of wire in its descent. Miles of wire have very little 'stretch' at ordinary tension, and hemp line a great deal, from which in the first case the indications of the dynamometer would be almost instantaneous, and in the second would be obscure and quite uncertain as to the exact depth and moment when the sinker reached the bottom. Other advantages are: the ease with which the wire is preserved from deterioration. It stated further: 'The problem of measuring the exact depths of the ocean, and bringing up parts of the soil from their beds, may now be regarded as solved.'

The deepest sounding known was taken by Belknap off the east coast of Japan, 4,655 fathoms, a little more than $5\frac{1}{4}$ statute miles in depth. He took 304 soundings of 1,000 fathoms or upwards, mean time of descent for the first 1,000 fathoms, 10 mins. 6 secs.; 161 of 2,000 fathoms or upwards, time of descent in the second thousand, 11 mins. 36 secs.; 38 of 3,000 or upwards, time of descent for the third thousand, 12 mins. 46 secs.; 9 of 4,000 fathoms or upwards, time of descent for the fourth thousand, 15 mins. 54 secs. The rate of reeling in by hand was much slower than now attained by the use of steam power, yet it was surprisingly rapid and easy in execution in comparison with the reeling in of hemp line.

In the great depths off the east coast of Japan, with the strong currents, Belknap's appliances were in fact taxed beyond a perfectly satisfactory execution, the wire having parted on one occasion at a depth of 4,643 fathoms, before reaching the bottom, and again in reeling in, after sounding in a depth of $5\frac{1}{4}$ statute miles. Larger wire and heavier apparatus can develope beyond a doubt the depths called by the Germans the 'Tuscarora Deep.' As now supposed from the soundings taken, this deep water lies at a mean distance of 120 miles from, and parallel to a line drawn between the most easterly Cape of Niphon and the most northerly Kurile Island. This is a general direction of N.E. half N. It appears to be at least 250 miles in length, and is probably much longer. Captain Belknap justly says that those extraordinary depths, contiguous to a region of elevations, afford a field of operations of great interest to the hydrographer.

The soundings made by Belknap comprise an arc of a great circle between the northern part of the island of Niphon, the Aleutian Islands, and Puget Sound; another line between San Diego, Cal., via the Sandwich Islands, and the Bay of Yokohama, and a development of the true ocean-bed from Puget Sound to San Diego. They reveal a dozen or more submerged elevations, veritable mountains 'full many a fathom deep.' In fact, these soundings furnish the first extended and undeniable development of extraordinary and abrupt inequalities in the depths of the sea far away from the land. We owe this to the inventive genius of Sir William Thomson, and to the professional capacity of Captain Belknap, who not only knew how to make the best use of what he was furnished with, but also had the capacity to cure defects in the apparatus such as they were. In depths of 3,000 fathoms he used a detachable sinker of 55 lbs. In greater depths he supplemented this with 20 to 30 lbs. of lead. In order to secure specimens of the bottom in larger quantity Belknap designed several cups, one of which is now unsurpassed for efficiency by whatever modification or other design, as it did its work perfectly.

Although at the time these soundings with wire were determined on, the Superintendent of the Coast Survey of the United States hardly hoped a favourable result from the use of wire, as it had not been adopted by the 'Challenger,' which had been fitted out for scientific investigation some months before, yet so able a man of science was not slow to adopt what Belknap had shown was so admirable. In Sigsbee's 'Deep-sea Sounding and Dredging,' published by the Coast Survey, Washington, 1880, we find, chap. 1, 'In August 1874 the "Blake," Commander John A. Howell, U.S.N., was provided with one of Sir W. Thomson's sounding machines for wire.' Commander Sigsbee in the following months made modifications in the apparatus giving additional facility and rapidity of execution in sounding, but nothing could be added to the accuracy of the results that had already been obtained by Sir W. Thomson and Belknap.

In the soundings of the Coast Survey, executed by Sigsbee, Bartlett, Tanner, and others, we have a veritable revelation in the contours and depths of our coasts. They have brought to our knowledge the wonderful cleft in the crust of the earth on the line of the Hudson River extending 100 miles beyond Sandy Hook. Scarcely less interesting, but not so startling, are the plaster casts of the Gulf of Mexico, and of the Caribbean Sea. It is a grateful duty to indicate to whom honour is due that the depths of seas are no longer an unrevealed and unfathomable mystery.

FRIDAY, AUGUST 29.

The following Papers and Report were read:—

1. *The Seat of the Electromotive Forces in the Voltaic Cell. By* Professor OLIVER J. LODGE, *D.Sc.*—See Reports, p. 464.

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2. *Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements.*—See Reports, p. 29.

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3. *On certain practical applications of a new Mechanical Principle. By* Professor H. S. HELE SHAW.

A paper by the author, dealing with the theory of continuous calculating machines, was communicated to the Royal Society by Sir William Thomson, and read on June 19 of this year.[1] In that paper a mechanism of a new principle was suggested which would in theory perform the same operation as the disk and roller mechanism, and at the same time was free from the defects of the latter. The present paper is an account of the further development of the principle in the direction of its practical application.

It was necessary, in order that the mechanism might be understood, to first briefly explain the principle of its action, which consists of two parts: (1) A property of the motion of a sphere when in contact under certain conditions with suitably placed rollers; (2) a geometrical principle connecting the relative position of the rollers in contact with the sphere, by which definite numerical results are obtained. The first is as follows: If two surfaces of revolution roll upon one another without slipping, their axes of revolution must lie in the same plane. Suppose any number of disks or rollers to be in contact with a sphere round one of its great circles; then they will roll upon it if their axes lie in the diametral plane which forms this great circle by its intersection with the sphere. The axis of revolution of the sphere must be also in this plane, but may have any position therein. Suppose a second set of disks or rollers in contact with the sphere round another great circle formed by the intersection of a diametral plane perpendicular to the first, and with their axes of revolution in this plane; then, as before, the axis of rotation of the sphere due to its rolling contact with the second set of rollers must lie somewhere in the second diametral plane. There is, however, only one position for the axis which can satisfy both the above conditions, and that is the intersection of the two diametral planes. Thus, by changing this axis by the mere *rolling* motion of one set of rollers in a movable frame, any required velocity ratio of two rollers belonging to the other set, which are placed in a fixed frame, can be obtained. This is, moreover, done without the application of any force which will produce an error, in the case of exact numerical results being required.

The practical applications proposed are of two kinds, viz.: (1) for performing mechanically continuous and discontinuous numerical calculations; and (2) for varying in any required manner appreciable forces transmitted through it. The determination of the proper materials and construction for each case has been to a certain extent guided by theoretical considerations, though it has been chiefly a matter of experiment.

The paper goes on to describe by means of diagrams, and the actual instrument itself, a rolling planimeter, similar in its method of use to those of Sang and Clerk Maxwell, but differing in its principle of operation and in its ready adaptation for measurement of the moment of area, and moment of inertia.

An instrument for indicating efficiency is also described and illustrated. In both the above instruments the forces transmitted are inappreciable, and the rolling motion of the sphere is obtained by contact with the disks or rollers in such a way

[1] See *Proc. Roy. Soc.* vol. xxxvii. p. 189.

as to ensure almost absolute accuracy. This method, which is explained, is not suitable for the second kind of application, where the forces transmitted have to be considered. The paper discusses the practical mode of dealing with this question, and by means of diagrams and a model (which was exhibited) shows that the transmission of moderate forces can be satisfactorily accomplished where accurate velocity ratios are not required.

4. *On some Irregularities depending on Temperature in Baily's experiments on the Mean Density of the Earth.* *By* Professor W. M. HICKS, *M.A.*

5. *On Safety Fuses for Electric Circuits.*
By Professor Sir WILLIAM THOMSON, *LL.D.*, *F.R.S.*

6. *A Lecture Experiment on Induction.*
By Professor Lord RAYLEIGH, *LL.D.*, *F.R.S.*

It is well known that an electro-magnet, interposed in the circuit of an alternate current machine, diminishes the effect far more than in a degree corresponding to the resistance of the additional wire. This behaviour of an electro-magnet may be exhibited to an audience in an instructive manner, by use of a helix wound with two contiguous wires (such as are commonly used for large instruments), one of which is included in the circuit of a De Meritens machine, and a few incandescent lamps. If the circuit of the second wire be open, the introduction of a few stout iron wires into the helix causes a very marked falling off in the incandescence. On closing the second circuit, currents develope themselves in it of such a kind as to compensate the self-induction, and the lights recover their brilliancy. Even without iron, the effect of closing the second circuit is perceptible, provided the degree of incandescence be suitable.

An arrangement suitable for illustrating the same phenomenon with currents of small intensity was described in 'Nature' for May 23, 1872.

7. *On Telephoning through a Cable.*
By Professor Lord RAYLEIGH, *LL.D.*, *F.R.S.*

The principles of this subject were laid down thirty years since by Thomson, but the author had not met with an application to the circumstances of the telephone.

A periodic variation of potential, imposed at one end, is propagated along the line in accordance with the law

$$v = e^{-\sqrt{\frac{n}{2k}}\cdot x} \cos.\left(nt - \sqrt{\frac{n}{2k}}\cdot x\right).$$

in which $\frac{n}{2\pi}$ is the frequency of the electrical vibration. For Atlantic cables the constant k, depending upon the resistance and the capacity, has in C.G.S. measure such a value as 2×10^{16}. The distance, in traversing which the amplitude is reduced in the ratio $e : 1$, is given by

$$x = \sqrt{\frac{2k}{n}} = \frac{2 \times 10^8}{\sqrt{n}} \text{ centimetres.}$$

If we take a pitch rather more than an octave above that of middle c, we have $n = 3{,}600$, $\sqrt{n} = 60$, so that

$$x = 3 \times 10^6 \text{ centimetres} = 20 \text{ miles approximately.}$$

A distance of twenty miles would thus reduce the intensity of sound to almost a tenth, an operation which could not be often repeated without rendering it inaudible. With such a cable the practical limit would not be likely to exceed fifty miles, more especially as the easy intelligibility of speech requires the presence of notes still higher than is supposed in the above numerical example.

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8. *On the Influence of Magnetism on the Discharge of Electricity through Gases.* *By* Professor ARTHUR SCHUSTER, *F.R.S.*

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9. *On a Galvanometer with Twenty Wires.*
By Professor Lord RAYLEIGH, *LL.D.*, *F.R.S.*

Galvanometers suitable for currents of an ampère or two are most accurately standardised by means of the silver voltameter, but this method ceases to be convenient when the current to be dealt with rises above five ampères. The present instrument is a kind of differential galvanometer, provided with two electrically distinct coils, whose constants are in the ratio of ten to one. A current of one ampère through one coil thus balances a current of ten ampères through the other. If the first be measured in terms of silver, the second serves to standardise an instrument suitable for the larger current.

The novelty consists in the manner in which the ten to one ratio is secured. Twenty pieces of No. 17 cotton-covered wire, being cut to equal lengths of about eight feet, were twisted closely together, two and two, so as to form ten pairs, which ten pairs were again in their turn twisted slightly together so as to form a rope. In each of the two circuits there are ten wires. In one, that intended for the larger current, these wires are in parallel; in the other circuit the ten wires are in series. Of each of the original twists one wire belongs to the parallel and one to the series group. Now the two wires forming an original twist are equally effective upon a needle suspended in any reasonable situation with respect to them, and thus if the ten wires in parallel have the same resistance, the circuit formed by the ten wires in series will be precisely ten times as effective as the circuit formed by the ten wires in parallel. This is independent of the disposition of the ten original pairs, but by winding them loosely into a rope we gain an additional security in case the ten parallel wires, though of the same length and cut from the same hank, should have slightly different resistances. If all the twenty wires could be assumed to have equal efficiency in deflecting the needle, the equality of resistances of the wires in parallel would be of no moment.

The rope is bent into a single circle of about a foot diameter with leads two feet long. At this distance the necessary junctions can be effected without fear of disturbance. The electrodes for the heavy current are formed of parallel copper strips, separated by an insulating layer, and the current is brought up through twisted leads as in Sir W. Thomson's graded galvanometers. In the case of the smaller current, which embraces the needle ten times, so much precaution is not required.

After the wires in parallel had been soldered up, but while those destined to be joined in series were still disconnected, insulation tests were made between each wire of the series group and the other wires of that group as well as the group in parallel. The resistance between each series wire and the parallel group was about $2\frac{1}{2}$ megohms, and (as might be expected) about twice as much between any pair of wires of the series group.

It will be seen that when, in the use of the instruments, two currents are balancing one another, every one of the twenty wires carries the same current. In the actual instrument this current might amount, without undue heating, to four ampères, so that the heavy current would be 40 ampères. If it be not thought necessary to deal with currents heavier than 10 ampères, the gauge of wire might be reduced, a change which would facilitate the winding of the rope.

The magnet and mirror should be of the kind used in reflecting galvanometers, and may be hung at the centre of the circle.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Papers and Reports were read:—

1. *On the Connection between Sunspots and Terrestrial Phenomena. By* Professor ARTHUR SCHUSTER, *F.R.S.*—See Reports, p. 446.

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2. *On certain Short Periods common to Solar and Terrestrial Meteorological Phenomena. By* Professor BALFOUR STEWART, *M.A., LL.D., F.R.S., and* WM. LANT CARPENTER, *B.A., B.Sc., F.C.S.*

In 1879 it was shown by one of us that the diurnal temperature ranges at Kew, Utrecht, and Toronto appeared to exhibit common periods around 24 days, and that similar phases occurred at Toronto eight days before they occurred at Kew. Using a method of analysis detecting the existence of unknown inequalities having apparent periodicity in a mass of observations previously described ('Proceedings Royal Society,' May 15, 1879), the authors have now made a detailed comparison between sun-spot observations extending from 1832 to 1867 inclusive, Toronto diurnal temperature ranges from 1844 to 1879 inclusive, and Kew temperature ranges from 1856 to 1879 inclusive. As Professor Stokes has pointed out, it is not necessary for present purposes to discuss whether these sun-spot inequalities have a real or only an apparent periodicity. The results of the comparisons made by the authors appear to justify the following conclusions:

(1) Sun-spot inequalities around twenty-four and twenty-six days seem to have periods very nearly the same as the Toronto and Kew temperature ranges.

(2) In the sun-spots and Kew temperature ranges there is only a single oscillation in the period, while there is evidence of a double oscillation in the Toronto temperature ranges.

(3) The solar maximum occurs eight or nine days after one of the Toronto maxima, and the Kew maximum occurs about seven days after the same Toronto maximum.

(4) The proportional temperature range oscillation is much less than that exhibited in the case of the solar inequalities.

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3. *Second Report of the Committee for the Harmonic Analysis of Tidal Observations.*—See Reports, p. 33.

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4. *Report of the Committee for reducing and tabulating the Tidal Observations in the English Channel made with the Dover Tide-gauge, and of connecting them with observations made on the French Coast.*—See Reports, p. 37.

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5. *On the Importance of Tidal Observations in the Gulf of St. Lawrence, and on the Atlantic Coast of the Dominion. By* Professor JOHNSON, *LL.D.*

The object of this communication is to draw attention to the fact that a considerable number of wrecks in past years, involving great loss of life and property, were probably due to want of knowledge of the Tides and Tidal Currents in the Gulf of St. Lawrence and on the adjacent Atlantic coasts, and to suggest that some means be adopted by the British Association to urge the Canadian Government to establish a series of stations where systematic Tidal Observations shall be taken, to be subsequently reduced and made available for practical and scientific purposes.

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6. *Report of the Committee for considering the best methods of recording the direct intensity of Solar Radiation.*—See Reports, p. 28.

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7. *Fourth Report of the Committee on Meteoric Dust.*—See Reports, p. 38.

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8. *On the Spot Spectrum from D to B. By the* Rev. S. J. PERRY, *F.R.S.*

The observations of the red end of the spot spectra, made at Stonyhurst Observatory in 1883, afforded good proof of the existence in solar spots of Fe, Ca, Na, H, Ti, Ba, and Ni, and also fair indications of many other substances. They likewise showed that the line of W.L. 6677·6 belongs to the spectra of both spots and chromosphere.

During the course of the current year the widening of 240 lines between B and D has been detected, 55 of which belong to Fe, 12 to Ti, 4 to Ni, 4 to Na, and others to Ca, Ba, Mn, &c.

Faint lines are most affected by the selective absorption of spot vapours, Ti, Fe, and Na, offering numerous examples.

Lines not visible in the solar spectrum are often seen in spot spectra, and the penumbra affects lines in some cases almost as much as the umbra.

Different elements are widened in different spots, and the lines of the same element are differently affected.

The widening of the D lines on the violet side only affords evidence of a decided uprush in certain spots.

Lastly, attention should be drawn to the fact that lines, marked as telluric in Ångström's map, are not unfrequently wider in spot spectra than on the surface of the photosphere in the immediate neighbourhood.

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9. *On Recent Progress in Photographing the Solar Spectrum. By* Professor H. A. ROWLAND.

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10. *On an Induction Inclinometer adapted for Photographic Registration. By* CHARLES CARPMAEL, *M.A.*

The instrument is a modification of Lloyd's Induction Inclinometer, the modifications consisting in—

1. The substitution of a bifilar for a unifilar suspension.

2. The placing of the induction bars at such a distance apart that, when the dip has approximately its mean value at the place, the suspended magnet may be in equilibrium at right angles to the magnetic meridian, under the action of the magnetic forces alone, the torsional force of the suspension threads having been made to vanish in that position.

Stops are employed to prevent the magnet from turning much beyond the limits of the scale; as, if either pole of the magnet is allowed to approach too near to the soft iron bars, their magnetic condition is permanently changed.

With this arrangement, if the *permanent* magnetism of the induction bars is eliminated, the reading in the mean position is unaffected by changes in the total force, which will, however, affect the scale coefficient. Except in great disturbances, therefore, no correction for force need be applied. Small changes in declination will not affect the readings, so that the instrument is well adapted for photographic registration of changes of the dip.

The permanent magnetism may be eliminated from each bar separately, by setting it in vibration when in the position in which the permanent magnetism opposes the induced, continuing the process until the reading of the instrument is unaltered on reversing the bar.

The equation for equilibrium is approximately

$$\text{M E cosec}\,\beta\ (\theta - \beta) = \text{G}\ (\text{I} - \text{K})$$

where M is the magnetic moment of the magnet, E the total force of the earth's magnetism, θ the angle of dip, I the scale reading corresponding to θ, K the scale reading (near the centre of the scale) in the position of no torsion, β the value of θ corresponding to K, and G is a constant depending on the arc value of each scale division, on the distance between the suspension threads, and on the magnetism induced in the bars by the suspended magnet. The value of G may be determined from the time of vibration about the position of equilibrium.

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11. *On an Electric Control for an Equatorial Clock-movement. By the* EARL OF ROSSE, *F.R.S.*

Although in the construction of timekeepers with intermittent motion a marvellous degree of accuracy has been arrived at, when it has been sought to obtain that constant and uniform motion, so important in the driving apparatus of an equatorial telescope, greatly increased difficulties have arisen.

In all the various examples we have the approximate control effected by the ordinary ball governor, whose balls, by moving outwards from the axis of rotation under the action of centrifugal force, when the required velocity has been nearly attained, bring into action a force of friction which prevents that velocity from being sensibly exceeded even with very considerable additions to the driving power. Now, although this simple contrivance has for some kinds of work proved sufficiently satisfactory, yet in all its forms and modifications, whether with approximate parabolic motion of the balls through a considerable range, or with their motion confined within the narrowest limits between a crutch or rest and a friction-ring, it has failed to afford unaided that accuracy of motion so desirable in celestial photography and spectroscopy.[1]

Hence the plan has been resorted to of adjusting the governor for a speed slightly too great, and reducing that speed to just what is required by means of a supplementary friction-break.

The friction-break has received several modifications. A brush dipping into oil and a fly revolving in air have been employed, and the pressure of a lever-arm clothed with leather against a metal disc revolving at a high velocity, being now the most usual and probably the most effective arrangement. I am now using a leather covering on the disc.

We have in all these modifications this principle in common for bringing the supplementary break into play. The break is connected with a cog-wheel, rolling between two others, the first of which, rigidly connected with the train and governor, revolves continuously at a normal speed of, say, a little greater than once a minute; the second, carrying a scape-wheel of, say, 30 teeth, is permitted by a seconds pendulum to rotate intermittently in the opposite direction once in a minute. The intermediate wheel thus tends to preserve its normal position, any slight excess or defect of velocity of the governor bringing the friction break into play for a portion of each second slightly longer, or slightly shorter, than the normal one, and so preventing further displacement.

(A). The arrangement in its simplest form is provided with an escapement and a pendulum, whose motion is kept up by the action of gravity upon the intermediate wheel and fittings through that escapement, but as the impelling force is augmented or diminished according as the break comes more or less into action, isochronism of the pendulum is only very imperfectly attained.

(B). Hence a modification was introduced by Mr. Howard Grubb, in which the pallets are inclined at the angle of friction throughout their length, and the scape-wheel drops without giving an impulse to the pendulum, and the motion is kept up,

[1] Dr. Huggins in working with his spectroscope, and Mr. Common in photography, have been obliged to aid this governor by continual personal attention.

and the isochronism with a regulator clock is preserved by alternate equal and opposite electric currents at every second, as in the ordinary system of controlled clocks.

This method appears to have proved satisfactory in the cases where it has been applied, but as the 3-foot reflector at Parsonstown, being unprovided with friction rollers, does not move quite so freely, and, being unprotected by a building, is necessarily more affected by the wind, and as the oil employed to lubricate the parts is more exposed to the action of the atmosphere, it appeared doubtful if the plan would be as good in practice as it is in theory.

For the sake of simplicity the pendulum-control without the intervention of electricity, described in (A), had first been tried, but though a marked improvement in the going over what it had been under the control of the governor alone was observed, still there remained much to be desired.

The ordinary electric control from a clock in the Observatory was then applied to the same pendulum, the impulse being given through the escapement as before, but the action of the control was not found sufficiently prompt. The pendulum was then discarded and the escapement re-arranged, so that the pallets were perpendicular to the motion of the scape-wheel, and cut square. Thus no impulse was given to it by the latter, and it was made to oscillate with the pendulum of the regulator-clock by the alternate action of two electro-magnets upon two pieces of soft iron attached to the escapement. The going of the clock-movement was now quite satisfactory, the electric control being sharp and prompt; but the battery power required to work it with certainty was considerable, and though this might have been much reduced by more refinement of workmanship, through diminution of the amplitude of motion of the escapement, and consequent reduction of the distance through which the magnets would have to exert their attractive force, it appeared preferable to vary the construction.

(C). The pallets are now inclined by an amount rather greater than the angle of friction, so that under the pressure of the scape-wheel the escapement would oscillate freely. Its oscillations are checked by the currents from the controlling clock, which are sent alternately through each of two electro-magnets. Thus the oscillations of the escapement are arrested on the attached piece of soft iron coming into contact with it.

It is now possible to lengthen the arm carrying the keeper to almost any desired extent, so as to gain power, as the attractive force is no longer required to attract the keeper from the opposite end of the range of motion, but simply to hold it when brought into contact until the current be diverted, and less than one-twelfth of the battery power is adequate to work the modified escapement. I am unable to say, *cæteris paribus*, the relative strengths of current required by this and by Mr. Grubb's arrangement, but it may be claimed that the former (C) is by no means so complicated, and that at *every* second it is brought under a quick and *certain* control from the Observatory clock, that no refined workmanship is needed—an important quality in the case of a telescope unprotected by a building, in a moist climate—and that in theory the battery power may be reduced to any desired extent by lengthening the lever-arm which carries the keeper.

It has been found of advantage to add a 'dash-pot' to retard the descent of the scape-wheel tooth from one pallet to the next, also to place the centre of motion so that the escapement may always have time to complete by its momentum its full amplitude of oscillation, and come into contact with the electro-magnet even when not pushed all the way by the pallet, and it may not even be necessary, in order to prevent tripping, that the current be sent into each magnet as soon as, or before, it ceases in the other. Probably the total duration of the currents need not be greater than in arrangement (B).

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12. *On Polishing the Specula of Reflecting Telescopes.* *By the* EARL OF ROSSE, *F.R.S.*

So little has been written on the polishing of specula, so few, comparatively, have had experience in the operation and the process is considered to be attended with so much difficulty, that it has occurred to me that, although my own experience is far inferior to that of my late father, a few observations may be of interest.

The process for preparing and completing a parabolic speculum, after that the casting, rough grinding, &c., have been completed, consists of two operations: first, the 'grinding' with emery of finer quality and smaller quantity as the operation proceeds, by which so fine and true a spherical surface may be given as may quickly receive a polish under the action of the polisher; and, secondly, the 'polishing' proper, which not only imparts the polish but changes, by the action of the elastic surface of pitch covered with a paste of rouge and water, the spherical into the paraboloid surface. The principal causes of uncertainty in the process are the variable hygrometric condition and temperature of the air. If the air be too moist, that gradual drying-up of the moisture of the polishing material which is essential to success will not take place; if, on the other hand, it be too dry, it will be difficult to preserve that uniformity of moisture which is equally desirable. Again, if the temperature be too high for the quality of pitch employed, the surface will be untrue in detail from undue wearing down of the softer parts, and the pitch will be pressed out too thin before the process is complete; while, if the pitch be too hard, the rouge will not become sufficiently embedded in it, and the polish will be imperfect, and also the pitch will not be able to adapt itself to the speculum, and an imperfection of figure will result. In short, we have three variables—temperature, moisture, and quality of pitch, and these must be so relatively adjusted as to give a satisfactory result. Two kinds of stroke were employed by my father, that known as the straight stroke, produced by the action of two eccentrics, one making many (say 15) revolutions to one of the other, and that known as the circular stroke, employed also by Mr. Lassell, where both eccentrics rotated in equal times, their radii being parallel to one another.

The *straight* stroke involved a considerable overhang of the polisher during two or three consecutive strokes, and a consequent difficulty in preventing too great local compression of the pitch, while there was some difficulty in preventing an unequal evaporation of the moisture when the air was a little too dry.

The circular stroke also involved a tendency to unequal drying, and a tendency to annular elevations, and depressions of the surface of the speculum could only be removed by a change at intervals of the distance from the centre of the circle described by the centre of the polisher from the centre of the speculum. This was effected in the case of the 3-foot speculum by a somewhat complicated contrivance, and in the case of the 6-foot speculum simply by hand.

The late Mr. Lassell, in the 'Phil. Trans. for 1875,' describes a machine in which the relative angular motions of the eccentrics differ a little only, but as at the time he had nearly given up observing owing to age and infirmity, the machine probably was not tested as it deserved.

I have, during the last two years, reconstructed the two polishing machines at Parsonstown, and have adapted them for giving to the polisher the stroke of Mr. Lassell's machine.[1] I have polished two 3-foot specula and one 6-foot speculum. In each case the result has been much above the average. There has been no appreciable unequal drying, and no tendency to annular depressions.

It should be observed that in *all* the machines the speculum has a slow movement of rotation on its axis, and also the polisher turns round, at a different rate. This was effected by Lassell by means of a ratchet. We have found no necessity for a special contrivance, as the polisher being grasped by a loose hoop, with perhaps $\frac{1}{2}$ to 1 inch of play, rotates by rolling inside the hoop.

With regard to the polishing of flat mirrors, as the required figure can be imparted in the grinding, it appears to be much the simplest to take pains to obtain as flat a surface as possible before polishing, and to impart as fine[2] a surface also as we can in the grinding. Care in this is well repaid by the shortness of time

[1] On reference to Mr. Lassell's paper, it appears that the relative angular velocities of his eccentrics are as 1 : 0·922. In my machine the relative velocities are as 1 : 0·806, but by means of change wheels any other relative velocities can be given.

[2] A bed of hones, made by cementing pieces of Welsh hones on to a metal plate, is well adapted for giving a fine surface before polishing.

(half an hour) required for polishing when little alteration of figure be required, and when no scratches have to be worked out.

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13. *An Account of some preliminary Experiments with Biram's Anemometers attached to Kite-wires.*[1] *By* Professor E. DOUGLAS ARCHIBALD, *M.A.*

In this paper the author recapitulated with additions the description of the kites and apparatus employed, together with the method of making the observations already given in the 'Quarterly Journal' of the Meteorological Society in 1883, Two kites are flown tandem, and the lower or main one carries about 2,000 feet of piano cord wire similar to that used by Sir William Thomson for his deep-sea sounder.

When the observations are grouped roughly for altitude only, the following results are obtained for the exponent x in the empirical formula $\frac{V}{v} = \left(\frac{H}{h}\right)^x$ where V, v, H, h, are the velocities in feet per minute and height in feet at the upper and lower elevations respectively.

No. of Observations	Mean upper height above place of observation in feet	Mean lower height in feet	Mean upper velocity in feet per min.	Mean lower velocity in feet per min.	Approximate value of x in the formula $\frac{V}{v} = \left(\frac{H}{h}\right)^x$
6	249	93	1,630	1,145	$\frac{1}{3}$
8	412	173	1,751	1,474	$\frac{1}{5}$
4	634	324	1,987	1,902	$\frac{1}{16}$

Thus, while the velocity is invariably found to increase, the rate of increase rapidly diminishes above the first 200 or 300 feet. Near the surface the increase of velocity is probably very rapid, and possibly agrees with Mr. Stevenson's formula $\frac{V}{v} = \frac{H}{h}$. Above the first fifty feet, however, it is plain that this formula will not hold. It must further be remembered that the station of observation is itself 500 feet above sea-level, and that about 200 feet above the ground the motion of the air corresponds nearly with what it would have at its real height above a sea-level plain. On this assumption, and adding the 500 feet to both the elevations in the two last groups of the table, we get $x = \frac{1}{2}$ and $\frac{1}{7}$ respectively, values which are probably nearer the truth than $\frac{1}{5}$ and $\frac{1}{16}$, and which hover round the mean value $\frac{1}{4}$, determined by the author from a discussion of cloud velocities up to a height of 25,000 feet above sea-level given by Dr. Vettin of Berlin, and discussed by the author in 'Nature' for May 1883.

Amongst other indirect results obtained by the author is the fact which tends strongly to support Dr. Köppen's theory of the diurnal period in the velocity of the surface-wind The author has frequently found that during the day his kite flew with difficulty, while in the evening it invariably flew steadier, higher, and with a stronger pull than during the day. According to Dr. Köppen there is an interchange of air (Luftaustausch) between the upper and lower layers occasioned by the surface heating during the day, which tends to increase the velocity of the lower air by the communication to it of the more rapid motion which the descending air brings with it from above. By an exactly converse action the motion of the upper layers is correspondingly diminished by the retarding action of the ascending air. This theory agrees perfectly with the phenomena observed by the author.

Evidence as to the existence of an ascending current under the front of cumuli and cumulo-strata, and a descending current under their rear portions is also furnished by the behaviour of the kites.

[1] Printed *in extenso* in *Nature*, November 20, 1884.

Appended is a list of the observations:

OBSERVATIONS MADE WITH BIRAM'S ANEMOMETERS ATTACHED TO KITE-WIRE AT SANDOWN PARK, TUNBRIDGE WELLS, COMMENCING SEPTEMBER, 1883.

(Height of place of observation above sea-level = 500 feet. The four instruments are labelled A, B, C, D.

Date	Time of commencement of observation h. m.	Height of anemometers above place of observation in feet	Velocity of the wind in feet per minute	Times of suspension in minutes	Direction of wind
Sept. 8	4 53	B 278 A 77	1,561 989	98 82	N. 22° W.
" 10	12 25	A 257 B 160	1,542 1,352	106 85	S. 8° E.
Oct. 6	3 59	B 425 A 178	1,177 833	121 109	N. 7° E.
" 20	3 29	B 380 A 146	1,163 882	75 59	N. 85° W.
" 20	5 12	A 217 B 98	1,209 864	34 25	N. 85° W.
" 24	4 12	B 230 A 110	1,907 1,248	25 19	S. 82° W.
Nov. 10	12 31	A 383 B 138	1,771 1,499	130 109	N. 48° W.
" 10	3 1	B 405 A 148	1,791 1,539	114 102	N. 75° W.
Feb. 16	4 42	A 232 B 107	2,079 1,638	26 20	S. 38° E.
" 23	4 31	B 430 A 294	2,534 2,441	90 85	S. 37° W.
" 27	5 26	A 130 B 40	1,147 746	56 45	S. 53° E.
March 8	5 13	B 270 A 88	1,392 1,012	73 37	S. 49° W.
" 15	4 50	B 268 A 79	1,632 1,119	103 89	S. 48° E.
" 19	4 44	A 433 B 215	1,518 1,234	62 53	S. 52° W.
" 20	3 14	B 354 A 167	2,384 2,016	79 66	S. 87° W.
April 2	5 49	A 446 B 212	1,639 1,165	78 68	S. 23° E.
" 4	3 34	B 430 A 228	2,202 1,916	101 79	S. 44° E.
May 14	3 13	D 422 C 292 B 185	2,038 1,936 1,904	112 99 90	S. 38° W.
" 26	2 58	B 495 D 207	1,994 1,879	69 59	N. 77° E.
" 29	3 44	D 646 B 310	1,769 1,648	98 90	N. 28° E.
" 30	3 38	B 631 D 329	2,102 2,025	97 88	N. 37° E.
" 30	5 0	D 643 B 334	2,039 1,987	87 78	N. 35° E.
June 14	11 5	A 618 C 324	2,040 1,950	52 38	N. 1° E.

During the ensuing year with improved apparatus the author hopes to make a more complete series of observations by which the variations in the velocity of the air at different heights may be discussed with reference to the action of the several factors, time of day, season, temperature, humidity, pressure, &c. The conclusions at present tentatively arrived at may be classified thus:

1. The velocity of the air invariably increases up to a height of 1,100 feet above sea-level.

2. The increase is rapid near the surface, and diminishes sensibly at heights of 200 feet or more above the surface.

3. The velocity at any moderate height may be very nearly found from an empirical formula of the form $\frac{V}{v} = \left(\frac{H}{h}\right)^{\frac{a}{\sqrt{h(H+h)}}}$, where V, v, H, h, are the velocities and heights at the upper and lower altitudes, and a a constant to be determined by comparison of observations.

4. That Köppen's theory of the diurnal period in the velocity of the wind is strongly supported by the behaviour of the kites.

5. That there is an ascending current in the front and a descending current in the rear of travelling cumuli and cumulo-strati.

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14. *On the recent Sun-glows and Halo in connection with the Eruption of Krakatoa. By* Professor E. Douglas Archibald, *M.A.*

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15. *On Whirlwinds and Waterspouts.*
By Professor James Thomson, *LL.D., F.R.S.*

Whirlwinds, whether on sea or on land, have their characters in great part alike. For simplicity it will be convenient to begin by taking up only the case of whirlwinds on sea, as thus the necessity for alternative expressions to suit both cases, that of sea and that of land, will be avoided.

It may be accepted as a fact sufficiently established both by dynamic theory and by barometric observations that, at the sea level, the pressure of the air is less in the neighbourhood of the axis of whirl, than it is at places further out from the axis, though within the region of the whirl. The apocentric force (centrifugal force) of the rapidly revolving air resists the inward pulsive tendency of the greater outer than inner pressure. But close over the surface of the sea there exists necessarily a lamina of air greatly deadened as to the whirling motion by fluid friction, or resistance, against the surface of the sea; and, all the more so, because of that surface being ruffled into waves, and often broken up into spray. This frictionally deadened lamina exerts, because of its diminished whirl speed, less apocentric force than the quicker revolving air above it, and so is incapable of resisting the inward pulsive tendency of the greater outer than inner pressure already mentioned. Hence, while rushing round in its whirl, the air of that lamina must also be flowing in centreward.

The influx of air so arriving at the central region cannot remain there continually accumulating: it is not annihilated, and it certainly does not escape downwards through the sea. There is no outlet for it except upwards, and, as a rising central core, it departs from that place. This is one way of thinking out some of the conditions of the complex set of actions under contemplation, but there is much more yet to be considered.

Hitherto, in the present paper, nothing has been said as to the cause or mode of origin of the diminished barometric pressure which, during the existence of the whirlwind, does actually exist in the central region. Often in writings on this subject the notion has been set forth that the diminished pressure is caused by the rapid gyratory motion of the whirling air; but were we to accept that view, we would have still to ask: 'How does the remarkably rapid whirling motion receive its own origin?' The reply must be that the view so offered is erroneous, and that in general a diminished pressure existing at some particular region is the cause rather than the effect of the rapid whirling motion, though in some respects, indeed, these two conditions can be regarded as being mutually causes and effects. each being essential to the maintenance of the other, while there are also some further promoting causes or conditions not as yet here mentioned.

It seems indubitably to be the truth that ordinarily for the genesis of a whirlwind the two chief primarily promoting conditions are:—Firstly: A region of diminished barometric pressure;—this diminution of pressure being, it may be presumed, due to rarefaction of the atmosphere over that region by heat and sometimes further by its condition as to included watery vapour; and, secondly: A previously existing revolutional motion, or differential horizontal motion, of the surrounding air; such revolutional or differential motion being not necessarily of high velocity at any part.

The supposed accumulation of air rarefied by heat or otherwise, for producing the abatement of pressure, may, the author supposes, in some cases extend upwards throughout the whole depth of the atmosphere; and in some cases may be in the form of a lower warm lamina which somehow may have been overflowed or covered by colder air above, through which, or into which, it will tend to ascend; or the lower lamina may in some cases be warmed in any of several ways, and so may get a tendency to rise up through the colder superincumbent atmosphere. On this part of the subject, the author believes, there is much scope for further researches and advancements both observational and considerational—that is to say, by encouragement of a spirit towards accurate observation, and by collection and scrutiny of observed facts and appearances, and by careful theoretical consideration, founded on observational results or suppositions.

To the author it seems probable that the great cyclones may have their region of rarefied air extending up quite to the top of the atmosphere; while often whirlwinds of smaller kinds, many of the little dust whirlwinds for instance, which are frequently to be seen, may terminate or gradually die out at top in a layer or bed of the atmosphere different in its conditions, both as to temperature, and as to original motion from the lower layer in which the whirlwind has been generated. In many such cases the upper air may probably be cooler than the lower air in which the whirlwind originates. On the subject of the actions going on at the upper parts, or upper ends, of whirlwind cores, in most cases, the author feels that he is able to offer at present little more than suggestions and speculative conjectures. In very many descriptions of the appearances presented by those whirlwinds with visible revolving cores, which are called waterspouts, it is told that the first appearance of the so-called waterspout consists in the rapid shooting down from a dense cloud, of a black, cloudy streak, seemingly tortuously revolving, and swaying more or less sidewise. This is said rapidly to prolong itself downwards till it meets the surface of the sea; and the water of the sea is often imagined and described as rising up bodily, or as being drawn up, into the partial vacuum, or central columnar place of diminished pressure. The frequently entertained notion —a notion which has even made its way into writings by men of science, and of authority in meteorology—that the water of the sea is sucked up as a continuous liquid column in the centre of waterspout whirlwinds, is by some writers and thinkers repudiated as being only a popular fallacy; and it is affirmed that it is only the spray from the broken waves that is carried up. In this denial of the supposition of the water being sucked up as a continuous liquid column, the author entirely agrees: and he agrees in the opinion that spray or spindrift from the sea, set into violent commotion by the whirlwind, is carried up in a central ascending columnar core of air.

On the other hand, the commonly alleged inception of the visible waterspout phenomena, in a descending, tortuously revolving, and laterally bending or swaying, cloudy spindle protruding from a cloud, the author supposes to be so well accredited by numerous testimonies that it must be seriously taken into account in the development of any true theory and explanation of the physical conditions and actions involved. He ventures to hazard a suggestion at present—perhaps a very crude and rash one. It is that the rising central core may perhaps, in virtue of its whirling motion and centrifugal tendency, afford admission for the cloudy stratum to penetrate down as an inner core within that revolving ascending core now itself become tubular. The cloudy stratum may be supposed not originally to have been endowed with the revolutional motion or differential horizontal motion with which the lower stratum of thermally expanded air has been assumed to be originally endowed. The upper stratum of air from which the cloudy spindle core is here taken to protrude down into the tubular funnel, is not to be supposed to be cold enough to tend to sink by mere gravity. Though it were warm enough to allow of its floating freely on the thermally expanded air below, it could still be sucked down into the centre of the revolving ascending core of the whirlwind.

The author wishes further to put forward the question as to whether it may not be possible, in some cases of whirlwinds, for the barometric pressure in the central or axial region to become abated through the combined influences of rarefaction by heat (increased, perhaps, by conditions as to included moisture), on the one hand, and of whirling motion, on the other hand, very much beyond the abatement that could be due to heat or heat and moisture alone, without the whirling motion. He thinks it very likely that in great whirlwinds, including those which produce the remarkable phenomena called waterspouts, it may be impossible for the whirling action to be confined to the lower region of the atmosphere; but that, even if commenced there, it would speedily be propagated to the top. It seems also not unlikely, and in some trains of thought it comes to appear very probable, that the whirling fluid, ascending by its levity, would drive outwards from above it all other air endowed with less whirling energy, and would be continually clearing away, upwards and outwards, the less energetic axial core which enters from below, and any, if such there be, that has entered from above. He thinks the question should at least be kept open as to whether the whirling and scouring action may not go forward, growing more and more intense, promoted always by energies from the thermal sources which have produced differences of temperature and moisture in different parts of the atmosphere, and that thus a much nearer approach to vacuum in the centre may be caused than would be due merely to the levity of the superincumbent air, if not whirling.

He also wishes to suggest that the dark and often frightful cloud usually seen in the early stages of whirlwinds and waterspouts, and the dark columnar revolving core often seen apparently protruding downwards from the cloud, may be due to precipitation of moisture into the condition of fog or cloud, on account of abatement of pressure by ascension in level and environment with whirling air, which, by its centrifugal tendency, acts in protecting the axial region from the pressure inwards of the surrounding atmosphere.

Addendum.—A few brief explanations and references will now be added to assist in the understanding of some of the principles assumed in what has been already said. It is to be clearly understood that in a whirling fluid, even if the velocity of the whirling motion be very small at great distances from the axis, if the fluid be impelled inwards by forces directed towards the axis, the absolute velocity will greatly increase with diminution of distance from the axis. Thus in the *Whirlpool of Free Mobility*, in which the particles are perfectly free to move outward or inward, the velocities of the particles are inversely proportional to the distances from the axis, the fluid being understood to be inviscid or frictionless. On this subject reference may be made to a paper by the author on 'Whirling Fluids,' published in the 'Brit. Assoc. Report, Belfast Meeting, 1852,' part ii. p. 130. Again, as to the inward flow caused, in a frictionally retarded bottom lamina of a whirlwind or whirlpool with vertical axis, by the frictional retardation from the bottom on which the whirling fluid rests, reference may be made to a paper by the author on the 'Grand Currents of Atmospheric Circulation,' in the 'British Association Report, Dublin Meeting, 1857,' part ii. p. 38. On another case of the manifestation of the same principle, reference may be made to a paper by the author in the 'Proceedings of the Royal Society for May 1876,' in respect to the flow of water round bends in rivers, &c., with reference to the effects of frictional resistance from the channel in the bends, and to another paper by him in the 'Proceedings of the Institution of Mechanical Engineers, August 1879,' p. 456, where the inward flow is explained as experimentally exhibited.

16. *On the Formation of Frasil Ice.* *By* G. H. Henshaw.

The author suggests the theory that 'frasil ice' is a true growth upon substances beneath the surface of the water, due to the refrigeration of these nuclei by cold currents, in contradistinction to the theory that this ice is first formed on the surface, and afterwards carried down by currents and attached by a process of regelation to substances at the bottom.

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17. *Note on the Internal Temperature of the Earth at Westville, Nova Scotia.* *By* H. S. Poole, *F.G.S.*

On the slope or incline of the Acadia colliery in the Picton coalfield, reaching a length of 2,350 feet, at a depth of 990 feet below the outlet, holes were bored in the freshly mined coal, thermometers inserted, the openings closed, and the temperature taken after some hours. The experiment was repeated, and the record of 55° Fahr. verified.

The ground immediately over the experimental station falls away with the dip of the measures, and is at that point about 930 feet in thickness: taking this as the depth, and allowing for the depth at which the mean surface temperature (42° Fahr.) is uniform by adding 1 to 13 (the difference in degrees between the surface mean temperature and that observed in the coal at the bottom of the incline), the number 14 is divided into 930, the depth, and the result obtained is an average depths of 66 feet for each degree in temperature.

The practical interest attached to such an experiment lies in connection with the depth at which in the future coal may be mined in Nova Scotia without inconvenience from high temperature.

The initial mean temperature being 9° (?) below that of the North of England, is, according to this experiment, equal to a depth of 600 feet greater than in England before a corresponding temperature is reached.

So far as is at present known, it is probable that seams of workable thickness in the Picton field lie at a depth of 4,000 feet; in the Cumberland field at still greater depth; and in Cape Breton, where the seams dip under the ocean, there is every reason to believe they extend to great distances and depths.

In the author's report as Inspector of Mines, in 1877, he referred to the value of these submarine fields, and to the necessity for care in working in our own day the out-crops of the seams near the shore, in order that the wealth seaward may be secured for our successors.

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18. *On the Formation of Mackerel Sky.* *By* Dr. H. Muirhead.

At the Glasgow meeting of the Association in 1876, Sir William Thomson read a short note on the formation of mackerel sky. The author having paid much attention to the various aspects of the congeries of cloudlets so named, has come to the conclusion that the following is the usual mode in which they are generated. Given a thinnish stratum of air moist in process of passing over a drier and cooler body of air, of different velocity or direction. The vapour by cooling will become visible, and from friction the stratum will get rolled into long cylinders. Now let another current of air brush across the cylinders at right angles to their length, or indeed any large angle. This will have the effect of rolling the thinnish stratum into cylinders crossing the first set. And now neither set will appear as long continuous rollers, but from being crossed will show as a congeries of little cloudlets or drums, *i.e.*, mackerel sky.

In favour of this hypothesis it may be noted that if attention be paid to the cloudlets there will often be observed, at one or other extremity of the formation, portions of the cylinders which extend continuously for a considerable length where they have not been divided into drums by a crossing current. Again, if one of the currents moves too rapidly, some of the cloudlets will get so torn by it that they will often show as wisps or mare's tails. Moreover, it may sometimes be observed that when a long slender cloud is sailing end-long across the sky, that a portion of its length gets segmented crosswise so as to show somewhat like the rattles of a snake.

Assuming that the foregoing is the usual mode of formation of this sky from a thinnish vapour-laden stratum, if the wedge does not push inwards in increased volume, the visible vapour will gradually disappear, diffused in the neighbouring drier air, and fair weather probably may follow. If, however, it drive in in largely increased volume, the cloudlets will be effaced into the formation of large continuous cloud—a likely harbinger of rain, as we know is often the case in such circumstances.

TUESDAY, SEPTEMBER 2.

Subsection of Mathematics.

The following Papers and Report were read:—

1. *Note on Newton's Theory of Astronomical Refraction, and on his Explanation of the Motion of the Moon's Apogee. By* Professor J. C. Adams, *F.R.S.*

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2. *Historical Note on Continuity. By the* Rev. C. Taylor, *D.D.*

I. A vital principle of all science is expressed by the term continuity.

It is the recognition of this principle which differentiates the modern from the ancient geometry, and in the department of geometry it asserts itself in the most complete and striking way in relation to the so-called circular points at infinity in any plane.

The study of mathematics from age to age has contributed directly and indirectly to the advancement of science in general, and even such parts of it as are most abstract have had their full practical effect in the formation and spread of scientific ideas. The doctrine even of the circular points at infinity is not to be regarded as barren or unpractical.

II. A passage of the utmost importance for the history of modern geometry, which has nevertheless escaped the notice of writers on that subject, is to be found in Kepler's 'Ad Vitellionem paralipomena,' cap. IV., §4 (1604).

In this passage, speaking of the foci of conics as points which then had no name, he himself proposes to call them foci. He shows that the parabola has a focus at infinity, that lines radiating from this 'cæcus focus' are parallel, and that it may be regarded as lying either within or without the curve.

Thus he regards every straight line or system of parallels as having one point only at infinity. From this we deduce that all the points at infinity in one and the same plane constitute a quasi-rectilinear locus, since a straight line drawn at random therein meets this locus in one point only.

He also shows how to pass by insensible gradations from the circle through the three normal forms of conics to the line-pair, laying down clearly and decisively the principle of continuity, not indeed under that name, but under the head of analogy.

How profoundly he was impressed with the depth and range of this principle will be gathered from his great saying:—

. . . *plurimum namque amo analogias, fidelissimos meos magistros, omnium naturæ arcanorum conscios.*

III. I conclude with three proofs of the existence of the circular points at infinity.

(1.) In a given plane draw a circle and let it meet the line at infinity in points x and y. Take an arc AB of the circle subtending any angle at the circumference, and therefore at x and y. Through x draw two straight lines at random. These may be regarded as parallel to xA and xB respectively, because x is on the line at infinity, and therefore as containing an angle equal to AxB, that is to say, as containing an *indeterminate* angle. Hence any two points in the plane may be regarded as subtending any angle whatsoever at x, and likewise at y. All circles in it therefore pass through these two points on the line at infinity.

(2.) Let two circles intersect at points A and B not at infinity, and likewise at points x and y. The arcs AB in the two circles subtending unequal angles at x, the angle AxB in the one must be equal to some other AxC in the other. It readily follows that x is a point at infinity; then, as in (1), that any two lines through it meet at an indeterminate angle, and hence that all circles pass through x and likewise through y.

(3.) Let a circle meet the line at infinity in x and y. Its centre C being the pole of xy, the radii Cx and Cy are tangents to the circle. Therefore each of them, being also the normal at its point of contact, is at right angles to itself, as consequently is every line in the system of parallels through x or y.

Join any point O to x and y, draw a circle round O as centre and let it cut Ox in x' and Oy in y'. The radii Ox' and Oy' are the normals and *therefore* also the tangents to the circle at x' and y', and their chord of contact is at infinity because O is the centre. Hence x' and y' are identical with the points x and y at infinity, which are therefore points on every circle in the given plane.

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3. *On a Model of the Cylindroid, showing the Nodal Line.* *By* Professor Robert S. Ball, *LL.D., F.R.S.*

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4. *On Solvable Irreducible Equations of Prime Degree.* *By* Professor George Paxton Young.

§ 1. Let $F(x)=0$ be an irreducible solvable equation of the mth degree, m prime, with roots r_1, r_2, &c. The equation being understood to have been deprived of its second term, the roots are of the forms:—

$$\left.\begin{aligned} mr_1 &= \Delta_1^{\frac{1}{m}} + a_1\Delta_1^{\frac{2}{m}} + b_1\Delta_1^{\frac{3}{m}} + \ldots \quad + c_1\Delta_1^{\frac{m-1}{m}} \\ mr_2 &= \omega\Delta_1^{\frac{1}{m}} + \omega^2 a_1\Delta_1^{\frac{2}{m}} + \omega^3 b_1\Delta_1^{\frac{3}{m}} + \ldots + \omega^{m-1} c_1\Delta_1^{\frac{m-1}{m}} \\ mr_3 &= \omega^2\Delta_1^{\frac{1}{m}} + \omega^4 a_1\Delta_1^{\frac{2}{m}} + \omega^6 b_1\Delta_1^{\frac{3}{m}} + \ldots + \omega^{2(m-1)} c_1\Delta_1^{\frac{m-1}{m}}, \end{aligned}\right\} \ldots (1)$$

and so on; where ω is a primitive m^{th} root of unity; and a_1, b_1, &c., involve only surds that occur in Δ_1 and are thus subordinate to $\Delta_1^{\frac{1}{m}}$. If we call

$$\Delta_1^{\frac{1}{m}},\ a_1\Delta_1^{\frac{2}{m}},\ b_1\Delta_1^{\frac{3}{m}},\ \ldots\ldots\ c_1\Delta_1^{\frac{m-1}{m}} \quad \ldots \quad (2)$$

the separate members of mr_1, I propose first of all to establish the fundamental theorem, that *the separate members of the root* r_1 *can be managed in groups* G_1, G_2, *&c., such that any symmetrical function of the terms in any one of the groups is a rational function of the root* (§8). The groups G_1, G_2, &c., may be defined more exactly as follows. The m^{th} powers of the terms in (2) are the roots of a rational equation of the $(m-1)^{\text{th}}$ degree auxiliary to $F(x)=0$. Should the auxiliary not be irreducible, it can be broken, after the rejection of roots equal to zero, into rational irreducible sub-auxiliaries. This being so, the terms constituting any one of the groups G_1, G_2, &c., are those separate members of r_1, which, severally multiplied by m, are m^{th} roots of the roots of the auxiliary, provided the auxiliary be irreducible; but when the auxiliary is not irreducible, the terms constituting any one of the groups G_1, G_2, &c., are m^{th} roots of the roots of a sub-auxiliary. *From the fundamental theorem above enunciated can be deduced as a corollary the theorem of Galois, that* r_1 *is a rational function of* r_2 *and* r_3. In fact, any symmetrical function of those separate members of r_1, which constitute any one of the groups G_1, G_2, &c., is a rational function of r_2 and r_3 (§ 13). Not only is it proved that r_1 is a rational function of r_2 and r_3, but *the investigation shows how the function is formed.* An instance in verification is given (§ 15). It incidentally appears that if c be the number of terms in any one of the groups G_1, G_2, &c., *the* c *sum of a cycle of primitive* m^{th} *roots of unity is a rational function of* r_1 *and* r_2 (§ 17). Finally, *the law of Kronecker, that the equation* $F(x)=0$ *is an Abelian when a certain expression* ρ_1, *the root of an Abelian equation of the* $(m-1)^{th}$ *degree, is taken as known, is deduced, the exact nature of* ρ_1 *being determined* (§ 18).

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5. *The Tactinvariant of a Conical Section and a Cubic Curve.* *By* Professor F. LINDEMANN, *Ph.D.*

Design by $a_\xi^6=b_\xi^6=c_\xi^6=\ldots$ a binary quantity of the sixth order, and by A, B, C, A_{mm} the invariants of it as they are defined by the following formulas (cf. Clebsch's 'Theorie der binaeren algebraischen Formen'):

$$i_\xi^4=(ab)^4a_\xi^2b_\xi^2=i'^4_\xi=i''^4_\xi=\ldots.$$

$$l_\xi^4=(ai)^4a_\xi^2,\ m_\xi^2=(li)^2i_\xi^2,\ n_\xi^2=(mi)^2i_\xi^2,$$

$$A=(ab)^6,\ B=(ii')^4,\ C=(ii')^2(i'i'')^2(i''i)^2,$$

$$A_{mm}=(mm')^2.$$

According to Mr. Brioschi, the discriminant of a_ξ^6 is given by the expression

$$2^7\cdot3\cdot A^5+2^3\cdot3\cdot5^3\cdot A^3B+2^4\cdot5^4\cdot A^2C+2\cdot3\cdot5^5\cdot AB^2+2^2\cdot3\cdot5^5\cdot BC+3^2\cdot5^5A_{mm}.$$

From this one may derive the tactinvariant of two plane curves, one of the second, the other of the third order, by a method which I have established in the 'Bulletin de la Société Mathématique de France' (t. v. et vi.). Suppose the equation of the first one given by

$$0=p_x^2=p'^2=p''^2_x=\ldots$$

and the equation of the cubic by

$$0=a_x^3=b_x^3=c_x^3=\ldots.$$

The tactinvariant of those two ternary quantics is evidently not changed, if we take the quantic

$$\alpha_x^3=\beta_x^3=\Delta a_x^3-\tfrac{9}{5}(ap'p'')^2a_x\cdot p_x^2$$

instead of a_x^3 $\left(\text{where } \Delta=(pp'p'')^2\right)$; and so we have to do if we follow the method referred to.

The simultaneous invariants of p_x^2 and a_x^3, wanted for our expression, may be introduced by the following system of formulæ:

$$i_x^2=(\alpha\beta p)^2\alpha_x\beta_x,\ H_x^3=(\alpha\beta\gamma)^2\alpha_x\beta_x\gamma_x,$$

$$l_x=(Hpp')^2H_x,\ \Theta_x^2u_\vartheta^2=(\alpha\beta u)^2\alpha_x\beta_x,$$

$$A=(ipp')^2,\ \Gamma=(\Theta\Theta'l)^2p\vartheta^2p\vartheta'^2,$$

$$S=(\alpha\beta\gamma)(\alpha\beta\delta)(\alpha\gamma\delta)(\beta\gamma\delta),$$

$$T=(\alpha\beta\gamma)(\alpha\beta H)(\alpha\gamma H)(\beta\gamma H).$$

Suppose now that a point x of the conic $p_x^2=0$ is represented by the parameter $\xi_1:\xi_2$, so that

$$x_1=k_\xi^2,\ x_2=k'^2_\xi,\ x_3=k''^2_\xi,$$

and put

$$D=(kk')(k'k'')(k''k);$$

then one has $3D^4=\Delta$ (cf. loc. cit.), and the further application of our method leads to the results

$$D^8A = -2A, \quad D^{16}B = \tfrac{2}{3}A^2 - \tfrac{1}{9}\Delta^2S,$$
$$D^{24}C = \tfrac{1}{27}\Delta^3T + \tfrac{2}{9}A^3 - \tfrac{5}{27}\Delta^2SA,$$
$$D^{32}A_{mm} = \tfrac{4}{3}\Gamma\Delta + \tfrac{2}{9}\Delta^2T\Delta - \tfrac{16}{27}A^3S + \tfrac{8}{81}\Delta^2AS^2 - \tfrac{1}{27}\Delta^3ST.$$

Those expressions have to be introduced in Brioschi's discriminant, and so will give immediately the tactinvariant of p_x^2 and a_x^3 for which we have been looking.

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6. *On the 'Analysis Situs' of Threedimensional Spaces.* *By* Professor WALTHER DYCK, *D.Ph.*

The following considerations refer to the analysis situs of threedimensional spaces, and its formulation is called forth by certain researches on the theory of functions, which, however, I canot enter upon here.

The object is to determine certain characteristical numbers for closed three-dimensional spaces, analogous to those introduced by Riemann in the theory of his surfaces, so that their indentity shows the possibility of its 'one-one geometrical correspondence.'

Supposing every part of the space in question behaves itself as our ordinary euclidian space, with this restriction, that the infinitely distant points are to be considered as condensed at one single point ('Raum der reciproken Radien'). Collecting under one representative all those spaces, between which a one-one correspondence is possible, we can form all possible closed threedimensional spaces by the following procedure:

We cut out of our space $2k$ parts, limited by closed surfaces, each pair being respectively of the deficiency (Geschlecht) $p_1, p_2, \ldots p_k$. Then, by establishing a mutual one-one correspondence between every two surfaces, we close the space thus obtained. The numbers $p_1, p_2, \ldots p_k$ of the surfaces, thus made use of, and the manner of their mutual correspondence then form what we may call the distinctive characteristic of our space. This characteristic is determined:—

1. By the existence of certain closed surfaces, which are not able to isolate a part of the space. These are surfaces surrounding the above-named surfaces of the deficiency $p_1, p_2 \ldots p_k$.

2. By the existence of certain closed curves in our space, which can neither be transformed into each other, nor be drawn together into one point.

We will now consider the last-named characteristic, which, so far as I know, has not been elsewhere discussed. Let me explain it by an easy example, suitable to show the general particularities. Suppose two rings (of the deficiency 1) cut off of our ordinary space. According to the manner in which the one-one correspondence of these two surfaces is defined, essentially differing spaces are formed. First, for example, we can make them correspond so that meridian curves fall on meridian curves, and latitudinal curves into latitudinal curves. Then there exist curves which cannot be contracted into one point. For if we put a closed curve surrounding the first ring, the curve, by all expansions and deformations it is liable to, always encloses one of the two rings. On the contrary, supposing we had made the meridional curves to correspond to the latitudinal ones and vice versâ, curves of the above description would not have been found. For a curve surrounding the one ring can first be contracted into a meridional curve of this ring. This curve is identical with a latitudinal curve of the second ring, and this last-mentioned curve can be removed from the ring into our space, and therefore be contracted into a point.

In this way the particular correspondences, above described, between every two of our surfaces give rise to particular kinds of closed spaces. The enumeration of these spaces is immediately connected with the enumeration of the canonical orthogonal substitutions, which give rise to $2p$ new periods from the periods $\omega_1, \omega_2 \ldots \omega_{2p}$ in the theory of Abelian integrals, according to Kronecker.

I hope to develope this subject further on another occasion.

7. *On the Expression of the Co-ordinate of a Point in terms of the Potential and Line of Force at the Point.* *By* Professor W. M. Hicks, *M.A.*

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8. *On the Pressure at a Point inside a Vortex-ring of Uniform Vorticity.* *By* Professor W. M. Hicks, *M.A.*

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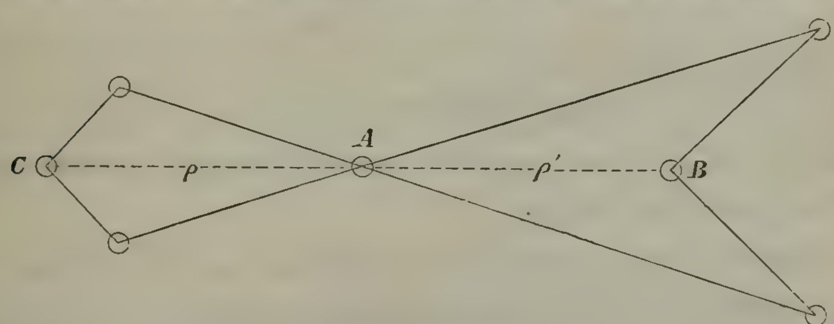
9. *Transformation of the Stereographic Equatorial Projection of a sphere by means of a certain form of the Peaucellier Cell.* *By* Professor A. W. Phillips.

The machine is made of bars of metal. A is a fixed point, B traces the original projection, and C the new projection.

If the point A is fixed on the equator in the *Stereographic Equatorial* Projection, and B traces the meridians and parallels of this projection, then C will trace the meridians and parallels of the *Stereographic Meridian* Projection.

(The proportions of the machine are made such that the projections of one half of the sphere in the two pictures are contained in circles of the same size.)



Outline of Machine.

If the point A is fixed on the parallel of θ° south of the equator in the original projection, and B traces the parallels and meridians as before, then C will trace the parallels and meridians of the *Stereographic Horizontal* Projection, in which the North Pole will be θ° from the Northern horizon.

The above propositions are proved by transforming the equations of the parallels and meridians in the original projection by means of the relation between ρ and ρ' with respect to the fixed point A. The transformed equations agree with the equations of these lines in the Meridian and Horizontal projections.

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10. *A Geometrical Theorem in connection with the Three-cusped Hypocycloid.* *By* R. F. Davis.

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11. *On the Discriminating Condition of Maxima and Minima in the Calculus of Variations.* *By* E. P. Culverwell, *M.A.*

Jacobi's method of reducing $\delta^2 U = \delta^2 \int f\left(x, y, \frac{dy}{dx}, \ldots \frac{d^n y}{dx^n}\right) dx$ to limiting variations, along with a term $\int \theta^2 \frac{d^2 f}{\left[d\left(\frac{d^n y}{dx^n}\right)\right]^2} dx$, where θ depends on δy and its differentials, is open to objection, not only because of its great length, but also as it appears to assume that the first $2n$ differential coefficients of δy must be continuous; and furthermore, it is not shown explicitly that terms containing $\frac{d^m \delta y}{dx^m}$, where m is greater than $n-1$, do not appear at the limits.

The following proof seems free from objection:—
If we adopt the notation

$$y^r = \frac{d^r y}{dx^r},$$

we may write

$$\delta U = \Sigma_0^n \int Y_r \, \delta y^r dx,$$

where

$$Y_r = \frac{df}{dy^r}:$$

and if

$$Y_{rs} = \frac{d^2 f}{dy^r dy^s},$$

we get

$$\delta^2 U = \Sigma \int Y_{rs} \delta y^r \delta y^s dx.$$

Again, observing that

$$\delta y^r \delta y^s = \frac{d}{dx}(\delta y^r \delta y^{s-1}) - \delta y^{r+1} \delta y^{s-1},$$

and that $Y_{rs} = Y_{sr}$, it is easily seen that any series of this kind can be reduced to limiting terms $+ \int \Sigma A_r \left(\delta y^r\right)^2 dx$.

Now write $\delta y = z_1 \delta_1 y$, and we get $\delta^2 U =$ limiting terms $+ \int \Sigma B_r (\delta_1 y^r)^2 dx$ after proper reductions. Since the B coefficients are functions of z_1 and its differential coefficients, we can determine z_1 so that $B_0 = 0$. Again, if $\delta_1 y$ be regarded as constant, the whole integral vanishes, and therefore $\delta^2 U$ depends only on limiting terms; consequently δy, or z_1, is a solution of the equation for δy got by

$$\delta Y_0 - \frac{d}{dx}(\delta Y_1) + \frac{d^2}{dx}(\delta Y_2) + \&c = 0 \quad \dots\dots\dots\dots \quad (1)$$

or if $y = \int (x, c_1, c_2, \dots c_{2n})$, then $z_1 = \frac{df}{dc_1}$ will do what we want. (The strict proof of this requires that we consider $\Delta \delta U$ in place of $\delta^2 U$, and make $\Delta_1 y$ constant, leaving $\delta_1 y$ arbitrary, $\Delta_1 y$ being $\frac{\Delta y}{z_1}$).

We now have $\delta^2 U =$ limiting terms

$$+ \int \Sigma_n^1 B_r \left(\left(\frac{dy}{z_1} \right)^{(r)} \right)^2 dx.$$

Write this as $= \int \Sigma_0^{n-1} C_r \left(\left(\frac{\left(\frac{\delta y}{z_1}\right)'}{\theta} \right)^{(r)} \right)^2 dx$, where in this and in what follows the dots mean differentiation with respect to x, and make C_0 vanish by choosing θ properly.

The value of θ is found by considering that if

$\left(\frac{\delta y}{z_1}\right)' = c\theta$, c being constant, δy must be a solution of (1)

and therefore

$$\theta = \left(\frac{z_2}{z_1}\right)' \text{ where } z_2 = \frac{df}{dc_2}$$

and so finally we get $\delta^2 U$ = limiting terms

$$+\int Y^n{}_n\left(\left[\left[\left(\frac{\delta y}{z_1}\right)'\div\left(\frac{z_2}{z_1}\right)'\right]'\div\left[\left(\frac{z_3}{z_1}\right)'\div\left(\frac{z_2}{z_1}\right)'\right]_1\cdots\right]'\right)^2 z_1{}^2 z_2{}^2 z^2{}_3 \ldots dx,$$

where the brackets go until we have z_n as $\frac{df}{dc_n}$ in the last of them. If Y_{nn} vanish, it is very easy to see what the criterion becomes.

The coefficient is

$$\left[Y_{\overline{n-1}\ \overline{n-1}} - \frac{dY}{dx}{}_{n(\overline{n-1})}\right]$$

in place of Y_{nn}, and we have to use one root less, and so on for any number of coefficients being absent.

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12. *On the Invariable Plane of the Solar System.* *By* David P. Todd, *M.A.*

According to the well-known principle of Laplace, that the sum of the products formed by multiplying each planetary mass by the projection of the area described by its radius vector in a given time is a maximum — γ being the inclination of the invariable plane to the ecliptic, and π the longitude of its ascending mode; and having from the *Mécanique Céleste*—

$$\tan\gamma\sin\pi = \frac{c''}{c}$$

$$\tan\gamma\cos\pi = \frac{c'}{c}$$

c, c' and c'' being constants depending upon the elements of the planets which make up the system, I determined in 1877 the position-elements of the invariable plane of the solar system for the epoch 1875. All the papers relating to this investigation were unhappily destroyed in the conflagration of the Walker Hall of Amhurst College two years ago; and only the approximate results, on a memorandum which I have recently found, were preserved elsewhere. They are—

$$\gamma = 1^\circ\,35'$$
$$\pi = 106^\circ\,10'$$

Better values of some of the planetary masses are now known, and I have lately repeated the determination, *ab initio*, employing the results of the latest available researches on the planetary elements, the epoch being the year 1900.

Subsection of Physics.

1. *Report of the Committee for facilitating the adoption of the Metric System of Weights and Measures in Great Britain.*—See Reports, p. 27.

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2. *On the Colours of Thin Plates.* *By* Professor Lord Rayleigh, *LL.D.*, *F.R.S.*

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3. *On Clark's Standard Cells.* *By* Professor Lord Rayleigh, *LL.D.*, *F.R.S.*

In the hope of finding a clue as to the origin of some of the minor anomalies of Clark cells, I have made experiments upon the E. M. F. of combinations, in which two different strengths of zinc amalgam take the place of the zinc and pure mercury of the Clark cell. No mercurous sulphate is employed, the liquid being simply a saturated solution of zinc sulphate.

If the same kind of amalgam be used for both poles, the symmetry is complete, and there should be no E. M. F. But if we take for one pole a strong, but fluid, amalgam, and for the other the same amalgam diluted with an equal volume of pure mercury, we find a very sensible E. M. F., the strong amalgam corresponding to the zinc of the ordinary Clark. In my experiment the E. M. F. was ·004 Clark, and remained pretty constant from day to day. In another cell the same strong amalgam was used for one pole, and for the other pole was diluted with three times its volume of pure mercury. In this case the E. M. F. was ·009 Clark.

If we replace the diluted amalgam with pure mercury, we obtain (without mercurous sulphate) nearly the full E. M. F. of the Clark cell, but, as might be expected, the force is very unsteady. From this it would seem that the function of the mercurous sulphate in the usual form of cell is to retain the purity of the mercury, and that the E. M. F. is largely due to the affinity of mercury for zinc.

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4. *On an Analogy between Heat and Electricity.* *By* Professor G. F. FITZGERALD, *F.R.S.*

The object of this communication was to point out the analogy that may be drawn between quantity of electricity and quantity of entropy when electric potential is considered as analogous to temperature. A non-conductor of electricity would be a non-conductor of entropy, which is the same as a non-conductor of heat. A conductor would be a heat engine in which the fall of temperature of the entropy was completely utilised.

It was pointed out that a molecular structure of the ether could be assumed which would not conduct heat as material gases do, but which might be thrown by differences of temperature into the state of stress that explains electrostatic phenomena. It was explained that this was a step beyond that made by Maxwell in his Electricity and Magnetism, where he avoids any hypothesis as to how electric displacement produces mechanical stress. It was, on the other hand, explained that the principal object of the paper was not to bring forward this very doubtful hypothesis, but to point out that the analogy of electric currents and displacements to the motion of an incompressible fluid was by no means the only one that could be drawn, and by pointing this out, to obviate the danger which is at present imminent of this mere analogy being considered as a likeness.

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5. *The Telemeter System.* *By* J. URQUHART MACKENZIE.

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6. *The Influence of an Electric Current on the Thinning of a Liquid Film.* *By* Professors A. W. REINOLD *and* A. W. RÜCKER.

The authors described the effect of passing a current of from 0·5 to 15 micro-ampères through a cylindrical liquid film. The films were about 40 mm. long and 33 mm. in diameter, and were formed of a solution either of common potash soap, or of Plateau's 'liquide glycérique,' with a small quantity of nitrate of potash added to improve the conductivity. A number of films were formed, and allowed to thin under the action of gravity alone, when no current flowed. They all behaved substantially in the same way. After a few minutes signs of colour were seen at the top, and in from 9 to 15 minutes a complete ring of black appeared. Three quarters of the film were colourless. When a downward current was passed through a film from the moment of its formation, rings of colour appeared with great rapidity, but much broader and more diffuse than before, and occupying a larger area of the liquid. If the film had already a ring of black at the top, the effect of the downward current was to augment this, and rapidly to thin the portion immediately below it. In all cases, provided the current was not too strong, the effect of the descending current was to promote the thinning of the film. An ascending current, on the other hand, checked the thinning of the film, retarded the formation of coloured rings if applied from the beginning, and rapidly caused the disappearance of the black if applied after a ring of black had already been formed. These effects were more marked with the soap solution than with the 'liquide glycérique,' but the nature of the effect was the same with the two liquids. The results are valuable, as giving the means of controlling the thinning of a film in cases where it is desired to compare the properties of two films of different thickness.

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7. *On the Diffusion of Metals.* *By* Professor W. CHANDLER ROBERTS, *F.R.S.*

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8. *On some Phenomena connected with Iron and other Metals in the solid and molten states, with notes of experiments.* *By* W. J. MILLAR.

(1.) *Object of Paper.*—Results of experiments by the author with various metals, such as cast-iron, gun-metal, phosphor bronze, lead, copper, and type-metal. The object being to determine the cause of the well-known phenomenon of the floatation of cold cast-iron on molten cast-iron, and as to whether any expansion took place upon solidification in the metals above noted.

(2.) Notes of some of the experiments from which the author concludes that the cause of floatation of the solid metal on liquid metal of the same kind is *buoyancy*, due to expansion suddenly set up in the immersed pieces, and that this expansion was foundby careful measurement to be at least equal to the shrinkage or total decrease in length of the piece from white hot solid to finally cooled down solid.

Further, that the expansion observed is obtained within much lower limits of temperature than the shrinkage; as the pieces, which were in all cases removed from the molten metal, immediately on appearing floating hardly showed redness, and when broken, it was found that the crystalline character of the metal remained.

(3.) Notes of experiments made by gradually heating pieces of cast-iron—the results of all these experiments leading the author to conclude that the *rate* of expansion in cast-iron is at first much more rapid at low temperature than afterwards at high temperature.

(4.) From experiments carried on with pieces of lead, copper, and type-metal it was found that if any floatation occurred, it was only with small light pieces—heavy pieces sinking and remaining at bottom of ladle.

Gun-metal and phosphor bronze behaved like cast-iron.

(5.) Consideration of the peculiar appearance, or '*break*,' observed on the surface of molten cast-iron, the figures presenting a geometrical pattern, like interlacing circles or stars.

The author believes that this appearance is due to cracks forming upon the rapidly forming skin—these cracks taking more or less a circular form from the convex forms, into which the various parts of the surface are thrown, due to the bubbling up of gas or air.

This appearance is limited to cast-iron, and experienced observers can tell the quality of the iron from the form of pattern or figures showing on the molten surface.

(6.) From observation and experiments carried out from time to time, the author concludes that no perceptible increase of volume of the metals noted occurs at the moment of solidification, at least when free from air or gas confined within the casting.[1]

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9. *On the Velocity of Light of different Colours.* *By* Professor GEORGE FORBES.

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[1] See also *Proceedings of the Royal Society of Edinburgh*, Session 1881–82.

10. *On the Velocity of Light in Carbon Disulphide and the Difference in Velocity of Red and Blue Light in the same.* By ALBERT A. MICHELSON.

The arrangement of apparatus was essentially the same as in the experiments of Foucault. The liquid was contained in a tube 2 feet long, with plate-glass ends. With about 300 turns per second, and a radius of 20 feet, a deflection of $1\frac{1}{2}$ mm. was obtained.

The principal difficulty was the obtaining a clear image through the liquid.

The ratio of the velocity in the liquid to that in air was found to be as one to 1·75. The theoretical value is the refractive index of the liquid, or 1·65.

In the second part of the work the light was coloured by a direct-vision prism placed before the slit. The colours selected were half way between C and D and half way between b and F.

It was found that the red ray travelled $2\frac{1}{2}$ per cent. faster than the blue, which is in accord with theory.

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11. *On a Systematic Research for Stars with a Measurable Annual Parallax, and its Results.* By Professor ROBERT S. BALL, *LL.D., F.R.S.*

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12. *On an Electrodynamometer, with extremely light moving coil, for the measurement of small alternating currents.*[1] By Dr. W. H. STONE.

The moving coil is made of aluminium wire, which for given mass conducts better than any known substance. This is silk-covered, and wound in an anchor-ring-shaped form on a hollow bobbin of cork. The two ends are brought up to a small plate of ebonite, and connection is perfectly made by means of minute clamping screws, with a bifilar suspension of gilt silver wire. The bobbin is then immersed in a small tank of petroleum oil, which serves at once (1) to lessen its weight, (2) to act as a preserver of the insulation, and (3) to damp any excessive vibration.

The instrument has the great additional advantage of moving quickly up to its full deflection, and thus giving less time for the running down of the battery attached to the primary inducing coil than that which occurs in the ordinary form of the instrument. As cork swims in heavy petroleum lamp oil, and the silk-covered aluminium wire sinks, a combination of the two of any given specific gravity within certain limits can easily be obtained. (See 'Nature,' Oct. 30, 1884.)

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13. *On the Law regulating the Connection between Current and Intensity of Incandescence of Carbon Filaments in Glow Lamps.* By W. H. PREECE, *F.R.S.*

In a paper read before the Royal Society in 1883, I pointed out, from experimental data, that the light emitted by a glow lamp varied apparently as the sixth power of the current.

I have verified this law, not only by subsequent experiments of my own, but, which is much more satisfactory, by experiments of others. Professor Kittler, of Darmstadt, and Captain Abney have made, independently of each other, most careful and exhaustive measurements in this direction. I have tabulated and traced them out in curves, which I submit. They fully confirm the law that

$$L = k\,C^6$$

but within limits, and that these limits embrace the ordinary range of a glow lamp when used for artificial illumination. As long as the resistance and the current vary uniformly together, the law holds good; but as the state of incandescence is increased, a point is reached, varying with each kind of lamp, when the resistance ceases to diminish at the same rate, and eventually to increase. When this occurs the law is departed from, and the light emitted increases much faster than the

[1] See *Nature,* October 30, 1884.

sixth power of the current. The filament speedily breaks. The point of departure from the law indicates a point when a change of state occurs in the carbon filament. Disintegration probably sets in. This point ought to be determined for each kind of lamp, and it should never be allowed to be reached, for it is from this point that decay commences and rupture follows.

14. *On the Equations of Dynamo-Electric Machines.* *By* Professor Silvanus P. Thompson.

15. *On Earth Currents.* *By* E. O. Walker.

Extended observations of these currents in India show potential to be east during the forenoons and west in the afternoons, that is to say, currents will flow in the telegraph lines from east to west in the forenoon, and west to east in the afternoon. The phenomenon seems to be a very invariable one on quiet days, both with regard to times of maxima and times of change. The maxima appear to occur about 9 to 10 A.M. and 2 to 3 P.M.

The fact of the existence of these currents is often attributed to the earth's magnetic field, and no doubt sensitive instruments would reveal such induced currents, underlying those produced by more local causes. The author thinks that the variable currents most generally noticed are due to the latter. Something else than the mere passage of a wire through a tolerably uniform magnetic field is required to explain observed facts. That elevation of one place above another will give a permanent difference of potential between the two, the amount varying according to circumstances, but observed to be at least 0·2 volt per 2,000 feet. That the current between two stations in land will change its direction an hour or two earlier than that between the westerly of those stations and a coast station west. That a general rainfall will diminish potential. That two places situated on the same line of telegraph, in the same latitude, may have with regard to another station east or west, the one a higher, the other a lower potential than the latter, giving rise in the same wire cut at an intermediate point, in the one case to a current east to west, and in the other case to a current west to east.

All these facts show that the currents usually observed are not created by the earth's magnetic force. Doubtless, in temperate regions, such large differences of potential are not experienced as in the tropics, and other causes may contribute to render the currents more variable. But it is in these, where the sun's rays are so much more powerful, and where irregular meteorological phenomena do not occur, that observers have the advantage day by day of witnessing difference of terrestrial potential in a more intense degree, and with such regularly recurrent changes as to leave no doubt on the mind as to their origin. It is difficult to frame a theory that can meet all observed phenomena, especially in the case of the currents observed in submarine cables which, it is largely agreed, reverse their direction with the change of tide. It is thought, however, that if the relative differences of temperature and humidity at the terminal stations had been always noticed, the same conclusion would have been reached which is forced upon the observer in a tropical country, viz., that the difference of potential is simply due to the rapidity with which evaporation is taking place at different places. Evaporation leaves a positive charge on the earth's surface; should this charge at A be of greater tension than at B, and these two places be put into connection by a wire, there will be a tendency to equalise the two charges, and a resultant current from A to B, which will be sustained as long as evaporation is proceeding more rapidly at A than at B. Such electric charges would produce no currents in the crust of the earth, and it is yet to be proved that such exist. According to this theory the greatest difference of potential would be obtained between two places far apart on the earths' surface, where at one place the burning rays of the sun were falling, say on the shore of some intertropical sea, and where at the other the still humid night was in the ascendant. So far as a judgment is able to be formed by the comparatively limited area—900 miles—observed by the author, it appears that this is borne out:—900 miles from Madras on the Bay of Bengal to Bombay on the Arabian Sea will give an average maxium difference on quiet days of 7 volts; between Bellary and Belgaum, two inland stations east and west, 200 miles, an average of 2 or $2\frac{1}{2}$ volts; between Belgaum and Vingurla, a station inland and one on the sea coast, seventy miles, an average of 2·3 volts. Perhaps 100 or 150 volts might be expected as the maxium obtainable at the widest limits on the earth's surface on quiet days. It has not always been possible to measure the potential difference occurring in so-called 'magnetic storms,' but 30 volts per 200 miles is not uncommon.

As recent years have taught with what minute currents speech and telegraphic symbols can be transmitted over long distances, the author suggests that the time may be coming when these earth currents shall be made of service for such purposes, and telegraphy shall in general benefit.

It is found on disturbed days that actual reversals of the earth's currents take place in a few minutes; but that, certainly within a range of 900 miles, these reversals all agree on different lines; that is, all places east are positive or negative, at the same time, and places west of the opposite sign simultaneously; a large area is affected at the same time and in the same way. Great throbs are felt, which increase or decrease the currents in all lines together like the beating of the pulses of the body.

Seeing that during the passage of sunspots, the obscured portion of the earth's surface is said to cease to receive heat, it may be conjectured that there will be consequent inequalities in the normal causes of difference of potential, sufficient to account for the strong currents, so inimical to telegraphy. Such phenomena need not discountenance the theory above set forth.

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16. *Description of a Cylindrical Slide Rule or Calculating Apparatus.* *By* Edwin Thacher.

This apparatus consists of twenty separate bars united in a frame which is movable about a cylinder. The bars present in sections printed logarithmic scales of sixty feet, and of thirty feet radii. These bars read into the cylinder upon which are printed two logarithmic scales of thirty feet radius each. In this apparatus the bars form slides and are worked similarly to the ordinary slide rule, the open divisions of the scales giving five places of figures instead of two as in the ordinary rules. This rule performs with facility the solution of any question in multiplication, division, and proportion of numbers, either simple or fractional, with or without powers and roots.

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17. *On the Inconveniences of the present Mode of quoting Scientific Journals.* *By* Dr. H. Borns, *F.C.S.*

The author called attention to the inconveniences arising from the injudicious and arbitrary modes of quoting in use, and suggested that:—1. Every Journal should bear its abridged title by which it is to be quoted on the title page, in a prominent position. 2. That all quotations should use, if necessary, the full title, or these abridged titles with place, year, volume and page.

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18. *An Account of unusual coloured Bows observed in Fogs.* *By* Philip Burton.

It is well known that a luminous bow is sometimes formed in fogs by the refraction and reflection of light in the particles of which they are composed. This appearance, though sometimes nearly equal in size to the rainbow, is often perceptibly smaller; and it differs from the latter also in not exhibiting any coloured rings, the various colours being blended into a uniform whitish arch.

Besides the ordinary fog-bow which can frequently be seen, a fainter or supernumerary one may also be observed on rare occasions. This bow is smaller than the primary and separated from it by a space of about three degrees. It consists of a ring of green succeeded on the inside by a ring of red light, each being about half a degree in breadth and concentric with the principal bow. Phenomena of this kind came under my notice on the mornings of the 22nd and 23rd September, 1862, and 14th July, 1876, in the neighbourhood of Kanturk, in the county of Cork. On some of these occasions I remarked that the outer verge of the green ring was better defined than the inner verge of the red one. The latter was sometimes irregular, owing apparently to the presence of small needles or lines of grey or whitish light crossing the arc. The appearances in each instance were visible for nearly an hour.

Having some time ago searched through various scientific periodicals up to the year 1880, I found therein only two instances in which corresponding phenomena had been recorded, one of which is in the description of a lunar fogbow seen off the coast of California, in 1860, by Lieut. J. M. Gillis, of the American Navy; in this no colours were observed ('American Journal of Science,' vol. xxx. p. 305). The other description referred to is contained in Col. Sykes' paper 'On the Atmospheric Tides and Meteorology of the Deccan,' where he says: 'Under a combination of favourable circumstances, it (the circular rainbow) appeared quite perfect of the most vivid colours, one half above the level on which I stood, the other half below it. * * * The brilliant circle was accompanied by the usual outer bow in fainter colours' ('Philosophical Transactions for 1835,' p. 193). In this instance it appears possible that the inner bow which he describes as a "brilliant circle" was exceeded in brilliancy by the outer bow, notwithstanding the statement that the latter appeared "in fainter colours;" for this may have reference to the mixture and consequent indistinctness of the colours, and not to the intensity of the light. Bearing in mind this acceptation, and leaving out the central figures, Col. Sykes' description of the phenomena would seem to agree with that which I have above given.

As to the cause of the additional rings, it would seem reasonable to regard them as analogous to the 'interference bows,' which so frequently appear in showers of rain, were it not that on such a supposition (according to received principles) the red colour ought to be the first to re-appear after evanescence, and should therefore be outermost. How the green comes to have that place instead, or why the colours appear separately in the additional bow though blended together in the primary and more brilliant one, is more than I have been able to determine.

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19. *On the Temperature of the Interior of a Block of Melting Ice.* *By* James B. Francis.

The paper by Professor James D. Forbes in the Proceedings of the Royal Society of Edinburgh for April 19, 1858, contains the following description of an experiment by him:

'Water being carefully frozen into a cylinder several inches long, with the bulb of thermometer in its axis, and the cylinder being then gradually thawed, or allowed to lie for a considerable time in pounded ice at a thawing temperature, showed also a temperature decidedly inferior to 32°, not less, I think, than 0·35° Fahrenheit.'

In this experiment it appears that the formation of ice on the bulb of the thermometer may have acted upon it mechanically and affected the accuracy of the results. To avoid error from this cause I procured a block of clear ice from Merrimack River, and cut it to fit loosely into a cask, the dimensions of the block when fitted being seventeen inches in diameter and sixteen inches high, the diameter of the block of ice being about two inches less than that of the cask. The space not occupied by the ice was filled with water from the same river, allowing the ice to float. A hole, one and three-fourths inches in diameter, and ten inches deep, was bored in the axis of the block, and a cover of ice closely fitted to it.

Two thermometers, No. 1 and No. 2, of similar form, by Seifort of Boston, were used. They had two bulbs with stems, about 3·25 inches long between them, graduated from 29° to 35° Fahrenheit; the length of a degree in No. 1 being 0·405 inches, and in No. 2, 0·390 inches; the graduation in both being to tenths of a degree. They were tested by immersing them in a wooden vessel filled with snow and water, placed in a room in which the temperature varied from 34° to 37°. By the means of several trials the corrections for the melting point of ice were found to be, for No. 1, 0·87° and for No. 2, 0·83°. No. 2 was found broken February 17, 1871, which brought the experiments to an end. Thirteen years afterwards No. 1 was tested again in a similar manner, and the correction was found to be 1·02°, the change being 0·15°. One of these thermometers was placed in the hole in the block of ice, and the other in the water in which it floated, and to eliminate errors from imperfect corrections they were interchanged from time to time.

The results of these experiments are given in the following table. To vary the conditions, the hole in the block of ice was filled with different substances as stated in the table. It was supposed that the substance that would enable the temperature of the ice to be ascertained with the greatest precision was benzine. The mean of the two results in this condition when thermometer No. 1 was in the interior of the ice, and No. 2 in the water in which the ice floated, gave the temperature of the interior of the ice 0·188° below that of the water in which it floated; and the mean of the two trials, when No. 2 was in the ice and No. 1 in the water, gave the temperature of the interior of the ice, 0·266° below that of the water in which the ice floated. The mean of the four trials in which benzine was used giving the temperature of the interior of the ice was 0·227° below that of the water in which it floated.

The mean of the two results in which air occupied the interior of the ice, the thermometers being interchanged, gave the temperature of the ice 0·073° below that of the water in which it floated.

In the single result in which the hole was filled with water, the readings gave the temperature of the interior 0·017° below that of the water in which the ice floated.

The mean result of all the trials gives the temperature of the interior of the block of ice 0·153° below that of the water in which it floated; the irregularities in the results of the several trials are however too great to permit the adoption of this mean as the exact difference. Every trial, however, gave a less difference than was found by Forbes, and I think it is safe to say that as a result of these experiments, the temperature of the interior of a block of fresh water ice floating in fresh water, the temperature of the air being between 30·5° and 46·6° Fahrenheit, is about one-fifth of a degree below thirty-two degrees, or the melting point of ice.

Time when the observations were made, February 1871	Condition in the hole in the ice	No. of the thermometer in the interior of the ice	No. of observations of the Temperature	Mean Temperature in degrees Fahr.	
				of the air in the room	of the interior of the ice
9th, 10.10 A.M. to 2.40 P.M. . .	Air . .	2	2	38·83	31·873
9th, 5.0 P.M. to 10th 8.40 A.M. .	Benzine .	2	2	38·50	31·755
11th, 3.25 P.M.	Benzine .	1	1	37·00	31·690
11th, 4.45 P.M. to 13th 4.10 P.M.	Benzine .	2	4	35·46	31·713
15th, 5.25 P.M.	Air . .	1	1	34·00	31·980
15th, 8.5 A.M. to 10.15 A.M. . .	Water .	1	3	38·83	31·983
15th, 11.21 A.M. to 4.40 P.M. . .	Benzine .	1	5	42·44	31·934
		Means		37·87	31·847

During the above experiments, the block of ice became reduced by thawing from its original diameter of seventeen inches to about fourteen inches.

Section B.—CHEMICAL SCIENCE.

President of the Section—
Professor Sir H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.

THURSDAY, AUGUST 28.

The President delivered the following Address:—

With the death of Berzelius in 1848 ended a well-marked epoch in the history of our science; with that of Dumas—and, alas! that of Wurtz also—in 1884 closes a second. It may not perhaps be unprofitable on the present occasion to glance at some few points in the general progress which chemistry has made during this period, and thus to contrast the position of the science in the 'sturm und drang' year of 1848, with that in the present, perhaps, quieter period.

The differences between what may properly be termed the Berzelian era and that with which the name of Dumas will for ever be associated show themselves in many ways, but in none more markedly than by the distinct views entertained as to the nature of a chemical compound.

According to the older notions, the properties of compounds are essentially governed by the qualitative nature of their constituent atoms, which were supposed to be so arranged as to form a binary system. Under the new ideas, on the other hand, it is mainly the number and arrangement of the atoms within the molecule, which regulate the characteristics of the compound, which is to be looked on not as built up of two constituent groups of atoms, but as forming one group.

Amongst those who successfully worked to secure this important change of view on a fundamental question of chemical theory, the name of Dumas himself must first be mentioned, and, following upon him, the great chemical twin-brethren Laurent and Gerhardt, who, using both the arguments of test-tube and of pen in opposition to the prevailing views, gradually succeeded, though scarcely during the lifetime of the first, in convincing chemists that the condition of things could hardly be a healthy one when chemistry was truly defined 'as the science of bodies which do not exist.' For Berzelius, adhering to his preconceived notions, had been forced by the pressure of new discovery into the adoption of formulæ which gradually became more and more complicated, and led to more and more doubtful hypotheses, until his followers at last could barely succeed in building up the original radical from its numerous supposed component parts. Such a state of things naturally brought about its own cure, and the unitary formulæ of Gerhardt began to be generally adopted.

It was not, however, merely as an expression of the nature of the single chemical compound that this change was beneficial, but, more particularly, because it laid open the general analogies of similarly constituted compounds, and placed fact as the touchstone by which the constitution of these allied bodies should be ascertained. Indeed, Gerhardt, in 1852, gave evidence of the truth of this in his well-known theory of types, according to which, organic compounds of ascertained constitution can be arranged under the four types of hydrogen, hydrochloric acid, water, and ammonia, and of which it is, perhaps, not too much to say that it has, more than any other of its time, contributed to the clearer understanding of the relations existing amongst chemical compounds.

Another striking difference of view between the chemistry of the Berzelian era and that of what we sometimes term the modern epoch is illustrated by the so-called substitution theory. Dumas, to whom we owe this theory, showed that chlorine can take the place of hydrogen in many compounds, and that the resulting body possesses characters similar to the original. Berzelius opposed this view, insisting that the essential differences between these two elements rendered the idea of a substitution impossible, and notwithstanding the powerful advocacy of Liebig, and the discovery by Melsens of reverse substitutions (that is the re-formation of the original compound from its substitution-product), Berzelius remained to the end unconvinced, and that which was in reality a confirmation of his own theory of compound radicals, which, as Liebig says, 'illumined many a dark chapter in organic chemistry,' was looked upon by him as an error of the deepest dye. This inability of many minds to see in the discoveries of others confirmation of their own views is not uncommon; thus Dalton, we may remember, could never bring himself to admit the truth of Gay-Lussac's laws of gaseous volume-combination, although, as Berzelius very truly says, if we write *atom* for *volume* and consider the substance in the solid state in place of the state of gas, the discovery of Gay-Lussac is seen to be one of the most powerful arguments in favour of Dalton's hypothesis.

But there is another change of view, dating from the commencement of the Dumas epoch, which has exerted an influence equal, if not superior, to those already named on the progress of our science. The relative weights of the ultimate particles, to use Dalton's own words, which up to this time had been generally adopted by chemists, were the equivalent weights of Dalton and Wollaston, representing, in the case of oxygen and hydrogen, the proportions in which these elements combine, viz., as 8 to 1. The great Swedish chemist at this time stood almost alone in supporting another hypothesis; for, founding his argument on the simple laws of volume-combination enunciated by Gay-Lussac, he asserted that the true atomic weights are to be represented by the relations existing between equal volumes of the two gases, viz., as 16 to 1. Still these views found no favour in the eyes of chemists until Gerhardt, in 1843, proposed to double the equivalent weights of oxygen, sulphur, and carbon, and then the opposition which this suggestion met with was most intense, Berzelius himself not even deigning to mention it in his annual account of the progress of the science, thus proving the truth of his own words: 'That to hold an opinion habitually often leads to such an absolute conviction of its truth that its weak points are unregarded, and all proofs against it ignored.' Nor were these views generally adopted by chemists until Cannizaro, in 1858, placed the whole subject on its present firm basis by clearly distinguishing between equivalent and molecular weights, showing how the atomic weights of the constituent elements are derived from the molecular weights of their volatile compounds based upon the law of Avogadro and Ampère, or where, as is the case with many metals, no compounds of known vapour-density exist, how the same result may be ascertained by the help of the specific heat of the element itself. Remarkable as it may appear, it is nevertheless true that it is in the country of their birth that Gerhardt's atomic weights and the consequent atomic nomenclature have met with most opposition, so much so that within a year or two of the present time there was not a single course of lectures delivered in Paris in which these were used.

The theory of organic radicals, developed by Liebig so long ago as 1834, received numerous experimental confirmations in succeeding years. Bunsen's classical research on cacodyl, proving the possibility of the existence of metallo-organic radicals capable of playing the part of a metal, and the isolation of the hydrocarbon ethyl by Frankland in 1849, laid what the supporters of the theory deemed the final stone in the structure.

The fusion of the radical and type theories, chiefly effected by the discovery in 1849 of the compound ammonias by Wurtz, brings us to the dawn of modern chemistry. Henceforward organic compounds were seen to be capable of comparison with simple inorganic bodies, and hydrogen not only capable of replacement by chlorine, or by a metal, but by an organic group or radical.

To this period my memory takes me back. Liebig at Giessen, Wöhler in Gottingen, Bunsen in Marburg, Dumas, Wurtz, and Laurent and Gerhardt in Paris, were the active spirits in continental chemistry. In our own country, Graham, whose memorable researches on the phosphates had enabled Liebig to found his theory of polybasic acids, was working and lecturing at University College, London; and Williamson, imbued with the new doctrines and views of the twin French chemists, had just been appointed to the chair of practical chemistry in the same college, vacant by the death of poor Fownes. At the same time, Hofmann, in whom Liebig found a spirit as enthusiastic in the cause of scientific progress as his own, bringing to England a good share of the Giessen fire, founded the most successful school of chemistry which this country has yet seen.

At the Edinburgh meeting of this Association in 1850, Williamson read a paper on 'Results of a Research on Ætherification,' which included not only a satisfactory solution of an interesting and hitherto unexplained problem, but was destined to exert a most important influence on the development of our theoretical views. For he proved, contrary to the then prevailing ideas, that ether contains twice as much carbon as alcohol, and that it is not formed from the latter by a mere separation of the elements of water, but by an exchange of hydrogen for ethyl, and this fact being in accordance with Avogadro's law of molecular volumes, could only be represented by regarding the molecule of water as containing two atoms of hydrogen to one of oxygen, one of the former being replaced by one of ethyl to form alcohol, and the two of hydrogen by two of ethyl to form ether. Then Williamson introduced the type of water (subsequently adopted by Gerhardt) into organic chemistry, and extended our views of the analogies between alcohols and acids, by pointing out that these latter are also referable to the water-type, predicting that bodies bearing the same relations to the ordinary acids as the ethers do to the alcohols must exist, a prediction shortly afterwards (1852) verified by Gerhardt's discovery of the anhydrides. Other results followed in rapid succession, all tending to knit together the framework of modern theoretical chemistry. Of these the most important was the adoption of condensed types, of compounds constructed on the type of two and three molecules of water, with which the names of Williamson and Odling are connected, culminating in the researches of Brodie on the higher alcohols, of Berthelot on glycerine, and of Wurtz on the dibasic alcohols or glycols; whilst, in another direction, the researches of Hofmann on the compound amines and amides opened out an entirely new field, showing that either a part or the whole of the hydrogen in ammonia can be replaced by other elements or elementary groups without the type losing its characteristic properties.

Again, in 1852, we note the first germs of a theory which was destined to play an all-important part in the progress of the science, viz., the doctrine of valency or atomicity, and to Frankland it is that we owe this new departure. Singularly enough, whilst considering the symmetry of construction visible amongst the inorganic compounds of nitrogen, phosphorus, arsenic, and antimony, and whilst putting forward the fact that the combining power of the attracting element is always satisfied by the same number of atoms, he does not point out the characteristic tetrad nature of carbon; and it was not until 1858 that Couper initiated, and Kekulé, in the same year, thoroughly established the doctrine of the linking of the tetrad carbon atoms, a doctrine to which, more than to any other, is due the extraordinary progress which organic chemistry has made during the last twenty years, a progress so vast, that it is already found impossible for one individual, even though he devote his whole time and energies to the task, to master all the details, or make himself at home with the increasing mass of new facts which the busy workers in this field are daily bringing forth.

The subject of the valency of the elements is one which, since the year above referred to, has given chemists much food for discussion, as well as opportunity for experimental work. But whether we range ourselves with Kekulé, who supports the unalterable character of the valency of each element, or with Frankland, who insists on its variability, it is now clear to most chemists that the hard and fast lines upon which this theory was supposed to stand cannot be held to be secure. For if the progress of investigation has shown that it is impossible in many instances to affix one valency to an element which forms a large number of different compounds, it is also equally impossible to look on the opposite view as tending towards progress, inasmuch as to ascribe to an element as many valencies as it possesses compounds with some other element, is only expressing by circuitous methods what the old Daltonian law of combination in multiple proportions states in simple terms. Still we may note certain generally-accepted conclusions: in the first place, that of the existence of non-saturated compounds both inorganic and organic, as carbon-monoxide on the one hand, and malic and citraconic acids on the other. Secondly, that the valency of an element is not only dependent upon the nature of the element with which it combines, but that this valency is a periodic function of the atomic weight of the other component. Thus the elements of the chlorine group are always monads when combined with positive elements or radicals, but triad, pentad, and heptad with negative ones. Again, the elements of the sulphur group are dyads in the first case, but tetrad and hexad in the second. The periodicity of this property of the atoms, increasing and again diminishing, is clearly seen in such a series as

$$AgCl_1, CdCl_2, InCl_3, SnCl_4, SbH_3, TeH_2, IH,$$

as well as in the series of oxides. The difficulties which beset this subject may be judged of by the mention of a case or two: Is vanadium a tetrad because its highest chloride contains four atoms of chlorine? What are we to say is the valency of lead when one atom unites with four methyls to form a volatile product, and yet the vapour-density of the chloride shows that the molecule contains one of metal to two of chlorine? Or, how can our method be said to determine the valency of tungsten when the hexchloride decomposes in the state of vapour, and the pentachloride is the highest volatile stable compound? How again are we to define the point at which a body is volatile without decomposition?—thus sulphur tetrachloride, one of the most unstable of compounds, can be vaporised without decomposition at all temperatures below $-22°$, whilst water, one of the most stable of known compounds, is dissociated into its elements at the temperature of melting platinum.

But, however many doubts may have been raised in special instances against a thorough application of the law of valency, it cannot be denied that the general relations of the elements which this question of valency has been the means of bringing to light are of the highest importance, and point to the existence of laws of nature of the widest significance; I allude to the periodic law of the elements first foreshadowed by Newlands, but fully developed by Mendelejeff and Lothar Meyer. Guided by the principle that the chemical properties of the elements are a periodic function of their atomic weights, or that matter becomes endowed with analogous properties when the atomic weight of an element is increased by the same or nearly the same number, we find ourselves for the first time in possession of a key which enables us to arrange the hitherto *disjecta membra* of our chemical household in something like order, and thus gives us means of indicating the family resemblances by which these elements are characterised.

And here we may congratulate ourselves on the fact that, by the recent experiments of Brauner, and of Nilson and Pettersen respectively, tellurium and beryllium, two of the hitherto outstanding members, have been induced to join the ranks, so that at the present time osmium is the only important defaulter amongst the sixty-four elements, and few persons will doubt that a little careful attention to this case will remove the stigma which yet attaches to its name. But this periodic law makes it possible for us to do more; for as the astronomer, by the perturbations of known planets, can predict the existence of hitherto unknown ones, so the chemist, though, of course, with much less satisfactory means, has been able to predict with precision the properties, physical and chemical, of certain missing links amongst the elements, such as ekaluminium and ekaboron, then unborn, but which shortly afterwards became well known to us in the flesh as gallium and scandium. We must, however, take care that success in a few cases does not blind us to the fact that the law of nature which expresses the relation between the properties of the elements and the value of the atomic weights is as yet unknown; that many of the groupings are not due to any well-ascertained analogy of properties of the elements, and that it is only because the values of their atomic weights exhibit certain regularities that such a grouping is rendered possible. So, to quote Lothar

Meyer, we shall do well in this, as indeed in all similar cases in science, to remember the danger pointed out in Bacon's aphorism, that 'The mind delights in springing up to the most general axioms, that it may find rest, but after a short stay here it disdains experience,' and to bear in mind that it is only the lawful union of hypothesis with experiment which will prove a fruitful one in the establishment of a systematic inorganic chemistry which need not fear comparison with the order which reigns in the organic branch of our science. And here it is well to be reminded that complexity of constitution is not the sole prerogative of the carbon compounds, and that before this systematisation of inorganic chemistry can be effected we shall have to come to terms with many compounds concerning whose constitution we are at present wholly in ignorance. As instances of such I would refer to the finely crystalline phospho-molybdates, containing several hundred atoms in the molecule, lately prepared by Wolcott Gibbs.

Arising out of Kekulé's theory of the tetrad nature of the carbon atom, came the questions which have caused much debate among chemists: (1) Are the four combining units of the carbon atom of equal value or not? and (2) Is the assumption of a dyad carbon atom in the so-called non-saturated compounds justifiable or not? The answer to the first of these, a favourite view of Kolbe's, is given in the now well-ascertained laws of isomerism; and from the year 1862, when Schorlemmer proved the identity of the hydrides of the alcohol radicals with the so-called radicals themselves, this question may be said to be set at rest; for Lossen himself admits that the existence of his singular isomeric hydroxylamine derivatives can be explained otherwise than by the assumption of a difference between each of the combining units of nitrogen, and the differences supposed by Schreiner to hold good between the methylethyl carbonic ethers have been shown to have no existence in fact. With respect to the second point the reply is no less definite, and is recorded in the fact, amongst others, that ethylene chlorhydrin yields on oxidation chloracetic acid, a reaction which cannot be explained on the hypothesis of the existence in ethylene of a dyad carbon atom.

Passing from this subject, we arrive, by a process of natural selection, at more complicated cases of chemical orientation—that is, given certain compounds which possess the same composition and molecular formulæ but varying properties, to find the difference in molecular structure by which such variation of properties is determined. Problems of this nature can now be satisfactorily solved, the number of possible isomers foretold, and this prediction confirmed by experiment. The general method adopted in such an experimental inquiry into the molecular arrangement or chemical constitution of a given compound is either to build up the structure from less complicated ones of known constitution, or to resolve it into such component parts. Thus, for example, if we wish to discriminate between several isomeric alcohols, distinguishing the ordinary or primary class from the secondary or tertiary class, the existence of which was predicted by Kolbe in 1862, and of which the first member was prepared by Friedel in 1864, we have to study their products of oxidation. If one yields an acid having the same number of carbon atoms as the alcohol, it belongs to the first class and possesses a definite molecular structure; if it splits up into two distinct carbon compounds, it is a secondary alcohol; and if three carbon compounds result from its oxidation, it must be classed in the third category, and to it belongs a definite molecular structure, different from that of the other two.

In a similar way orientation in the much more complicated aromatic hydrocarbons can be effected. This class of bodies forms the nucleus of an enormous number of carbon compounds which, both from a theoretical and a practical point of view, are of the highest interest. For these bodies exhibit characters and possess a constitution totally different from those of the so-called fatty substances, the carbons atoms being linked together more intimately than is the case in the latter-named group of bodies. Amongst them are found all the artificial colouring matters, and some of the most valuable pharmaceutical and therapeutical agents.

The discovery of the aniline colours by Perkin, their elaboration by Hofmann, the synthesis of alizarin by Graebe and Liebermann, being the first vegetable colouring matter which has been artificially obtained, the artificial production of indigo by Baeyer, and lastly the preparation by Fischer, of kairine, a febrifuge as potent as quinine, are some of the well-known recent triumphs of modern synthetical chemistry. And these triumphs, let us remember, have not been obtained by any such 'random haphazarding' as yielded results in Priestley's time. In the virgin soil of a century ago, the ground only required to be scratched and the seed thrown in to yield a fruitful crop; now the surface soil has long been exhausted, and the successful cultivator can only obtain results by a deep and thorough preparation, and by a systematic and scientific treatment of his material.

In no department of our science has the progress made been more important than in that concerned with the accurate determination of the numerical, physical, and chemical constants upon the exactitude of which every quantitative chemical operation depends. For the foundation of an accurate knowledge of the first of these constants, viz., the atomic weights of the elements, science is indebted to the indefatigable labours of Berzelius. But 'humanum est errare,' and even Berzelius' accurate hand and delicate conscientiousness did not preserve him from mistakes, since corrected by other workers. In such determinations it is difficult if not impossible always to ascertain the limits of error attaching to the number. The errors may be due in the first place to manipulative faults, in the second to inaccuracy of the methods, or lastly to mistaken views as to the composition of the material operated upon; and hence the uniformity of any series of similar determinations gives no guarantee of their truth, the only safe guide being the agreement of determinations made by altogether different methods. The work commenced by Berzelius has been worthily continued by many chemists. Stas and Marignac, bringing work of an almost astronomical accuracy into our science, have ascertained the atomic weights of silver and iodine to within one hundred-thousandth of their value, whilst the numbers for chlorine, bromine, potassium, sodium, nitrogen, sulphur, and oxygen may now be considered correct to within a unit in the fourth figure. Few of the elements, however, boast numbers approaching this degree of accuracy, and many may even still be erroneous, from half to a whole unit of hydrogen. And (as Lothar Meyer says) until the greater number of the atomic weights are determined to within one or two tenths of the unit, we cannot expect to be able to ascertain the laws which certainly govern these numbers, or to recognise the relations which undoubtedly exist between them and the general chemical and physical properties of the elements. Amongst the most interesting recent additions to our knowledge made in this department we may note the classical experiments, in 1880, of J. W. Mallet on aluminium, and in the same year of J. P. Cooke on antimony, and those, in the present year, of Thorpe on titanium.

Since the date of Berzelius' death to the present day no discovery in our science has been so far-reaching, or led to such unforeseen and remarkable conclusions, as the foundation of Spectrum Analysis by Bunsen and Kirchhoff in 1860.

Independently altogether of the knowledge which has been gained concerning the distribution of the elementary bodies in terrestrial matter, and of the discovery of half-a-dozen new elements by its means, and putting aside for a moment the revelation of a chemistry not bounded by this world, but limitless as the heavens, we find that over and above all these results spectrum analysis offers the means, not otherwise open to us, of obtaining knowledge concerning the atomic and molecular condition of matter.

Let me recall some of the more remarkable conclusions to which the researches of Lockyer, Schuster, Liveing and Dewar, Wüllner and others in this direction have led. In the first place it is well to bear in mind that a difference of a very marked kind, first distinctly pointed out by Alex. Mitscherlich, is to be observed between the spectrum of an element and that of its compounds, the latter only being seen in cases in which the compound is not dissociated at temperatures necessary to give rise to a glowing gas. Secondly, that these compound spectra—as, for instance, those of the halogen compounds of the alkaline-earth metals—exhibit a certain family likeness, and show signs of systematic variation in the position of the lines, corresponding to changes in the molecular weight of the vibrating system. Still this important subject of the relation of the spectra of different elements is far from being placed on a satisfactory basis, and in spite of the researches of Lecoq de Boisbaudran, Ditte, Troost and Hautefeuille, Ciamician and others, it cannot be said that as yet definite proof has been given in support of the theory that a causal connection is to be found between the emission spectra of the several elements belonging to allied groups and their atomic weights or other chemical or physical properties. In certain of the single elements, however, the connection between the spectra and the molecular constitution can be traced. In the case of sulphur, for example, three distinct spectra are known. The first of these, a continuous one, is exhibited at temperatures below 500°, when, as we know from Dumas' experiments, the density of the vapour is three times the normal, showing that at this temperature the molecule consists of six atoms. The second spectrum is seen when the temperature is raised to above 1,000°, when, as Deville and Troost have shown, the vapour reaches its normal density, and the molecule of sulphur, as with most other gases, contains two atoms, and this is a band spectrum, or one characterised by channelled spaces. Together with this band spectrum, and especially round the negative pole, a spectrum of bright lines is observed. This latter is doubtless due to the vibrations of the single atoms of the dissociated molecule, the existence of traces of a band spectrum demonstrating the fact that in some parts of the discharge the tension of dissociation is insufficient to prevent the reunion of the atoms to form the molecule.

To this instance of the light thrown on molecular relations by changes in the spectra, others may be added. Thus the low-temperature spectrum of channelled spaces, mapped by Schuster and myself, in the case of potassium, corresponds to the molecule of two atoms and to the vapour-density of seventy-nine, as observed by Dewar and Dittmar. Again, both oxygen and nitrogen exhibit two, if not three, distinct spectra: of these the line spectrum seen at the highest temperatures corresponds to the atom; the band spectrum seen at intermediate temperatures represents the molecule of two atoms; whilst that observed at a still lower point would, as in the case of sulphur, indicate the existence of a more complicated molecule, known to us in one instance as ozone.

That this explanation of the cause of these different spectra of an element is the true one, can be verified in a remarkable way. Contrary to the general rule amongst those elements which can readily be volatilised, and with which, therefore, low-temperature spectra can be studied, mercury exhibits but one spectrum, and that one of bright lines, or, according to the preceding theory, a spectrum of atoms. So that, judging from spectroscopic evidence, we infer that the atoms of mercury do not unite to form a molecule, and we should predict that the vapour-density of mercury is only half its atomic weight. Such we know, from chemical evidence, is really the case, the molecule of mercury being identical in weight with its atom.

The cases of cadmium and iodine require further elucidation. The molecule of gaseous cadmium, like that of mercury, consists of one atom; probably, therefore, the cadmium spectrum is also distinguished by one set of lines. Again, the molecule of iodine at 1,200° separates, as we know from Victor Meyer's researches, into single atoms. Here spectrum analysis may come again to our aid; but as Schuster remarks, in his report on the spectra of the non-metallic elements, a more extensive series of experiments than those already made by Ciamician is required before any definite opinion as to the connection of the different iodine spectra with the molecular condition of the gas can be expressed.

It is not to be wondered at that these relations are only exhibited in the case of a few elements. For most of the metals the vapour-density remains, and probably will remain, an unknown quantity, and therefore the connection between any observed changes in the spectra and the molecular weights must also remain unknown. The remarkable changes which the emission spectrum of a single element—iron, for instance—exhibits have been the subject of much discussion, experimental and otherwise. Of these, the phenomenon of long and short lines is one of the most striking, and the explanation that the long lines are those of low temperature appears to meet the facts satisfactorily, although the effect of dilution, that is, a reduction of the quantity of material undergoing volatilisation, is, remarkably enough, the same as that of diminution of temperature. Thus it is possible, by the examination of a spectrum by Lockyer's method, to predict the changes which it will undergo, either on alteration of temperature, or by an increase or decrease of quantity. There appears to be no theoretical difficulty in assuming that the relative intensity of the lines may vary when the temperature is altered, and the molecular theory of gases furnishes us with a plausible explanation of the corresponding change when the relative quantities of the luminous elements in a mixture are altered. Lockyer has proposed a different explanation of the facts. According to him, every change of relative intensity means a corresponding change of molecular complexity, and the lines which we see strong near the poles, would bear the same relation to those which are visible throughout the field, as a line spectrum bears to a band spectrum; but then almost every line must be due to a different molecular grouping, a conclusion which is scarcely capable of being upheld without very cogent proof.

The examination of the absorption spectra of salts, saline and organic liquids, first by Gladstone, and afterwards by Bunsen, and by Russell, as well as by Hartley for the ultra-violet, and by Abney and Festing for the infra-red region, have led to interesting results in relation to molecular chemistry. Thus Hartley finds that in some of the more complicated aromatic compounds, definite absorption bands in the more refrangible region are only produced by substances in which three pairs of carbon atoms are doubly linked, as in the benzene ring, and thus the means of ascertaining this double linkage is given. The most remarkable results obtained by Abney and Festing show that the radical of an organic body is always represented by certain well-marked absorption bands, differing, however, in position, according as it is linked with hydrogen, a halogen, or with carbon, oxygen, or nitrogen. Indeed, these experimenters go so far as to say that it is highly probable that by this delicate mode of analysis the hypothetical position of any hydrogen which is replaced may be identified, thus pointing out a method of physical orientation of which, if confirmed by other observers, chemists will not be slow to avail themselves. This result, it is interesting to learn, has been rendered more than probable by the recent important researches of Perkin on the connection between the constitution and the optical properties of chemical compounds.

One of the noteworthy features of chemical progress is the interest taken by physicists in fundamental questions of our science. We all remember, in the first place, Sir William Thomson's interesting speculations, founded upon physical phenomena, respecting the probable size of the atom, viz., 'that if a drop of water were magnified to the size of the earth, the constituent atoms would be larger than small shot, but smaller than cricket balls.' Again, Helmholtz in the Faraday lecture, delivered in 1881, discusses the relation of electricity and chemical energy, and points out that Faraday's law of electrolysis, and the modern theory of valency, are both expressions of the fact, that when the same quantity of electricity passes through an electrolyte, it always either sets free, or transfers to other combinations, the same number of units of affinity at both electrodes. Helmholtz further argues, that if we accept the Daltonian atomic hypothesis, we cannot avoid the conclusion that electricity, both positive and negative, is divided into elementary portions which behave like atoms of electricity. He also shows that these charges of atomic electricity are enormously large as compared, for example, with the attraction of gravitation between the same atoms; in the case of oxygen and hydrogen, 71,000 billion times larger.

A further subject of interest to chemists is the theory of the vortex-ring constitution of matter thrown out by Sir William Thomson, and lately worked out from a chemical point of view by J. J. Thomson, of Cambridge. He finds that if one such ring be supposed to constitute the most simple form of matter, say the monad hydrogen atom, then two such rings must, on coming into contact with nearly the same velocity, remain enchained together, constituting what we know as the molecule of free hydrogen. So, in like manner, systems containing two, three, and four such rings constitute the dyad, triad, and tetrad atoms. How far this mathematical expression of chemical theory may prove consistent with fact remains to be seen.

Another branch of our science which has recently attracted much experimental attention is that of thermo-chemistry, a subject upon which in the future the foundation of dynamical chemistry must rest, and one which already proclaims the truth of the great principle of the conservation of energy in all cases of chemical as well as of physical change. But here, although the materials hitherto collected are of very considerable amount and value, the time has not yet arrived for expressing these results in general terms, and we must, therefore, be content to note progress in special lines and wait for the expansion into wider areas. Reference may, however, be properly made to one interesting observation of general significance. It is well known that, while, in most instances, the act of combination is accompanied by evolution of heat—that is, whilst the potential energy of most combining bodies is greater than that of most compounds—cases occur in which the reverse of this is true, and heat is absorbed in combination. In such cases the compound readily undergoes decomposition, frequently suddenly and with explosion. Acetylene and cyanogen seem to be exceptions to this rule, inasmuch as, whilst their component elements require to have energy added to them in order to enable them to combine, the compounds appear to be very stable bodies. Berthelot has explained this enigma by showing that, just as we may ignite a mass of dynamite without danger, whilst explosion takes place if we agitate the molecules by a detonator, so acetylene and cyanogen burn, as we know, quietly when ignited, but when their molecules are shaken by the detonation of even a minute quantity of fulminate, the constituents fly apart with explosive violence, carbon and hydrogen, or carbon and nitrogen being set free, and the quantity of heat absorbed in the act of combination being suddenly liberated.

In conclusion, whilst far from proposing even to mention all the important steps by which our science has advanced since the year 1848, I cannot refrain from referring to two more. In the first place, to that discovery, more than foreshadowed by Faraday, of the liquefaction of the so-called permanent gases by Pictet and Cailletet; and secondly to that of the laws of dissociation as investigated by Deville. The former, including Andrews's discovery of the critical point, indicates a connection, long unseen, between the liquid and the gaseous states of matter; the latter has opened out entirely fresh fields for research, and has given us new views concerning the stability of chemical compounds of great importance and interest.

Turning for a moment to another topic, we feel that, although science knows no nationalities, it is impossible for those who, like ourselves, exhibit strong national traits to avoid asking whether we Anglo-Saxons hold our own, as compared with other nations, in the part we have played and are playing in the development of our science. With regard to the past, the names of Boyle, Cavendish, Priestley, Dalton, Black, Davy, are sufficient guarantees that the English have, to say the least, occupied a position second to none in the early annals of chemistry. How has it been in the era which I have attempted to describe? What is the present position of English chemistry, and what its look-out for the future? In endeavouring to make this estimate I would take the widest ground, including not only the efforts made to extend the boundaries of our science by new discovery, both in the theoretical and applied branches, but also those which have the no less important aims of spreading the knowledge of the subject amongst the people, and of establishing industries dependent on chemical principles by which the human race is benefited. Taking this wide view, I think we may, without hesitation, affirm that the progress which chemistry has made through the energies of the Anglo-Saxon race is not less than that made by any other nation.

In so far as pure science is concerned I have already given evidence of the not inconsiderable part which English chemists have played in the progress since 1848. We must, however, acknowledge that the number of original chemical papers now published in our language is much smaller than that appearing in the German tongue, and that the activity and devotion displayed in this direction by the heads of German laboratories may well be laid to heart by some of us in England; yet, on the other hand, it must be remembered that the circumstances of different countries are so different that it is by no means clear that we should follow the same lines. Indeed our national characteristics forbid us to do so, and it may be that the bent of the Germanic lies in the assiduous collection of facts, whilst their subsequent elaboration and connection is the natural work of our own race.

As regards the publication of so-called original work by students, and speaking now only for myself as the director of an English chemical laboratory, I feel I am doing the best for the young men who, wishing to become either scientific or industrial chemists, are placed under my charge, in giving them as sound and extensive a foundation in the theory and practice of chemical science as their time and abilities will allow, rather than forcing them prematurely into the preparation of a new series of homologous compounds, or the investigation of some special reaction, or of some possible new colouring matter, though such work might doubtless lead to publication. My aim has been to prepare a young man, by a careful and fairly complete general training, to fill with intelligence and success a post either as teacher or industrial chemist, rather than to turn out mere specialists who, placed under other conditions than those to which they have been accustomed, are unable to get out of the narrow groove in which they have been trained. And this seems a reasonable course, for whilst the market for the pure specialist, as the colour chemist, for example, may easily be overstocked, the man of all-round intelligence will always find opportunity for the exercise of his powers. Far, however, from underrating the educational advantages of working at original subjects, I consider this sort of training to be of the highest and best kind, but only useful when founded upon a sound and general basis.

The difficulty which the English teacher of chemistry—and in this I may include Canada and the United States—has to contend against is, that whilst in Germany the value of this high and thorough training is generally admitted, in England a belief in its efficacy is as yet not generally entertained. 'The Englishman,' to quote from the recent Report of the Royal Commission on Technical Instruction, 'is accustomed to seek for an immediate return, and has yet to learn that an extended and systematic education, up to and including the methods of original research, is now a necessary preliminary to the fullest development of industry, and it is to the gradual but sure growth of public opinion in this direction that we must look for the means of securing to this country in the future, as in the past, the highest position as an industrial nation.'

If, in the second place, we consider the influence which Englishmen have exerted on the teaching of our science, we shall feel reason for satisfaction; many of our text-books are translated into every European language and largely used abroad; often to the exclusion of those written by continental chemists.

Again, science teaching, both practical and theoretical, in our elementary and many secondary schools is certainly not inferior to that in schools of similar grade abroad, and the interest in and desire for scientific training is rapidly spreading throughout our working population, and is even now as great as, if not greater than, abroad. The universities and higher colleges are also moving to take their share of the work which has hitherto been far less completely done in our country than on the continent of Europe, especially in Germany, where the healthful spirit of competition, fostered by the numerous State-supported institutions, is much more common than with us, and, being of equal value in educational as in professional or commercial matters, has had its due effect.

Turning lastly to the practical applications of our science, in what department does England not excel? and in which has she not made the most important new departures? Even in colour chemistry, concerning which we have heard, with truth, much of German supremacy, we must remember that the industry is originally an English one, as the names of Perkin and of Maule, Simpson and Nicholson testify; and if we have hitherto been beaten hollow in the development of this branch, signs are not wanting that this may not always be the case. But take any other branch of applied chemistry, the alkali trade, for instance, what names but English, with the two great exceptions of Leblanc and Solvay, do we find in connection with real discoveries? In the application of chemistry to metallurgical processes, too, the names of Darby, Cort, Neilson, and Bell in iron, of Bessemer

Thomas, Gilchrist, and Snelus in steel, of Elkington and Matthey in the noble metals, show that in these branches the discoveries which have revolutionised processes have been made by Englishmen; whilst Young, the father of paraffin, Spence the alum maker, and Abel of gun-cotton fame are some amongst many of our countrymen whose names may be honourably mentioned as having founded new chemical industries.

Hence, whilst there is much to stimulate us to action in the energy and zeal shown by our continental brethren in the pursuit both of pure and applied chemistry, there is nothing to lead us to think that the chemistry of the English-speaking nations in the next fifty years will be less worthy than that of the past half-century of standing side by side with that of her friendly rivals elsewhere.

The following Papers were read:—

1. *On Complex Inorganic Acids. By* Professor WOLCOTT GIBBS.

The author gave a *résumé* of his work on Complex Inorganic Acids, including many details not hitherto published. The work may be regarded as a series of generalisations of the class of silico-tungstates, discovered by Marignac in 1861, and of the analogous class of phospho-molybdates, the first systematic study of which is due to Deville. To form a proper basis for the investigation it was necessary to make a preliminary thorough study of the tungstates and molybdates. The author's results taken in connection with the prior work of Marignac, Scheibler and Ullik, established the fact that there are two series only of tungstates and molybdates—the normal and the meta-series, the latter being best represented by the compounds of tungsten; the former of those by molybdenum. Thus the lowest meta-tungstate has the formula $4WO_3 . H_2O$ considered as an acid, while the highest is represented by $16WO_3 . 7H_2O$. The lowest normal molybdic acid has the formula $MoO_3 . H_2O$; the highest the formula $9MoO_3 . H_2O$, as shown by Ullik. Scheibler discovered two distinct series of phospho-tungstates. The author finds that there are at least ten, the highest compound having the formula, as an acid, $24WO_3 . P_2O_5 . 6H_2O$, the lowest the formula $6WO_3 . P_2O_5 . 6H_2O$, and that the phospho-molybdates are at least equally numerous, and have a similar range. Odd numbers of molecules of tungstic and molybdic oxides also occur, and there are reasons for doubting all the formulæ of this class of compounds. Corresponding compounds containing arsenic pentoxide also exist, and a few of them had already been observed. To generalise these results still further, the author replaced phosphoric oxide by vanadic pentoxide and antimonic pentoxide, so as to form vanadio-tungstates and antimonio-tungstates and corresponding compounds of molybdenum. Many of these salts are very beautiful. He has also rendered it probable that the greater number of oxides of the type R_2O_5 form similar compounds, the general formula for the group being:

$$m\ R^{vi}O_3 \,.\, n\ R^{v}{}_2O_5 \,.\, p\ R^{i}{}_2O.$$

A second series of complex acids contains two oxides of the type $R^{v}{}_2O_5$, so that we have various phospho-vanadio-tungstates, and phospho-vanadio-molybdates, and it is at least probable that any two oxides of the type $R^{v}{}_2O_5$ may enter into similar combinations, the general formula being:

$$m\ R^{vi}O_3 \,.\, n\ R^{v}{}_2O_5 \,.\, p\ R^{v}{}_2O_5 \,.\, q\ R^{i}{}_3O.$$

The generalisation of the first term, WO_3 or MoO_3, in these series is also possible to a certain extent at least. Thus it appears that compounds exist in which fluorine and sulphur partially replace oxygen in WO_3 or MoO_3.

The author found that hypophosphorous and phosphorous acids unite in a similar manner with tungstic and molybdic oxides. The relations of these two to the others will perhaps appear from the formulæ:

$$6WO_3 \,.\, 2\{H_2 \,.\, PO \,.\, OH\}2H_2O \text{ and } 8MoO_3 \,.\, 2\{H_2 \,.\, PO \,.\, OH\}2(NH_4)_2O + 2\text{ aq.},$$

and, in the case of the salts containing phosphorous acid, from the formulæ:

$$12WO_3 . 2\{H . PO . (OH)_2\} 2(NH_4)_2O + 8 \text{ aq. and } 12MoO_3 . 2\{H . PO . (OH)_2\} 2K_2O + 12 \text{ aq.}$$

The author found that various organic radicals so-called, as for instance the methyl, ellyt, phenyl, &c., derivatives of hypophosphorous and phosphorous acids, appeared to form similar complex acids, so that an immense field for further research is at once opened.

He in the next place studied the relations of tungstic and molybdic oxides to the various isomeric modifications of phosphoric acid. Pyro-phospho-tungstates and pyro-phospho-molybdates may perhaps exist, but the author could not at present speak positively upon this point, as the phosphoric oxide passed with great rapidity into the ortho-phosphoric acid. With respect to the various meta-phosphoric acids, the case is different. These enter freely into combination with tungstic and molybdic oxide to form new acids. Thus the formulæ of a hexa-meta-phospho tungstate analysed in $8WO_3 . 6\, PO_3K . 2K_2O + 21$ aq., and of an analogous molybdenum compound $14MoO . 6PO_3Ba_3 . BaO + 55$ aq. The author considers the existence of salts containing ethylo-phosphoric acid, and its congeners as at least probable. Compounds also occur in which part of the oxygen of phosphoric or arsenic pentoxide is replaced by sulphur or fluorine.

In place of pentoxides, the teroxides of the same elements may combine with tungstic or molybdic oxide. Thus we have various series of arsenoso-tungstates and molybdates, and corresponding compounds containing antimonious and vanadious oxides. Sb_2O_3 and V_2O_3 . These pass by oxidation into the salts containing the pentoxides. The general formula is:

$$m\ R^{iii}O_3 .\ n\ R^{iii}{}_2O_3 .\ p\ R^{i}{}_2O.$$

Double compounds of this series also exist, the general formula being:

$$m\ R^{vi}O_3 .\ n\ R^{iii}{}_2O_3 .\ n\ R^{iii}{}_2O_3 .\ p\ R^{i}{}_2O.$$

Mixed types containing both pentoxides and teroxides also occur, the general formula being:

$$m\ R^{vi}O_3 .\ n\ R^{iii}{}_2O_3 .\ R^{v}{}_2O_5 .\ p\ R^{i}{}_2O$$

in which R^{iii} and R^{vi} may be different.

The formulæ of two compounds containing R_2O_3 are respectively $18WO_3 . 2As_2O_3 . 8BaO + 42$ aq., and $8MoO_3 . 2As_2O_3 . 3BaO + 13$ aq. Into these and similar compounds platinous chloride, $PtCl_2$, may enter to form new series in which the complex $R_2O_3 . 2PtCl_2$ replaces R_2O_5.

In place of platinous chloride, other metals of the same group may enter, while on the other hand, the chlorine may be replaced by bromine, iodine, or the complexes $SO_3 K . SeO_3K$ and TeO_3K.

The author found that the type of the silico-tungstates discovered by Marignac was also susceptible of generalisation; SiO_2 being replaceable by a large number of similar oxides, as for example by the oxides of selenium, tellurium, platinum, &c. Mixed types containing $R^{iv}O_2$ and $R^{vi}{}_2O_5$ also exist as well as types containing $R^{iii}{}_2O_3$ and $R^{iv}O_2$. As illustrations of the former, the author gave the formulæ:

$$28MoO_3 . 4V_2O_5 . VO_2 . 11(NH_4)_2O + 20 \text{ aq., and } 12WO_3 . 2V_2O_5 . 3VO_2 . 6Na_2O + 43 \text{ aq.,}$$

and as a further illustration of the fertility of this field of investigation the formulæ:

$$60WO_3 . 3P_2O_5 . 2V_2O_5 . VO_2 . 18BaO + 144 \text{ aq., and } 60WO_3 . 3P_2O_5 . V_2O_5 . VO_2 . 18BaO + 150 \text{ aq.,}$$

the former having the molecular weight 20,058, and the latter the molecular weight 20,066.

In conclusion the author stated, that in formulating certain compounds containing V_2O_5, he had found that much simpler expressions resulted when a part of the V_2O_5 was supposed to have the structure $(V_2O_2)O_3$, V_2O_2 replacing W or Mo. To support this view, he brought forward several new series of complex acids, containing neither tungstic nor molybdic oxide, as for instance, $12V_2O_5 . P_2O_5 . 3BaO + 45$ aq., and $20V_2O_5 . P_2O_5 . 6H_2O + 53$ aq. These compounds he termed phospho-vanadates; arsenico-vanadates also occur as well as various series containing vanadic dioxide, as well as pentoxide—a particular case being for instance, $18V_2O_5 . VO_2 . 2P_2O_5 . 7(NH_4)_2O + 50$ aq. In conclusion the author showed that the numerous compounds of the type, $PCl_5 . SbCl_5$, long known to chemists, in many cases at least corresponded to very simple forms of complex acids.

2. *On an Example of Chemical Equilibrium.* *By* A. Vernon Harcourt, *M.A., LL.D., F.R.S.*

3. *On the Incomplete Combustion of Gases.* *By* H. B. Dixon, *M.A.*

(1) Bunsen's original experiments on the incomplete combustion of mixtures of carbonic oxide and hydrogen are vitiated by the presence of aqueous vapour in the eudiometer. Both Horstmann's experiments and my own show that no alteration *per saltum* occurs in the ratio of the products of combustion.

(2) A mixture of dry carbonic oxide and oxygen does not explode when an electric spark is passed through it. The union of carbonic oxide and oxygen is effected indirectly by steam. A mere trace of steam renders a mixture of oxygen and carbonic oxide explosive. The steam undergoes a series of alternate reductions and oxidations, acting as a 'carrier of oxygen' to the carbonic oxide. With a very small quantity of steam, the oxidation of carbonic oxide takes place slowly. As the quantity of steam is increased, the rapidity of the explosion increases. The mean rate of explosion for one metre was found to increase from 36 metres a second —when the mixture was passed over anhydrous phosphoric acid—to 317 metres per second, when the mixture was saturated with aqueous vapour at 60° C.

(3) When a mixture of dry carbonic oxide and hydrogen is exploded with a quantity of oxygen insufficient for complete combustion, the ratio of the carbonic acid to the steam formed depends upon the length of the column of gases and the pressure under which the gases are fired. By continually increasing the initial pressure, a point is reached where no further increase in the pressure affects the products of the reaction. At and above this 'critical pressure' the result is independent of the length of the column of gases. The larger the proportion of oxygen used, the lower the 'critical pressure' is found to be.

(4) When dry mixtures of carbonic oxygen and hydrogen in varying proportions are exploded above the 'critical pressure' with oxygen insufficient for complete combustion, an equilibrium is established between two opposite chemical changes represented by the equations:—

$$\text{(i)}\ CO + H_2O = CO_2 + H_2$$
$$\text{(ii)}\ CO_2 + H_2 = CO + H_2O$$

so that at the end of the reaction the product of the carbonic oxide and steam molecules is equal to the product of the carbonic acid and hydrogen molecules multiplied by a coefficient of affinity. This result agrees with Horstmann's conclusion. But Horstmann considers the coefficient to vary with the relative mass of oxygen taken.

(5) A small difference in the initial temperature at which the gases are fired, makes a considerable difference in the products of the reaction. This difference is due to the condensation of steam by the sides of the vessel during the explosion, and its consequent removal from the sphere of action during the chemical changes. When the gases are exploded at a temperature sufficiently high to prevent any condensation of steam during the progress of the reaction the coefficient is found to be constant, whatever the quantity of oxygen used, provided the hydrogen is more than double the oxygen.

(6) The presence of an inert gas such as nitrogen, by diminishing the intensity of the reaction, favours the formation of carbonic acid in preference to steam.

When the hydrogen is less than double the oxygen, the excess of oxygen cannot react with any of the three other gases present—carbonic oxide, carbonic acid and steam, but has to wait until an equal volume of steam is reduced to hydrogen by the carbonic oxide. The excess of inert oxygen has the same effect as the inert nitrogen in favouring the formation of carbonic acid.

The variations in the coefficient of affinity found by Horstmann with different quantities of oxygen, are due partly to this cause, but chiefly to the varying amounts of steam condensed by the cold eudiometer during the reaction in different experiments.

(7) As the general result of these experiments it has been shown, that when a mixture of carbonic oxide and hydrogen is exploded with insufficient oxygen for complete combustion, at a temperature at which no condensation of steam can take place during the reaction, and at a pressure greater than the critical pressure, an equilibrium between two opposite changes is established, which is independent of the quantity of oxygen taken, so long as this quantity is less than half the hydrogen. Within the limits marked out above, the Law of Mass is completely verified for the gaseous system composed of carbonic oxide, carbonic acid, hydrogen and steam at a high temperature.

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4. *Spectroscopic Studies of Explosions.* *By* Professors LIVEING, *F.R.S.*, *and* DEWAR, *F.R.S.*[1]

The explosions observed were chiefly those of hydrogen with oxygen, and of carbonic oxide with oxygen, and were made in an iron tube fitted with quartz ends. The spectra were both observed with the eye and photographed. Linings of thin sheet metal of various kinds were introduced into the tube, and in some cases metallic salts in fine powder were put in. When the tube was clean, many iron lines were seen in the flash, nine lines in the green were identified, and forty-nine more in the blue, violet and ultra-violet. Only one line more refrangible than O was observed, and that was T. Twenty-five lines of nickel and twenty-two of cobalt, all lying between G and P, were photographed. No other metal gave anything like so many lines as these three, but magnesium gave the *b* group, copper gave one green and two ultra-violet lines, manganese the violet triplet; chromium, three triplets in the green, indigo and ultra-violet respectively; silver, two ultra-violet lines; sodium gave D and the pair near Q; potassium, the violet lines and the pair near O. On the other hand, zinc, cadmium, mercury, aluminium, tin, bismuth, antimony and arsenic developed no lines in the flash; marsh gas, sulphuretted, arsenetted and antimoniuretted hydrogen exploded with oxygen gave no peculiar lines, merely a more continuous spectrum. It appears to be proved that iron, nickel and cobalt are volatile in some degree at 3,000°, which, according to Bunsen and Berthelot, appears to be about the temperature of the exploding gas; and this may help to explain the appearance of iron lines in the highest parts of solar prominences. It might be possible to establish a spectroscopic scale of temperatures if the lines successively developed with increasing temperatures were noted. Thus the iron line T seems to be barely developed at 3,000°, the aluminium lines at H only come out at a somewhat higher temperature, the lithium blue line may be just seen in the inner green cone of a Bunsen burner, while the green line comes out in the explosion flash.

FRIDAY, AUGUST 29.

The following Papers were read:—

1. *On the Constitution of the Elements.* *By* Professor DEWAR, *F.R.S.*

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[1] For details, see *Phil. Mag.* for September 1884.

2. *On the Chemical Aspect of the Storage of Power.* *By* Professor E. Frankland, *D.C.L., M.D., F.R.S.*

The author has continued his experiments on electrical accumulators, and in the present paper communicates the results of a study of the phenomena attending the discharge of accumulator cells containing alternate plates of plumbic peroxide and spongy lead. The storage cell employed contained ten plates with an aggregate active surface of 12·3 square feet, and it was charged by a current of from 15 to 20 ampères generated by a Siemens' shunt machine, and was then allowed to rest for three days.

The discharge was made through a piece of platinum wire 1·035 m.m. in diameter and 10 inches long. This wire was maintained at a red heat, so long as the current did not sink below 17 ampères. The discharge occupied 73 hours in one experiment, 147½ in a second, and 141 hours in a third.

In all these experiments, moderate currents only were drawn from the cells, such as would be used for the supply of 14 or 15 Swan lamps of 20-candle power; but very much heavier currents can be obtained if desired, even up to 250 ampères.

From the results of these experiments, the author draws the following conclusions:

1. The energy of a charged storage cell is delivered in two separate portions, one having an E. M. F. of 2 volts and upwards; the other an E. M. F. of 0·5 volt and under. One of these may be conveniently termed *useful*, and the other *useless* electricity.

2. The proportion of useful electricity obtainable is greatest when the cell is discharged intermittently, and least when the discharge is continuous.

3. Neither in the intermittent nor continuous discharge at high E. M. F. is the current, through uniform resistance, augmented by rest. At low E. M. F., however, the current, *after continuous discharge of the high E. M. F. portion*, is greatly augmented, but only for a few minutes. This augmentation of current, at low E. M. F. after rest, is barely perceptible when the high E. M. F. discharge has been taken intermittently.

4. The suddenness of fall in potential during discharge indicates two entirely distinct chemical changes, the one resulting in an E. M. F. of about 2·5 volts, the other in one of about 0·3 volt.

5. The chemical change producing low E. M. F. is the first to occur in charging, and the last to take place in discharging the cell. It is the change which occurs during what is called the 'formation' of a cell, and, for economy's sake, a reversal of this change should never be allowed to take place.

6. It would not be difficult to suggest an explanation of the nature of these two chemical changes, but the author refrains pending their actual investigation in which he is now engaged.

7. Currents of enormous strength can be readily obtained from storage batteries coupled up in parallel. For instance, a current of 25,000 ampères is quite feasible from only 100 cells. Such a current reduces to insignificance the output of the largest dynamo ever built. It is to be hoped that currents of this magnitude will open up new possibilities of research into the constitution of matter.

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3. *On the Magnetic Rotation of Compounds in relation to their Chemical Composition.* *By* W. H. Perkin, *Ph.D., F.R.S.*

The author gave a *résumé* of his researches on the magnetic rotary polarisation of compounds in relation to their chemical composition. After referring to the remarkable discovery of Faraday in relation to this subject and the results obtained by more recent workers in this field, it was shown that no relationship in reference to chemical composition was likely to be found by the usual method of calculating the results of the observation of unit lengths of the fluid bodies examined, but that if lengths related to each other in proportion to their molecular weights, making the necessary correction for the difference of densities, were compared, that useful results would probably be obtained. Experiments have proved this to be the case, and in the series of homologous compounds it was found that for every addition of CH_2 a definite increase of what is called the 'molecular rotation' is obtained; besides this it was found that the rotation also was capable of indicating differences in the constitution of organic compounds. Isosecondary and tertiary bodies give different results from normal compounds. The compounds containing the halogens were also referred to, and formulæ given, by which molecular rotation of twenty-six series of compounds could be calculated.

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4. *On the present state of our Knowledge of Refraction Equivalents.* *By* Dr. J. H. Gladstone, *F.R.S.*

The law that the refraction equivalent of a compound is the sum of the refraction equivalents of its constituents, although of general, is not of universal application. The departures from it indicate some important change in the mode of combination of the elements, and thus the specific refraction or dispersion of light by a compound body proves a valuable means of investigating its chemical structure. The papers of Brühl three years ago gave a new impulse to the study of this subject, and during the past twelve months several important communications have been made, especially by Kanonnikov of the Kasan University, by Nasini of Rome, and by Bleekrode of the Hague, while the author of this paper has published observations that have been accumulating for some years.

Refraction-Equivalents of the Elements.

Element	Atomic Weight	Refraction Equivalent	Element	Atomic Weight	Refraction Equivalent
Aluminium	27·5	7·7	Manganese	55	11·7
Antimony	122	24·5	„ in permanganates	„	about 25
Arsenic	75	15·4	Mercury	200	19·4?
Barium	137·2	15·8	Nickel	58·7	10·0
Beryllium	9·3	5·1	Nitrogen	14	4·1
Bismuth	208·2	38·2	„ in bases, oxides, &c.	„	5·1
Boron, in Borates	11	about 4	Oxygen, single bonds	16	2·8
Bromine	80	15·3	„ double bonds	„	3·4
Cadmium	111·6	13·1	Palladium	106	21·6?
Caesium	132	19·1	Phosphorus	31	18·3
Calcium	40	10·0	Platinum	195	24·7
Carbon	12	5·0	Potassium	39·1	7·85
„ double linked	„	6·1	Rhodium	103·4	23·4?
Cerium	138·2	19·6?	Rubidium	85·4	12·1
Chlorine	35·5	9·9	Selenium	78	30·1
Chromium	52·4	15·4	Silicium	28	7·4
„ in Chromates	„	about 22	„ in Silicic Acid	„	about 6
Cobalt	58·7	10·4	Silver	108	13·2
Copper	63·4	11·5	Sodium	23	4·4
Didymium	145	23·3	Strontium	87·5	13·0
Fluorine	19	1·6?	Sulphur	32	16·0
Gold	196·2	23·1	„ single bonds	„	14·1
Hydrogen	1	1·3	Thallium	203·6	20·4
Iodine	127	24·5	Tin, bivalent	118	27·0?
Iron, bivalent	56	11·6	„ quadrivalent	„	18·6?
„ trivalent	„	19·4	Titanium	48	24·6
Lanthanum	138	22·9	Uranium	237·6	19·4
Lead	207	24·3	Vanadium	51·3	24·8?
Lithium	7	3·5	Zinc	65·3	9·8
Magnesium	24	6·7	Zirconium	90	21·3

Besides the increased data thus obtained, fresh light has been thrown on (1) The physical question at the basis of the inquiry. Additional proofs have been given that specific refraction is constant (or nearly so) notwithstanding solution or change from the gaseous to the liquid or solid condition. (2) The refraction equivalents of the elementary bodies. A revision of the old list ('Phil. Trans.' 1869) in the light of our present knowledge has led to the results embodied in the table given above. Many of the figures will doubtless require future modification. (3) The chemical structure of many compounds, especially among organic bodies rich in carbon. Some of these deductions have already become the subject of controversy in the scientific journals of the Continent.

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5. *On the Diffusion of Metals. By* Professor W. CHANDLER ROBERTS, *F.R.S.*

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6. *On some Phenomena of Solution illustrated by the case of Sodium Sulphate. By* Professor WILLIAM A. TILDEN, *D.Sc., F.R.S.*

From a study of the solubility of sodium sulphate in water at temperatures above 100° C., the author (in conjunction with Mr. Shenstone) has arrived at the conclusion that at these high temperatures the salt dissolves in the anhydrous state. In order to determine whether this salt dissolves in water at lower temperatures in the anhydrous or in the hydrated state he has made a series of calorimetric measurements of the thermal changes which attend the act of solution of Na_2SO_4 in water at temperatures below and above 33°–34°, the critical point in the curve of solubility. The following are the chief results:

Calorimetric effect, C, of dissolving Na_2SO_4 in n molecules of water at t°.

n.	*t*°	*C.*
100	31·70	1740
100	35·40	1522
100	42·85	1342
100	46·10	1071
100	55·00	985

These figures establish the fact that by dissolving anhydrous sulphate of sodium in water at temperatures above 33°–34° the thermal change is still positive, although a diminishing quantity, and hence that the act of solution is still attended at these temperatures by chemical combination between the salt and a portion of the water. These results when plotted out give a line which is nearly parallel with the solubility curve between these limits of temperature.

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7. *A Theory of Solution. By* W. W. J. NICOL, *M.A., B.Sc.*

This paper contained a *résumé* of the experimental evidence accumulated by the author in support of his theory, a complete enunciation of which was given in a paper read before the Royal Society of Edinburgh in January 1883, and published in the 'Philosophical Magazine' for February of the same year.

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8. *On Evaporation and Dissociation.*
By Professor WILLIAM RAMSAY, *Ph.D. and* SYDNEY YOUNG, *D.Sc.*

The authors described experiments made with the object of ascertaining whether the coincidence of the curves which represent the vapour pressures of stable solid and liquid substances at different temperatures with those indicating the maximum temperatures attainable by the same substances at different pressures, when evaporating with a free surface, holds good also for substances which dissociate in their passage to the gaseous state. The substances examined were chloral hydrate, ammonium carbonate, phthalic acid, succinic acid, aldehyde ammonia, ammonium chloride, nitric peroxide, and acetic acid. It was found that with chloral hydrate and ammonium carbonate, which cannot exist at all in the gaseous state, the temperatures of volatilisation do not form a curve. When the dissociation was considerable but not complete, as in the case of phthalic and succinic acids, an indication of a curve was observed at low pressures, but it differed widely both in form and position from that representing the vapour pressures or pressures of dissociation. As the dissociation decreases the curves approach each other more closely, and they appear to be coincident in the case of ammonium chloride and nitric peroxide within the limits of temperature at which observations were made, and at which the amount of dissociation is probably small. With acetic acid very numerous observations proved the perfect coincidence of the curves.

The results appear to be unfavourable to the view that when liquefaction of a gaseous stable substance takes place, gaseous molecules coalesce to form more complex groups of molecules, and that these complex molecules dissociate when the substance is vaporised.

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5. *On Molecular Volumes. By* Professor WILLIAM RAMSAY, *Ph.D.*

1. The object of this research was to ascertain whether, as has been long taken for granted, the boiling-points of compounds under equal pressures really afford suitable points for a comparison of their molecular volumes. The experiments described in detail in the original paper were made during the years 1880 and 1881, and a preliminary notice was read to the Chemical Society in the spring of that year. An account of experiments by W. Staedel appeared subsequently, in which he showed that the element chlorine possesses at least three different volumes in combination. Subsequent researches by Lossen, Schiff, and others have since that time thoroughly proved that no element enters into combination with invariable atomic volume. The experiments made by the author decisively prove that in the following series of compounds: water, methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, isobutyl alcohol, and ether; the value of the group CH_2 is by no means constant, while at the boiling-points of the liquids at low pressures the value is approximately constant, fluctuating between 17·5 and 22; at high temperatures the difference becomes much more apparent, attaining, at pressures of 20,000 mins. (which was the highest measured), the greatest irregularity. Thus the difference between the molecular volumes of ether and isobutyl alcohol, two isomeric substances, amounts to a total of about 20 units, whereas the hypothesis that at the boiling-points under equal pressures the molecular volumes are comparable, and for isomeric substances should be equal, no difference between these substances should be observable.

2. It was supposed that as liquids at high temperatures corresponding to high pressures are extremely compressible, the volumes might be comparable, provided they were compared under critical pressure; the temperatures, however, at which they were compared still being those at which their vapours exert equal pressure. To elucidate this point, careful measurements of the compressibility of these liquids were made, and also of their critical temperatures and pressures, and it was found that when the liquids were at the temperatures corresponding to equal vapour pressure, but exposed to their critical pressures, no correspondence between their molecular volumes was observable.

3. As a last alternative it was thought possible that if the liquids still at temperatures corresponding to equal vapour pressures, could have existed under no pressure, some basis of comparison might be found. Necessarily such a state is unrealisable in practice, but as the compressibility of the liquids had been determined, it was calculable. Again, it was found that in this hypothetical condition, although the relative volumes at high temperatures were considerably altered, yet no point of comparison had been reached.

4. The author therefore concludes that, contrary to what has usually been supposed, the boiling-points of liquids under whatever pressure they may be taken are not suitable temperatures at which to compare their molecular volumes.

Still it cannot be denied that a certain regularity is noticeable. The approximate constancy of the atomic volumes of elements which is made by Kopp the foundation of his system has been amply shown not to exist; by Staedel for chlorine, and by Kopp and others for nitrogen, oxygen, and sulphur.

5. On comparing the molecular volumes of compounds containing carbon, hydrogen, and oxygen, with the number of atoms contained in the compound, it is observable that in every case approximate proportionality is to be observed. This would imply that these elements enter the liquid state with approximately the same volumes which they would possess before combination, were it possible for these *to* exist in a perfect gaseous state. Expressed differently, the quotient obtained by dividing the molecular volume of a compound by the number of atoms contained in the compound yields a nearly constant number. This has been noticed by Schröder. But in order to reconcile the discrepancy observable between different series, Schröder has supposed that the atoms of some elements possess at one time double or treble the volume which they exhibit at another time. The author has shown that Schröder's method does not reconcile the observed discrepancies. On attempting to correlate the divergency from the above-mentioned very simple relation with the heats of formation of organic substances, no absolute regularity is noticeable, although there is general correspondence between a large molecular volume and a small evolution of heat during formation of the compound from its elements.

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10. *On Calcium Sulphide and Sulphocarbonate.* *By* V. H. Veley, *M.A.*, *F.C.S.*

Berzelius, 'Schweigger Journ.,' 34.12, has described a process for the preparation of calcium sulphide by passing hydrogen sulphide over lime, heated to a red heat. The equivalent weights of the water and calcium sulphide as the resultants of the equation,

$$CaO + H_2S : CaS + H_2O$$

were found to be in the proportion of 87 : 89 or practically 1 : 1.

In another memoir, Berzelius, 'Pogg. Annal.,' 6.444, describes the preparation of calcium sulphocarbonate by digesting calcium sulphide, water, and carbon disulphide, at a temperature of 30° in a flask from which air is excluded.

Calcium Sulphide.—As the formation of calcium sulphide is involved in the processes of purification of coal gas, and presumably abstracts the carbon disulphide from gas contaminated with that substance, it seemed of interest to study more particularly the formation of these compounds by the methods indicated by Berzelius.

Calcium oxide, free from the metals of the iron group, was obtained by heating perfectly transparent crystals of Iceland spar in porcelain tube in a current of hydrogen. This oxide was hydrated in a damp atmosphere free from carbonic anhydride, and converted into the hydroxide $Ca\ (OH)_2$.

The hydroxide, introduced into a convenient apparatus, was heated to 60°, and hydrogen sulphide passed through it, air being carefully excluded throughout the experiment. The resultant calcium sulphide and water were weighed, and the synthetic results thus obtained were found to agree with the results of the analysis of the calcium sulphide.

It is worthy of note that perfectly dry calcium oxide is perfectly unaltered by the passage of perfectly dry hydrogen sulphide, and generally the formation of calcium sulphide proceeded the more rapidly the greater the quantity of water originally present in the hydroxide. This result may be due to the formation at first, either of the hydrosulphide Ca SH, SH, or hydroxyhydrosulphide Ca, OH, SH, and the conversion of either of these substances into the monosulphide.

Calcium Sulphocarbonate.—The calcium sulphide, prepared as described above, was moistened with water, and hydrogen, saturated with carbon disulphide, was passed through it. It gradually turned yellow, and finally red, and on exhaustion with cold water there was obtained a red solution, from which on evaporation in vacuo there separated red deliquescent, prismatic crystals. The composition of these crystals on analysis was found to be in accordance with the formula $Ca(OH)_2$.

$CaCS_3$, together with a large excess of water. The solution of calcium sulphocarbonate in water gave with hydrochloric acid a red oil, probably sulphocarbonic acid, described by Berzelius and Zeise, dark brown precipitates with solutions of bismuth, stannous, lead, copper, mercurous, silver, platinum and gold salts, olive green solutions with nickel and manganese salts, with zinc salts golden white precipitates. These substances, some of which have been described by Berzelius, are presumably the sulphocarbonates of the various metals. The author hopes shortly to enter into a more minute examination of the composition and chemical properties of these substances.

11. *On the Action of Sulphuretted Hydrogen upon Silver.* *By* Professor F. P. Dunnington.

In view of the rapidity with which silver decomposes sulphuretted hydrogen under ordinary conditions, it appeared of interest to ascertain what would take place if water was completely excluded.

Three experiments were made under varied conditions, the results of which indicated that it was peculiarly difficult to remove all the moisture from the silver.

A fourth experiment was made as follows:—a piece of pure silver was flattened and carefully polished on each face, this was placed in the middle of a two-foot glass tube, in each end of the latter was put a plug of five inches of phosphoric anhydride, confined by glass wool. Pure dry hydrogen was slowly passed through this tube while it was gently heated throughout, the hydrogen was then removed by a Sprengel pump, the silver being heated to about 300° C.; again dry hydrogen was let into the tube, and again exhausted while the silver was heated; again hydrogen was let into the tube, and then pure dry sulphuretted hydrogen was slowly passed through the apparatus for an hour, and the tube finally drawn off and sealed at each end so as to leave the silver confined between the plugs of phosphoric anhydride. After several days the silver was darkened only a little near its edges, and after five months (as exhibited to the Section) the silver is blackened on its edges, while the main portion of the surface is still white.

Attention is also drawn to the fact that when the silver was heated to about 300° C., and the pressure removed, the brilliant polish of the silver was destroyed by a blistering of its surface, no doubt due to the oxygen which had been occluded.

From the above we may infer that in absence of water silver does not decompose sulphuretted hydrogen at common temperatures. The foregoing work was conducted by Mr. J. M. Cabell, a student in my laboratory.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Reports and Papers were read:—

1. *Report of the Committee upon the present state of our knowledge of Spectrum Analysis.*—See Reports, p. 295.

2. *Second Report of the Committee on Chemical Nomenclature.*—See Reports, p. 39.

3. *On Coal-Tar Colouring Matters.* *By* W. H. Perkin, *Ph.D., F.R.S.*

4. *On the Manufacture of Soda and Chlorine.* *By* W. WELDON, *F.R.S.*

5. *On the Chemistry of the Natural Silicates.* *By* Professor T. STERRY HUNT, *LL.D., F.R.S.*

The genesis of the crystalline stratified rocks, including the fundamental granite and the succeeding crystalline eozoic schists, is a subject for the chemist, without whose aid the natural history student, whether he styles himself mineralogist or geologist, can never hope to solve this great riddle of geogeny. The intervention of water, as taught by Werner, in the formation of the granitic substratum is now conceded, and we are prepared for a restatement of Neptunism upon an igneous basis, as I have elsewhere attempted under the name of the crenitic hypothesis. The chief chemical problem involved therein will be evident when we consider the composition of the rocks already referred to. These, excluding carbonates, quartz, and non-silicated oxides, are made up essentially of silicates, hydrous or anhydrous of a few bases, chiefly potash, soda, lime, magnesia, ferrous oxide, and alumina. The most important distinction among these is that between aluminous and non-aluminous silicates, due to the ready solubility and wide diffusion of salts of the protoxide bases in natural waters, and to the stability and insolubility of the silicates of alumina. Of natural aluminous silicates we have a series from simple hydrous and anhydrous species, through the pinites and muscovites and damourites, in which the oxygen ratio of protoxide to alumina is 1 : 12, 1 : 9, or 1 : 6. We then come to the great zeolite and feldspar group in which it is 1 : 3, and to silicates like epidote, garnet, magnesian micas and chlorites, in which it becomes 1 : 1 and even 2 : 1. That of the feldspar, which we may call the normal ratio, is found also in aluminates, and its significance is clear to the chemist. Aluminous double silicates with this ratio are formed in solutions in presence of excess of alkalies, and appear as natural results of aqueous action on igneous basic rocks as seen in basalts, in amygdaloids, and in volcanic mud in the deep sea. The studies of Bunsen and those of Daubrée throw great light on this process. The simultaneous production in many cases of protoxide silicates like pectolite, gyrolite, okerite, and apophyllite, is next to be considered. All of these are non-magnesian, but by reaction on dissolved salts of magnesia take up this base by exchange. Hence serpentines, chrysolite, pyroxene and talc.

The decomposition by heat of alkaline solutions of alumina and silica, in some cases with depositions of quartz and productions of more basic solutions which react with magnesian salts, explains the origin of aluminous silicates with excess of protoxide bases. The power of alkaline silicates in aqueous solution to hold dissolved various metallic oxides, throws light in the production of oxides of the spinel and corundum groups.

The origin of simple aluminous silicates and others with small amounts of protoxide is found in the diagenesis of the kaolin from subaërial decay of feldspathic rocks, soluble silicates of the zeolitic type often intervening.

In the various reactions set forth in this paper it was said that we have, by the working of known chemical laws, an explanation of the genesis of the great groups of natural silicates and the basis of a rational system of mineralogy and of lithology.

6. *On the Liquefaction of Oxygen and the Density of Liquid Hydrogen.* *By* Professor JAMES DEWAR, *M.A., F.R.S.*

7. *On the Physical Constants of Solutions.* *By* Professor W. L. GOODWIN, *D.Sc., and* Professor D. H. MARSHALL, *M.A., F.R.S.E.*

Previous experimenters have prepared solutions containing *m* molecules of anhydrous chlorides to *n* molecules of water. Such solutions do not contain equal numbers of molecules of the salts in equal volumes of the solutions. The object of this research is to determine the curves of expansion of solutions which contain, in equal volumes, weights of the salts proportional to the molecular weights. The experiments made show the feasibility of employing simpler apparatus than that hitherto used in determining the coefficients of expansion of saline solutions. The apparatus is a graduated bulb-tube with a bore large enough to admit a small capillary tube with which the solutions are run into the bulb-tube. The solutions are boiled a few seconds, while still hot poured into the bulb-tube, and are then closed off from the air by a mercury thread. The bath is a large vessel of water stirred constantly. Two series of readings are taken, one with the temperature rising and one with the temperature falling. The experiment is rejected unless these two sets give the same results. The experiments recorded in our paper were made with an ordinary thermometer graduated in single degrees and do not give sufficiently accurate results, but we hope with more delicate thermometers to very much increase the accuracy.

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8. *On the Production of Permanent Gas from Paraffin Oils.* *By* Dr. STEVENSON MACADAM, *F.R.S.E.*

The paraffin oils employed in the investigation were *crude paraffin oil*, being the oil obtained direct from the destructive distillation of shale in retorts; *green paraffin oil*, which is obtained by distilling or re-running the crude paraffin oil and removing the lighter or more inflammable oil by fractional distillation and freezing out the solid paraffin; and *blue paraffin oil*, which is the product obtained by rectifying the paraffin oil by sulphuric acid and soda, and distilling off the paraffin spirit, burning oil and intermediate oil, and freezing out the solid paraffin as paraffin scale. After many trials it was found that the best results were obtained by the simple arrangement of employing iron retorts at a good cherry-red heat, and running the oil as a thin stream direct into the retorts, so that it quickly impinged upon the red-hot metal, and without the intervention of any coke or other material in the retort. The following table gives the condensed results of one series of trials:—

	Crude Paraffin Oil	Green Paraffin Oil	Blue Paraffin Oil
Specific gravity of oil, (water = 1000)	850	884	878
Flashing point in close tester	92° F.	165° F.	163° F.
Gas from gallon of oil	98·76 cub. ft.	102·52 cub. ft.	127·42 cub. ft.
Gas from tun of oil	26,026 cub. ft.	25,977 cub. ft.	32,492 cub. ft.
Candle power of gas	50·36 candles	53·24 candles	54·28 candles
Light value of one cubic foot of gas in sperm candles	1208·64 grains	1277·76 grains	1302·72 grains
Light value of gas from gallon of oil in sperm candles	17·052 lbs.	18·718 lbs.	23·704 lbs.
Light value of gas from tun of oil in sperm candles	4494 lbs.	4741 lbs.	6047 lbs.
Light value of the oils as oils, determined from previous experimental data	5565 lbs.	5936 lbs.	7420 lbs.
Percentage of oil light obtained in gas light	80·75	79·87	81·49

In these trials, therefore, the gas obtained from the oils is equal in light power to 80 per cent. or four-fifths of the total light of the oils when such are consumed as oils under the most favourable conditions, and there is a loss of 20 per cent. or one-fifth of the light power.

The practical working of mineral oil apparatus on the large scale has resulted in the obtainment of permanent gas with an illuminating power of 75 per cent. of the total light of the oil as oil. The best working apparatus I have met with is Pintsch's, where such results can be obtained day by day.

The permanent character of the gas obtained from mineral oils has been proved by the testing of the gas after storage in gas-holders in the ordinary way; and even under the exceptionally severe test of submitting the gas to the pressure of 10 atmospheres, as in Pintsch's storage cylinders, the loss in candle power after a month's compression was not more than three candles or about 5 per cent. of the light.

The oil gas has now been successfully employed in the lighting of dwelling-houses and railway carriages, for lighthouse service in the illumination of buoys, and in the working of gas engines for sounding fog-horns, as at Langness in the Isle of Man; and at the present time large apparatus are being fitted up on Ailsa Craig in the Firth of Clyde for the production of the oil gas to be used alike for the illumination of the lighthouse lanterns and for the working of the gas engines connected with the fog-horns.

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9. *On the Diamondiferous Deposits of South Africa and the Ash of the Diamond.*[1] *By* Professor Sir H. E. Roscoe, *Ph.D., LL.D., F.R.S.*

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10. *On a Redetermination of the Atomic Weight of Cerium.* *By* H. Robinson.

TUESDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Chemical Changes in their relations to Micro-organisms.* *By* Professor E. Frankland, *D.C.L., M.D., F.R.S.*

The author explained the two kinds of chemical action—viz., that in which substances brought into contact mutually undergo chemical change; and, secondly, that in which chemical change is effected in one substance by contact with another, which itself suffers apparently no alteration. To the latter are usually assigned the chemical changes forming the subject of this paper.

The discussion was confined to the study of organisms belonging to the animal kingdom, and, in order to narrow the discussion, the author proposed the following definitions:—

1. A plant is an organism performing synthetical functions, or one in which these functions are greatly predominant.

2. An animal is an organism performing analytical functions, or one in which these functions greatly predominate.

From a physical point of view these definitions may be thus formulated:—

1. A plant is an organism which transforms actual into potential energy.

2. An animal is one which changes potential into actual energy.

All micro-organisms appear to belong to the second class. In that portion of the animal world with which we are best acquainted *oxidation* is the essential condition of life; it is the kind of action by which the animal changes potential into actual energy, and this actual energy is manifested in the phenomena which we term life. There are, however, many other chemical transformations in which potential becomes actual energy, and which, therefore, can support life. Besides such changes as are known to be thus utilised by micro-organisms there are many

[1] Printed in full in *Proc. Lit. and Phil. Soc. Manchester*, vol. xxiii. pp. 5–10, 1884.

others which might be possibly so utilised. It is even conceivable that animal life could be supported by allotropic or isomeric changes, such as the transformation of amorphous into waxy phosphorous, or of amorphous into crystalline antimony.

The author then described the chemical changes produced by a large number of micro-organisms, and concluded as follows:—

There is no break in the continuity of chemical functions between micro-organisms, and the higher forms of animal life. Both alike owe their vitality to the liberation of the energy stored in their food, and both go through a cycle of existence and then lose their vitality. It is true that there are apparently certain sharp distinctions between them. Thus the enormous fecundity of micro-organisms and their tremendous appetites (on the assumption that all the changed matter passes through their bodies) seem to separate them from the higher orders of animals. But this distinction is only comparative.

Thus in regard to fecundity, the power of multiplication gradually increases as the animal descends in the scale of organisation. There are, of course, exceptions, but this is the rule. The sheep produces only one or two lambs annually. The herring in the same time multiplies itself many thousandfold, whilst the aphis produces young at such a rate, that a single specimen would, if all its progeny lived, produce in three months a weight of aphides greater than that of the whole contemporary human race. And, as to appetite, voracity is greatest in the lowest animals. A sheep or cow consumes about one-sixth of its own weight in twenty-four hours; an earthworm, a caterpillar, or a silkworm, many times its own weight. The yeast organism must therefore, taking into account its position in nature, be considered decidedly abstemious, inasmuch as it only consumes two-thirds of its own weight of sugar in twenty-four hours. Moreover, it must be borne in mind that the sheep converts much of its food into carbonic anhydride, water, and hippuric acid, thus utilising nearly the whole of the potential energy, whilst the micro-organism, as a rule, utilises only a small portion. Further, those micro-organisms which have been chemically studied produce, like the higher animals, perfectly definite chemical changes. There is in this respect, therefore, no essential difference between a mass of yeast, a populous town, a herd of cattle, and a colony of snakes; each produces its own peculiar chemical changes in the food it consumes, and thereby obtains the energy necessary to its vitality.

The position of micro-organisms in nature is only just beginning to be appreciated. Their study both from chemical and biological points of view is, however, of the highest importance to the welfare of mankind, and I venture to predict that whilst there is no danger of their being spoiled by petting, or by their welfare being made the special care of sentimentalists, these lowly organisms will receive much more attention in the future than they have done in the past. Their study leads the inquirer right into those functions of life which are still shrouded in obscurity.

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2. *On Nitrification.* *By* R. WARINGTON.[1]

The Theory of Nitrification.—Till the commencement of 1877 it was generally supposed that the formation of nitrates from ammonia or nitrogenous organic matter in soils and waters was the result of simple oxidation by the atmosphere. In the case of soil it was imagined that the action of the atmosphere was intensified by the condensation of oxygen in the pores of the soil; in the case of waters no such assumption was possible. This theory was most unsatisfactory, as neither solutions of pure ammonia, or of any of its salts, could be nitrified in the laboratory by simple exposure to air. The assumed condensation of oxygen in the pores of the soil also proved to be a fiction as soon as it was put by Schlœsing to the test of experiment.

Early in 1877, two French chemists, Messrs. Schlœsing and Müntz, published preliminary experiments showing that nitrification in sewage and in soils is the

[1] The original paper will be found in full in *Nature*, xxx. p. 644.

result of the action of an organised ferment, which occurs abundantly in soils and in most impure waters. The evidence for the ferment theory of nitrification is now very complete. Nitrification in soils and waters is found to be strictly limited to the range of temperature within which the vital activity of living ferments is confined. Thus nitrification proceeds with extreme slowness near the freezing-point, and increases in activity with a rise in temperature till 37° are reached; the action then diminishes, and ceases altogether at 55°. Nitrification is also dependent on the presence of plant-food suitable for organisms of low character. Recent experiments at Rothamsted show that in the absence of phosphates no nitrification will occur. Further proof of the ferment theory is afforded by the fact that antiseptics are fatal to nitrification. In the presence of a small quantity of chloroform, carbon bisulphide, salicylic acid, and apparently also phenol, nitrification entirely ceases. The action of heat is equally confirmatory. Raising sewage to the boiling-point entirely prevents its undergoing nitrification. The heating of soil to the same temperature effectually destroys its nitrifying power. Finally, nitrification can be started in boiled sewage, or in other sterilised liquid of suitable composition, by the addition of a few particles of fresh surface soil, or a few drops of a solution which has already nitrified; though without such addition these liquids may be freely exposed to filtered air without nitrification taking place.

The nitrifying organism has been submitted as yet to but little microscopical study: it is apparently a micrococcus.

It is difficult to conceive how the evidence for the ferment theory of nitrification could be further strengthened; it is apparently complete in every part. Although, however, nearly the whole of this evidence has been before the scientific public for more than seven years, the ferment theory of nitrification can hardly be said to have obtained any general acceptance; it has not indeed been seriously controverted, but neither has it been embraced. It is partly with the view of calling the attention of English and American chemists to the importance of a decision on this question that I have been induced to bring this subject before them on the present occasion.

The Distribution of the Nitrifying Organism in the Soil.—Small quantities of soil were taken, at depths varying from two inches to eight feet, from freshly-cut surfaces on the sides of pits sunk in the clay soil at Rothamsted. The soil removed was at once transferred to a sterilised solution of diluted urine, which was afterwards examined from time to time to ascertain if nitrification took place. From the results it would appear that in a clay soil the nitrifying organism is confined to about eighteen inches from the surface; it is most abundant in the first six inches. It is quite possible, however, that in the channels caused by worms, or by the roots of plants, the organism may occur at greater depths. In a sandy soil we should expect to find the organism at a lower level than in clay, but of this we have as yet no direct evidence.

Some very practical conclusions may be drawn from the facts now stated. It appears that the oxidation of nitrogenous matter in soil will be confined to matter near the surface. The nitrates found in the subsoil, and in subsoil drainage waters, have really been produced in the upper layer of the soil, and have been carried down by diffusion, or by a descending column of water. Again, in arranging a filter-bed for the oxidation of sewage, it is obvious that with a heavy soil lying in its natural state of consolidation very little will be gained by making the filter-bed of considerable depth; while, if an artificial bed is to be constructed, it is clearly the top soil, rich in oxidising organisms, which should be exclusively employed.

The Substances susceptible of Nitrification.—The analyses of soils and drainage waters have taught us that the nitrogenous humic matter resulting from the decay of plants is nitrifiable; also that the various nitrogenous manures applied to land, as farmyard manure, bones, fish, blood, rape-cake, and ammonium salts, undergo nitrification in the soil. In the Rothamsted Laboratory experiments have been made on the nitrification of solutions of various substances. Besides solutions containing ammonium salts and urea, I have succeeded in nitrifying solutions of asparagine, milk, and rape-cake. Thus, besides ammonia, two amides, and two forms of albuminoids have been found susceptible of nitrification. In all cases in which amides or albuminoids were employed, the formation of ammonia preceded the production of nitric acid.

As ammonia is so readily nitrifiable, we may safely assert that every nitrogenous substance which yields ammonia when acted on by the organisms present in soil is also nitrifiable.

Certain Conditions having Great Influence on the Process of Nitrification.—If we suppose that a solution containing a nitrifiable substance is supplied with the nitrifying organism, and with the various food-constituents necessary for its growth and activity, the rapidity of nitrification will depend on a variety of circumstances:—(1) The degree of concentration of the solution is important. Nitrification always commences first in the weakest solution, and there is probably in the case of every solution a limit of concentration beyond which nitrification is impossible. (2) The temperature has great influence. Nitrification proceeds far more rapidly in summer than in winter. (3) The presence or absence of light is important. Nitrification is most rapid in darkness; and in the case of solutions, exposure to strong light may cause nitrification to cease altogether. (4) The presence of oxygen is of course essential. A thin layer of solution will nitrify sooner than a deep layer, owing to the larger proportion of oxygen available. The influence of depth of fluid is most conspicuous in the case of strong solutions. (5) The quantity of nitrifying organism present has also a marked effect. A solution seeded with a very small amount of organism will for a long time exhibit no nitrification, the organism being (unlike some other bacteria) of very slow growth. A solution receiving an abundant supply of the ferment will exhibit speedy nitrification, and strong solutions may by this means be successfully nitrified, which with small seedings would prove very refractory. The speedy nitrification which occurs in soil (far more speedy than in experiments in solutions under any conditions yet tried) is probably owing to the great mass of nitrifying organism which soil contains, and to the thinness of the liquid layer which covers the soil particles. (6) The rapidity of nitrification also depends on the degree of alkalinity of the solution. Nitrification will not take place in an acid solution, it is essential that some base should be present with which the nitric acid may combine; when all available base is used up nitrification ceases. It appeared of interest to ascertain to what extent nitrification would proceed in a dilute solution of urine without the addition of any substance save the nitrifying ferment. As urea is converted into ammonium carbonate in the first stage of the action of the ferment, a supply of salifiable base would at first be present, but would gradually be consumed. The result of the experiment showed that only one-half the quantity of nitric acid was formed in the simple urine solution, as in similar solutions containing calcium and sodium carbonate. The nitrification of the urine had evidently proceeded till the whole of the ammonium had been changed into ammonium nitrate, and the action had then ceased. This fact is of practical importance. Sewage will be thoroughly nitrified only when a sufficient supply of calcium carbonate, or some other base, is available. If instead of calcium carbonate a soluble alkaline salt is present, the quantity must be small, or nitrification will be seriously hindered. Sodium carbonate begins to have a retarding influence on the commencement of nitrification when its amount exceeds 300 milligrammes per litre, and up to the present time I have been unable to produce an effective nitrification in solutions containing 1·000 gramme per litre. Sodium hydrogen carbonate hinders far less the commencement of nitrification. Ammonium carbonate, when above a certain amount, also prevents the commencement of nitrification. The strongest solution in which nitrification has at present commenced contained ammonium carbonate equivalent to 368 milligrammes of nitrogen per litre. This hindrance of nitrification by the presence of an excess of ammonium carbonate effectually prevents the nitrification of strong solutions of urine, in which, as already mentioned, ammonium carbonate is the first product of fermentation. Far stronger solutions of ammonium chloride can be nitrified than of ammonium carbonate, if the solution of the former salt is supplied with calcium carbonate. Nitrification has in fact commenced in chloride of ammonium solutions containing more than two grammes of nitrogen per litre.

The details of the recent experiments, some of the results of which we have now described, will, it is hoped, shortly appear in the *Journal* of the Chemical Society of London.

3. *On the Assimilation of Atmospheric Nitrogen by Plants. By* Professor W. O. Atwater.

Plants (dwarf peas) were cultivated in purified sand to which were added nutritive solutions with known quantities of nitrogen in forms of potassium and calcium nitrates. The amounts of nitrogen supplied in solution and seed were compared with amounts found at the end of the experiment in residual solution and plants. The excess of the latter over the former must represent nitrogen acquired from the atmosphere.

A number of trials were made, with varying degrees of concentration of the nutritive solutions, with different amounts of food per plant, and with larger and smaller supplies of nitrogen in the solution; the object being to test the effect of normal and abnormal conditions upon the acquisition of atmospheric nitrogen by the plants. In concentrated solutions, which are known to be prejudicial to assimilation, the plants acquired little or no nitrogen from the air.

In the moderately dilute solutions, however, whose concentration was such as has elsewhere been found favourable to healthy growth, the nitrogen of the plants largely exceeded that supplied by nutritive solution and seed, and is shown by the following figures:—

	Atmosphere's Nitrogen Acquired by Plants			
	In milligrammes per experiment		In per cent. of total nitrogen of plants	
	With smaller nitrogen ration	With larger nitrogen ration	With smaller nitrogen ration	With larger nitrogen ration
	mgm.	mgm.	per cent.	per cent.
With six plants, *i.e.* smaller food-supply . . .	81·7	99·2	38·7	38·1
With three plants, *i.e.* larger food-supply . .	93·2	142·0	50·0	51·1

That is to say, in four trials with solutions sufficiently dilute to permit normal assimilation, the very poorly fed plants obtained over one-third, and the tolerably well fed ones, one-half, their whole nitrogen from the atmosphere.

The plants acquired a milligramme of nitrogen from the air, for every milligramme taken from the solution and seed. And what is even more noticeable, not only where the amount of nitrogen supplied was very small did they do this, but also where it was more than twice as large. The results show very clearly that the assimilation of nitrogen decreased with the concentration of the solution, and with the reduction of the supply of total food, or of nitrogen in the food. In other words, the acquisition of aerial nitrogen was greater in proportion as the conditions of growth were more nearly normal. This fact is of interest in view of the circumstance that the experiments upon which the belief that plants acquire little or no free nitrogen from the atmosphere is based, have been made under conditions more or less abnormal.

The experiments do not show whether the nitrogen acquired from the atmosphere was combined or free nitrogen. It is, however, very difficult to believe that so much nitrogen could have been gathered from the nitrogen compounds, ammonia, nitrates, nitrites, &c., of the atmosphere.

The total combined nitrogen brought to the earth annually in measured aqueous deposits—snow, rain, &c.—has been found to be only 6·12 kilos per hectare.

An acid solution and a moist, acid, porous soil have been found to absorb, for the period of these experiments (seventy-two days in April, May, and June), combined nitrogen at the rate of some 10 kilos per hectare. The amount of nitrogen acquired from the atmosphere in the one of these experiments, in which the conditions were most nearly normal, was at the rate of 137 kilos per hectare, twice as much as the total nitrogen contained in grain and straw of a wheat crop or thirty bushels, and more than the total nitrogen of three tons of clover hay.

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4. *On some points in the Composition of Soils, with results illustrating the Sources of Fertility of Manitoba Prairie Soils. By* Sir JOHN B. LAWES, *Bart., F.R.S., and* Dr. J. H. GILBERT, *F.R.S.*

This paper was a continuation of one given by the authors at the meeting of the American Association, held at Montreal two years previously, entitled: 'Determinations of nitrogen in the soils of some of the experimental fields at Rothamsted, and the bearing of the results on the question of the sources of the nitrogen of our crops.' The first part of the present paper consisted of a *résumé* of the previous one.

It was shown that when crops were grown year after year on the same land without nitrogenous manure, the produce, and the yield of nitrogen, declined in a very marked degree. This was the case even when a full mineral manure was applied; and it was the case not only with cereals and with root-crops, but also with *Leguminosæ*. Further, with this great decline in the annual yield of nitrogen of these very various descriptions of plant, when grown without artificial nitrogenous supply, there was also a marked decline in the stock of nitrogen in the soil. Thus a soil-source, of at any rate some, of the nitrogen of the crops was indicated. Other evidence was also adduced clearly pointing to the same conclusion.

Next, determinations of the amounts of nitrogen as nitric acid, in soils of known history as to manuring and cropping, and to a considerable depth, showed that the amount of nitrogen in the soil in that form was much less after the growth of a crop than under corresponding conditions without a crop. It was hence concluded that nitrogen had been taken up by the plant as nitric acid. In the case of gramineous crops, and some others, the evidence pointed to the conclusion that most, if not the whole, of the nitrogen was so taken up from the soil. It was also clear that some, at any rate, of the nitrogen of *Leguminosæ* had the same source, and the results were in favour of the supposition that in some of the cases the whole of it might be so accounted for. Still it was admitted that, in some cases, this seemed very doubtful.

The conditions and the results of a large number of new experiments were next described. It was found that there was very much more nitrogen as nitric acid, in soils and sub-soils, down to the depth of 108 inches, where leguminous than where gramineous plants had grown. The results pointed to the conclusion that under the influence of leguminous growth and crop-residue, especially in the case of strong and deep-rooted plants, the conditions were more favourable for the development and distribution of the nitrifying organism; and, if this view were confirmed, an important step would be gained towards the more complete explanation of the sources of the nitrogen of the *Leguminosæ* which assimilate a very large quantity of nitrogen, inducing, as above supposed, the nitrification of the nitrogen of the subsoil, which may thus become the source of the nitrogen of such crops. An alternative obviously was, that the plants might still take up nitrogen from the subsoil, but as organic nitrogen, and not as nitric acid. There was, however, no direct experimental evidence in favour of such a view, whilst some physiological considerations, which were discussed, seemed to be against it. Again, results showed that the soil and subsoil contained less nitrogen as nitric acid after the growth of good crops of *vicia sativa*, than where the more shallow-rooted *trifolium repens* had failed to grow. This was further evidence that the *Leguminosæ* took up nitrogen as nitric acid; and in the experiments in question the deficiency of nitric nitrogen in the soil and subsoil of the *vicia sativa* plots, compared with the amount in those of the *trifolium repens* plot to the depth examined, was sufficient to account for a large proportion of the nitrogen estimated to be contained in the *vicia* crops.

Other experiments were quoted which bore less directly on the point, the results of which were, however, accordant; and they at the same time afforded illustrations of the loss of nitrogen that the land may sustain by fallow in a wet season, and therefore of the benefits arising from the ground being covered with a crop which takes up the nitric acid as it is produced. To conclude on this part of the subject, it might be considered established that much, at any rate, of the nitrogen of crops is derived from the stores within the soil, and that much, and in some cases the whole, of the nitrogen so derived, is taken up as nitrates.

This led to the consideration of the second part of their subject, namely, the sources of fertility of some Manitoba Prairie soils.

Soils from Portage la Prairie, from the Saskatchewan district, and from near Fort Ellice, were first examined. They proved to be about twice as rich in nitrogen as the average of arable soils in Great Britain, and perhaps about as rich as the average of the surface soil of permanent pasture land.

Four other Manitoba soils were examined in greater detail. One was from Niverville, forty-four miles west of Winnipeg, the second from Brandon, the third from Selkirk, and the fourth from Winnipeg itself. These soils showed a very high percentage of nitrogen; that from Niverville nearly twice as high a percentage as in the first six or nine inches of ordinary arable land, and about as high as in the surface soil of pasture land, in Great Britain. The soil from Brandon was not so rich as that from Niverville; still the first twelve inches of depth was as rich as the first six or nine inches of good old arable lands. The soil from Selkirk showed an extremely high percentage of nitrogen in the first twelve inches, and in the second twelve inches as high a percentage as in ordinary pasture surface soil. Lastly, both the first and second twelve inches of the soil from Winnipeg were shown to be very rich in nitrogen, richer than the average of old pasture surface soil.

The question arose—how far the nitrogen in these soils was susceptible of nitrification, and so of becoming easily available to vegetation. The soils and subsoils were placed in shallow dishes, covered with plates of glass, kept under proper conditions of temperature and moisture for specified periods, extracted from time to time, and the nitric acid determined in the extracts.

The periods were never less than twenty-eight days, and sometimes more. The rate of nitrification declined after the third and fourth periods. There was a very marked increase in the rate of nitrification in the subsoils during the eighth period compared with the seventh, there having been only as much as a tenth of a gram of garden soil containing nitrifying organisms added. This result was of much interest, affording confirmation of the view that the nitrogen of subsoils is subject to nitrification, if only under suitable conditions, and that the growth of deep-rooted plants may favour nitrification in the lower layers.

Records show that the rich prairie soils of the North-west are competent to yield large crops; but under existing conditions they certainly do not, on the average, yield amounts at all commensurate with their richness compared with the soils of Great Britain which have been under arable cultivation for centuries That the rich prairie soils do not yield more produce than they do, is due partly to climate, but largely to scarcity of labour, and consequent imperfect cultivation, and too luxuriant a growth of weeds; and until mixed agriculture, with stock feeding, can be had recourse to, and local demand arises, the burning of the straw, and deficiency or waste of manure, are more or less inevitable, but still exhausting practices. So long as land is cheap and labour dear some sacrifice of fertility is unavoidable in the process of bringing these virgin soils under profitable cultivation; and the only remedy is to be found in increase of population. Still the fact should not be lost sight of, that such practices of early settlement, however unavoidable, do involve serious loss of fertility.

A table was exhibited which showed the comparative characters, as to percentage of nitrogen and carbon, of exhausted arable soils, of newly laid-down pasture, and of old pasture soils, at Rothamsted; also of some other old arable soils in Great Britain; of some Illinois and Manitoba prairie soils; and lastly, of some very rich Russian soils. From these results there could be no doubt that a characteristic of a rich virgin soil, or of a permanent pasture surface soil, was a relatively high percentage of nitrogen and carbon. On the other hand, soils which have long been under arable culture are much poorer in these respects; whilst arable soils under conditions of known agricultural exhaustion show a very low percentage of nitrogen and carbon, and a low relation of carbon to nitrogen.

In conclusion, the authors said it had been maintained by some that a soil was a laboratory and not a mine; but not only the facts adduced by them in this and former papers, but the history of agriculture throughout the world, so far as it was known, clearly showed that a fertile soil was one which had accumulated within it the residue of ages of previous vegetation; and that it became infertile as this residue was exhausted.

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5. *On the Velocity of Explosions in Gases.* *By* H. B. Dixon, *M.A.*

MM. Berthelot and Vieille have found that in hydrogen and oxygen, ethane and oxygen, and many other mixtures of gases, the 'explosive wave' is propagated with a velocity closely approximating to the mean velocity of translation of the gaseous products of combustion, calculated on the assumption that all the heat of the reaction is retained for the moment in the products formed. Thus the mean of a number of determinations with electrolytic gas gave a velocity of 2,810 metres per second; the calculated mean velocity of the steam molecule formed being 2,831 metres per second. But with carbonic oxide, exploded either with oxygen or nitrous oxide, the velocity of explosion was much less than the calculated velocity. The author has shown that steam is necessary for the burning of carbonic oxide, both with oxygen and nitrous oxide, and that as the proportion of steam is increased the rate of inflammation is also increased.

Preliminary experiments made in a lead tube, 55 metres long and 13 mm. internal diameter, entirely confirmed MM. Berthelot and Vieille's experiments with electrolytic gas. The velocity of the explosive wave was found to be 2,817 metres per second, as the mean of several closely concordant determinations at 10° C.

With a nearly dry mixture of carbonic oxide and oxygen, the explosive wave was not established until the flame had traversed a distance of 700 mm. from the firing point. The explosive wave was found to have a velocity of rather over 1,500 metres per second. After the explosion a fine layer of carbon was found to cover the inside of the tube, showing that at the enormous temperature reached in the explosive wave, carbonic oxide is decomposed into its constituents.

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6. *On the Colour of Chemical Compounds.*[1] *By* Professor Thos. Carnelley, *D.Sc.*

The colour of chemical compounds is conditioned by at least three circumstances, viz.:—(1) Temperature (Ackroyd), (2) the quantity of the electronegative element present in a binary compound (Ackroyd), (3) the atomic weights of the constituent elements of the compound (Carnelley), and that in such a way that the colour passes or tends to pass through the following chromatic scale:—

White or colourless	Indigo	Green	Orange	Brown
Violet	Blue	Yellow	Red	Black

either by (1) *rise* of temperature, or (2) *increase* of the quantity of the electronegative element in a binary compound, or (3) with *increase of the atomic weights* of the elements A, B, C, &c., in the compounds $A_x R_y$, $B_x R_y$, $C_x R_y$, &c., in

[1] *Phil. Mag.* (5), 18, 130.

which R is *any* element or group of elements, whilst A, B, C, &c., are elements belonging to the *same subgroup* of Mendleljeff's classification of the elements.

Tables accompany the paper in illustration of the above.

Out of 426 cases, in which the third of the above rules has been applied, there are but sixteen exceptions, or less than 4 per cent.

Finally, a theoretical explanation is given, which appears to account in a very simple manner for the influence of the above three circumstances, on the colour of chemical compounds.

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7. Preliminary Notes on a Blue-colouring matter found in certain wood undergoing decomposition in the forest. By Professor G. P. GIRDWOOD, *M.D., and* J. BEMROSE, *F.C.S.*

The wood, the origin of these remarks, was found in numerous pieces in travelling through the forests, but could never be found in such large pieces as to be capable of identification, the bark being absent in all cases, and the wood moss grown; several knots and fragments of roots leading to the supposition (borne out by the microscopical characters) that it is from the balsam pine (*Abies balsamea*). All specimens have been found lying on the ground; never in standing trees.

The blue-colouring matter has been observed in the junction between the heart wood and the sap wood; it seems to percolate or be absorbed by the sap wood more freely than the heart wood. It is frequently developed between the laminæ of the roots to such an extent that it becomes almost submetallic in lustre, like indigo.

In making sections of the wood, and examining these under the microscope, the wood thus far has been found to possess the pitted tissue peculiar to coniferous trees, confirming the opinion that the tree is the balsam pine. The colour is found in the material within the cell, and not in the cell wall.

We have acted on the wood with the following reagents and obtained the results mentioned:—

Water	a dirty yellow solution	leaving on evaporation a brown residue.
Alcohol	a pale coloured green solution in time	leaves a brown residue on evaporation.
Ether	dirty yellow	a dirty brown residue.
Benzol	a pale yellow solution.	
Petroleum Spirit	colourless.	
Boiling White Vaselin	no action.	
Melted Paraffin	no action.	
Carbolic Acid	dissolves out blue colour.	
Amylic Alcohol	dark greenish blue solution, being part of colouring matter.	
Chloroform	deep blue solution, dissolves out the whole of the colouring matter.	

Wood treated successively with excess of water, H_2O, alcohol, C_2H_6O, ether, $C_4H_{10}O$, amylic alcohol, $C_5H_{12}O$, and then exhausted with chloroform, $CHCl_3$.

The chloroform solution evaporated yielded the colour in scales with a slight submetallic lustre.

Blue colour treated with HNO_3 sp. gr. 1·42, dissolved, and evaporated without change.

" " " H_2SO_4 dissolved, precipitated on dilution.

" " " $H_2SO_4 \times K_2Cr_2O_7$, reduced CrO_3 to Cr_2O_3.

" " " H_3PO_4 no change.

" " " A dissolved without apparent change.

Nitrobenzol	Greenish solution.	
Ol. Cinnam.	Dissolved.	Green.
Ol. Amygd.	Dissolved.	Green.
Ol. Terebinth	Not dissolved.	
Ol. Olivæ	Not dissolved.	
KHO	decolorised to a yellowish-green solution, colour restored by H_2SO_4.	
$(NH_4)_2S$.	destroyed colour, not restored by acid.	
$(Sn\ Cl_2)$	destroyed colour, not restored by acid.	
Cl.	no change.	
Br	no change.	

Viewed through spectroscope, produces an absorption of whole spectrum, but no absorption bands. It is possible, from the colour apparently commencing formation in the sap wood, from its solubilities and insolubilities, that it may be a result of the decomposition of the balsam in the outer layer of the woody tissue. As soon as a larger supply of the wood can be obtained an inquiry into the composition and origin of these colours will be made.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—W. T. BLANFORD, LL.D., F.R.S., Sec.G.S., F.R.G.S.

THURSDAY, AUGUST 28.

The PRESIDENT delivered the following Address:—

IN commencing an address to the Geological Section of the British Association on the first occasion on which that body has met outside of the British Islands I feel much difficulty. Amongst the eminent geologists who have filled the post which you have done me the honour of calling upon me to occupy for the present year there are several who would have been able, from their knowledge of both European and American geology, to treat with authority of the many points of interest elicited by comparison of geological phenomena on opposite sides of the Atlantic Ocean. My own experience has been chiefly derived from the distant continent of Asia, and I have not that intimate acquaintance with the geology of Europe, nor that knowledge of the progress of geological research in America, which would justify my entering upon any comparison of the two continents. It has, however, occurred to me that amongst the questions of wide importance connected with the correlation of strata in distant parts of the world there is one to which some interesting contributions have been made by the work of the Geological Survey of India, and by the geologists of Australia and South Africa; and that a short time might be profitably devoted to a consideration of a few remarkable exceptions to the rule that similarity of faunas and floras in fossiliferous formations throughout the surface of the world implies identity of geological age.

It has probably occurred to other geologists here present, as it has to myself, to be engaged in examining a country the geology of which was absolutely unknown, and to feel the satisfaction that attends the first discovery of a characteristic fossil form. A clue is at once afforded to the geology of the region; one horizon at least is believed to be determined, and from this horizon it is possible to work upwards and downwards until others are found.

It is, therefore, of especial importance to those engaged in geological exploration to satisfy themselves whether the conclusion is correct that identity, or close specific similarity, amongst fossil forms, is a proof that the beds containing them are of the same geological age. It has been pointed out by some of the most careful thinkers, and especially by Forbes and Huxley, that a species requires time to spread from one area to another; that, in numerous cases, a migratory specific form must flourish in the region to which it has migrated, after it has died out in its original birthplace; and that the presence of the same species in two deposits at distant localities may rather tend to indicate that both were not formed simultaneously. Huxley, as is well known, invented the term 'homotaxis' to express the relations between such beds, and to avoid the possibly misleading expressions 'geological synchronism,' and 'contemporaneous origin.'

Despite such cautions, however, it still appears to be generally assumed by palæontologists that similarity between faunas and floras is evidence of their belonging to the same geological period; that the geological age of any formation, whether marine, fresh-water, or subaërial, can be determined by a comparison of its organic remains with those of other deposits, no matter how distant, of which the position in the geological sequence is ascertained: in short, that homotaxis of marine, fresh-water, and terrestrial forms implies geological synchronism.

That, as a general rule, homotaxis affords evidence that beds exhibiting it belong approximately to the same geological period appears supported by a large amount of evidence. But there are some startling exceptions. I propose to notice a few typical instances, several of them Indian, in which the system of determining the age of various formations by the fauna or flora has led to contradictory results, before attempting to show wherein the source of the error appears to lie. Nothing would be gained and much time would be lost by entering upon the details of all the cases known, even if I were able to give authentic particulars, which is doubtful. It will be sufficient to cite some characteristic examples, concerning the details of which satisfactory evidence is forthcoming.

Pikermi Beds.—There are but few fossiliferous deposits on the face of the earth that have attracted more attention than the Pikermi beds of Greece. In one of the most classical and famous sites of the world, a few miles east of Athens, just where

The mountains look on Marathon
And Marathon looks on the sea,

some red, silty beds occur, abounding in vertebrate remains. Some of the bones were described by Wagner and others, but for a complete account of the fauna we are indebted to Professor Albert Gaudry, who has himself collected by far the greater portion of the remains hitherto procured. The following is a list of the genera determined; it is unnecessary to give the specific names:—

MAMMALIA.

PRIMATES.—*Mesopithecus*, 1 sp.
CARNIVORA.—*Simocyon*, 1; *Mustela*, 1; *Promephitis*, 1; *Ictitherium*, 3; *Hyænarctus*, 1; *Hyæna*, 1; *Hyænictis*, 1; *Felis*, 4; *Machærodus*, 1.
PROBOSCIDEA.—*Mastodon*, 2; *Dinotherium*, 1.
UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Acerotherium*, 1; *Leptodon*, 1; *Hipparion*, 1; *Sus*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Orasius*, 1; *Palæotragus*, 1; *Protragelaphus*, 1; *Palæoryx*, 2; *Tragocerus*, 2; *Palæoreas*, 1; *Antidorcas* (?), 1; *Gazella*, 1; *Antilope*, 3; *Dremotherium*, 2; *Cervus*, 1.
RODENTIA.—*Mus* (*Acomys*), 1; *Hystrix*, 1.
EDENTATA.—*Ancylotherium*, 1.

AVES.

Phasianus, 1; *Gallus*, 1; *Gen. gallinac. indet.*, 1; *Grus*, 1; *Gen. ciconidar. indet.*, 1.

REPTILIA.

Testudo, 1; *Varanus*, 1.

Of mammalia alone there are known from this deposit 33 genera, of which 22 are extinct, and 47 species.

Now, this fauna is almost invariably in European works quoted as Miocene. Of the species found no less than 14—*Simocyon diaphorus*, *Ictitherium robustum*, *I. hipparionum*, *Hyæna eximia*, *Hyænictis græca*, *Machærodus cultridens*, *Mastodon turicensis*, *Dinotherium giganteum*, *Rhinoceros schleiermacheri*, *Hipparion gracile*, *Sus erymanthius*, *Helladotherium duvernoyi*, *Tragocerus amaltheus*, and *Gazella brevicornis*—are met with in other European deposits assigned to the Miocene period. It is true that one of these deposits at least—that of Eppelsheim—had been shown on stratigraphical grounds to be much more probably Pliocene than Miocene, and the position of other deposits has been determined by the kind of argument which, as I shall show, has proved misleading in the case of Pikermi itself. Nevertheless so general is the consensus of opinion amongst palæontologists, that the beds with *Hipparion* at Pikermi and elsewhere are quoted as especially included in the Miocene system by the French Committee of the International

Geological Congress. Amongst English writers the Miocene age of the Pikermi beds appears generally admitted, as by Mr. Wallace,[1] Professor Boyd Dawkins,[2] Mr. E. T. Newton,[3] and many others. Professor Gaudry himself is much more cautious; he classes the fauna as intermediate between Pliocene and Miocene, and only relegates it to Upper Miocene because that is the position assigned by other palæontologists to beds containing remains of *Hipparion*. However, in his subsequent works Professor Gaudry has classed the Pikermi fauna as Miocene.

Now, the lowest of the beds with the vertebrate fauna at Pikermi were by Professor Gaudry himself found to be interstratified with a band of grey conglomerate containing four characteristic *marine* Pliocene mollusca—*Pecten benedictus*, Lam.; *Spondylus gœderopus*, L.; *Ostrea lamellosa*, Brocchi; and *O. undata*, Lam. It should be remembered that the Pliocene fauna of the Mediterranean area is the richest and most typical in Europe, and is as well known as any geological fauna in the world. It should also be remembered that the Pliocene beds are well developed in Greece at other localities besides Pikermi. Professor Gaudry especially points out that the vertebrate remains, supposed to be those of Miocene animals, are deposited in a stratum overlying a marine bed of undoubted Pliocene age, and he proposes the following hypothesis to account for the presence of Miocene fossils in a Pliocene stratum. The remains found at Pikermi are, he thinks, those of animals that inhabited the extensive plains which in Miocene times extended over a considerable proportion of the area now occupied by the Eastern Mediterranean, and which united Greece to Asia; the plains were broken up by the dislocations that took place at the close of the Miocene period, and the animals escaped to the mountains, where they died for want of space and of food. Their bones were subsequently washed down by the streams from the hills and buried in the Pliocene deposits of Pikermi.

Professor Gaudry evidently has no very profound faith in this hypothesis, and it is unnecessary to refute it at length. One fact is sufficient to show that it is untenable. However sudden may have been the cataclysm that is supposed to have broken up the Miocene plains of Attica, a very long period, measured in years, must have elapsed before the Pliocene marine fauna could have established itself. Now, the bones of mammals exposed on the surface decay rapidly; the teeth break up, the bones become brittle. It is doubtful if bones that had been exposed for only five or six years would be washed down by a stream without being broken into fragments; the teeth especially would split to pieces. The condition of the Pikermi fossils proves, I think, that they must have been buried very soon after the animals died, that they were not exposed on the surface for any length of time, and that they could not have been washed out of an earlier formation, and it appears to me incredible that the Pikermi mammals were not contemporary with the Pliocene mollusca that occur in the same beds. In short, I cannot but conclude that the Pikermi mammals were Pliocene and not Miocene.

This view is entirely in accordance with the opinions of Theodor Fuchs.[4] He has given a good account of the geology of various places in Greece, and amongst others of Pikermi. He found, again, the conglomerate with Pliocene marine mollusca interstratified with the basal portion of the mammaliferous beds, and he concludes[5] that not only is it clear that these mammaliferous beds are of Pliocene age, but that a comparison of their geological position with that of the marine strata of the Piræus proves that the Pikermi beds occupy a very high position in the Pliocene, and are probably the highest portion of the system as developed in the neighbourhood.

Fuchs also shows that the principal Pliocene mammaliferous beds are of later date than the typical Pliocene (Subapennine) beds of Italy, and that some mammalia found associated with the latter comprise forms identical with those of the Pikermi

[1] *Geographical Distribution of Animals*, i. p. 115.
[2] *Q. J. G. S.* 1880, p. 389.
[3] *Q. J. G. S.* 1884, pp. 284, 287, &c.
[4] *Denkschr. K. Acad. Wiss. Wien*, 1877, xxxvii. 2e Abth.
[5] *L. c.* p. 30.

beds. In subsequent papers on the age of the beds containing *Hipparion* the same writer shows reasons for classing these strata in Italy, France (Vaucluse), and Germany as intermediate between Miocene and Pliocene. This leaves the difficulty unsolved, for he had shown the Pikermi beds to be high in the Pliocene system. They rest unconformably upon certain fresh-water limestones, clays, &c., containing plants and mollusca, and classed by Gaudry as Miocene, but by Fuchs as Pliocene. Thus by both writers the mammaliferous beds of Pikermi are referred to a considerably later geological horizon than those containing identical species in other parts of Europe.

It would require too much time to enter into the still more difficult question of the various plant-bearing beds in different parts of Europe and in Greenland containing a flora classed by Heer and others as Miocene. Gardner has given reasons for considering the Greenland beds Eocene; Fuchs, as just stated, is of opinion that the Greek beds are Pliocene. One point should be noted, that the more northern flora is considered older than the more southern, and it will be remarked that the same observation applies to the supposed Upper Miocene fauna of France and Germany and the Pikermi fauna of Greece.

Siwalik.—The next instance which I shall describe is another of the most important fossil mammalian faunas of the Old World, that found in the Upper Tertiary beds that fringe the Himalayas on the south. The name applied to this fauna is taken from one of the localities in which it was first found, the Siwalik (correctly, I believe, Shib-wála) hills, between the Deyra Dun and the plains north by east of Delhi. Bones of Siwalik mammalia are found, however, throughout a considerable area of the Northern Punjab.

The Siwalik fauna has been worked out, chiefly by Falconer and Lydekker, the last-named being still engaged in describing the species. The following is a list of the genera found in the true Siwalik beds:—[1]

MAMMALIA.

PRIMATES.—*Palæopithecus*, 1 sp.; *Macacus*, 2; *Semnopithecus*, 1; *Cynocephalus*, 2.

CARNIVORA.—*Mustela*, 1; *Mellivora*, 2; *Mellivorodon*, 1; *Lutra*, 3; *Hyænodon*, 1; *Ursus*, 1; *Hyænarctus*, 3; *Canis*, 2; *Viverra*, 2; *Hyæna*, 4; *Hyænictis*, 1; *Lepthyæna*, 1; *Æluropsis*, 1; *Ælurogale*, 1; *Felis*, 5; *Machærodus*, 2.

PROBOSCIDEA.—*Elephas*, 6 (*Euelephas*, 1; *Loxodon*, 1; *Stegodon*, 4); *Mastodon*, 5.

UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Equus*, 1; *Hipparion*, 2; *Hippopotamus*, 1; *Tetraconodon*, 1; *Sus*, 5; *Hippohyus*, 1; *Sanitherium*, 1; *Merycopotamus*, 1; *Cervus*, 3; *Dorcatherium*, 2; *Tragulus*, 1; *Moschus*, 1; *Propalæomeryx*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Hydaspitherium*, 2; *Sivatherium*, 1; *Alcelaphus*, 1; *Gazella*, 1; *Antilope*, 2; *Oreas* (?), 1; *Palæoryx* (?), 1; *Portax*, 1; *Hemibos*, 3; *Leptobos*, 1; *Bubalus*, 2; *Bison*, 1; *Bos*, 3; *Bucapra*, 1; *Capra*, 2; *Ovis*, 1; *Camelus*, 1.

RODENTIA.—*Mus* (*Nesokia*), 1; *Rhizomys*, 1; *Hystrix*, 1; *Lepus*, 1.

AVES.

Graculus, 1; *Pelecanus*, 2; *Leptoptila*, 1; *Gen. non. det. ciconid.*, 1; *Mergus*, 1; *Struthio*, 1; *Dromæus*, 1; *Gen. non. det. struth.*, 1.

REPTILIA.

CROCODILIA.—*Crocodilus*, 1; *Gharialis*, 3.

LACERTILIA.—*Varanus*, 1.

CHELONIA.—*Colossochelys*, 1; *Testudo*, 1; *Bellia*, 2; *Damonia*, 1; *Emys*, 1; *Cautleya*, 1; *Pangshura*, 1; *Emyda*, 1; *Trionyx*, 1.

[1] Lydekker, *J. A. S. B.* 1880, pt. 2, p. 34; *Palæontologia Indica*, ser. x. vols. i. ii. iii.; *Records Geol. Surv. India*, 1883, p. 81. I am indebted to Mr. Lydekker for some unpublished additions, and for aid in compiling both the Siwalik and Pikermi lists.

PISCES.

Bagarius, 1.

Now, until within the last few years, this fauna was classed as Miocene by European palæontologists as unhesitatingly as the Pikermi fauna still is, and in the majority of European geological works, despite the unanimous opinion of all the geologists who are acquainted with the sub-Himalayan beds, the Siwalik fauna is still called Miocene. The geologists of the Indian Survey, however, class the fossiliferous Siwaliks as Pliocene, on both geological and biological grounds. With regard to the latter not only does the fauna comprise a large number of existing genera of mammals, such as *Macacus*, *Semnopithecus*, *Ursus*, *Elephas* (*Euelephas*), *Equus*, *Hippopotamus*, *Camelopardalis*, *Bos*, *Hystrix*, *Mus*, and especially *Mellivora*, *Meles*, *Capra*, *Ovis*, *Camelus*, and *Rhizomys*, but three out of six or seven clearly determined species of reptiles, viz.—*Crocodilus palustris*, *Gharialis gangeticus*, and *Pangshura tectum*—are living forms now inhabiting Northern India, whilst all the known land and fresh-water mollusca, with one possible exception, are recent species.

These data, however, although very important and very cogent, belong to a class of facts that have led, I believe, in other cases to erroneous conclusions. The geological evidence is far more satisfactory, and it is not liable to the same objection.

The whole Siwalik fauna, as given above, has been obtained from the upper beds of a great sequence or system. Beneath the fossiliferous strata at the base of the North-West Himalaya there is an immense thickness, amounting in places to many thousands of feet, of sandstones, clays, and other beds, from none of which recognisable fossils have been procured. The first beds of known age that are met with below the mammaliferous Siwaliks are marine rocks belonging to the Eocene system.

But as we pass from the Himalayas to the south-west, along the western frontier of India in the Punjab, and onwards to the south in Sind, the same Siwalik system can be traced almost without interruption, and in the last-named country the lower unfossiliferous strata become intercalated with fossiliferous beds. In Sind the upper Siwaliks no longer yield any vertebrate remains that can be identified, but far below the horizon of the Siwalik fauna a few bones have been found, and the following mammals have been identified :—[1]

CARNIVORA.—*Amphicyon palæindicus*.

PROBOSCIDEA.—*Mastodon latidens*, *M. perimensis*, *M. falconeri*, *M. pandionis*, *M. angustidens*, *Dinotherium indicum*, *D. sindiense*, *D. pentepotamiæ*.

UNGULATA.—*Rhinoceros sivalensis*, *var. intermedius*, *Acerotherium perimense*, *A. blanfordi*, *Sus hysudricus*, *Hyotherium sindiense*, *Anthracotherium silistrense*, *A. hyopotamoides*, *Hyopotamus palæindicus*, *H. giganteus*, *Hemimeryx blanfordi*, *Sivameryx sindiensis*, *Agriochœrus sp.*, *Dorcatherium majus*, *D. minus*.

EDENTATA.—*Manis* (?) *sindiensis*.

Although about one-third of the species above named have been found also in the upper Siwalik beds of the Punjab, it is unnecessary to point out in detail why the lower Siwalik fauna is clearly by far the older of the two. The absence of such living genera as *Elephas*, *Bos*, *Equus*, &c., and the presence of so many typically Middle Tertiary forms, such as *Dinotherium*, *Anthracotherium*, and *Hyopotamus*, shows a great change. The mollusca tell the same tale. All the forms known from the upper Siwaliks, with one exception, are recent species of land and fresh-water shells now living in the area. Of seven fresh-water mollusca[2] found associated with the lower Siwaliks none appears to be identical with any living species, and only two are allied, one closely, the other more remotely, to forms now met with in Burma 30° of longitude further east.

[1] *Pal. Ind.* ser. x.; *Rec. Geol. Surv. Ind.* 1883. pp. 82, &c.
[2] *Mem. Geol. Surv. Ind.* vol. xx. pt. 2, p. 129.

Before proceeding with the argument it is as well to call attention to the very important fact just mentioned. It has been asserted over and over again that species of *mammalia* are peculiarly short-lived, far more so than those of *mollusca*. In this case, so far as the evidence extends at present, one-third of the species of *mammalia* survived the changes that took place, whereas not a single mollusk is found both in the upper and lower Siwaliks. It should be remembered that the recent molluscan river fauna of this part of India is very poor in species, and that we probably know a considerable proportion of that existing in Siwalik times.

The geological age of the lower Siwalik beds of Sind is shown by their passing downwards into marine fossiliferous beds, known as the Gáj group, of Miocene age, the following being the section of Tertiary strata exposed in the hills west of the Indus:—

		Ft.	
SIWALIK OR MANCHAR	Upper	5,000 unfossiliferous	Pliocene
	Lower	3,000 to 5,000 fossiliferous	Upper Miocene or Lower Pliocene
GÁJ		1,000 to 1,500 fossiliferous	Miocene
NARI	Upper	4,000 to 6,000 unfossiliferous.	Lower Miocene
	Lower	100 to 1,500 fossiliferous	Oligocene
KHIRTHAR	Upper	500 to 3,000 fossiliferous	Eocene
	Lower	6,000 fossiliferous	

Clearly the lower Siwaliks of Sind cannot be older than Upper Miocene; therefore the Upper Siwaliks, which are shown by both biological and geological evidence to be of much later date, must be Pliocene.

Gondwána System of India.—In the peninsula of India there is a remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus valley there is, with one exception (some cretaceous rocks in the Nerbudda valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of Gondwána System has been applied. The uppermost beds of this system, in Cutch to the westward, and near the mouth of the Godávari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.

The Gondwána system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from Middle Carboniferous to Middle Jurassic. The Gondwána beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

The subdivisions of the Gondwána system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the subdivisions of most importance on account of their fauna and flora, or of their geological relations:—

Upper Gondwána	Cutch and Jabalpur	
	Kota-Maleri	
	Rájmahál	
Lower Gondwána	Panchet	
	Damuda	Ráníganj and Kámthi
		Barákar
	Karharbári	
	Tálchir	

The upper Gondwánas, where best developed, attain a thickness of 11,000 feet, and the lower of 13,000 ft.

The Tálchir and Barákar subdivisions are far more generally present than any of the others.

Tálchir.—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Tálchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt.

Karharbári.—The Karharbári beds are found in but few localities. They contain some coal-seams, and the following plants have been met with:—[1]

CONIFERÆ.—*Euryphyllum*, 1 sp.; *Voltzia*, 1; *Albertia*, 1; *Samaropsis*, 1.
CYCADEACEÆ.—*Glossozamites*, 1; *Noeggerathiopsis*, 1.
FILICES.—*Neuropteris*, 1; *Glossopteris*, 4; *Gangamopteris*, 4; *Sagenopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 2; *Vertebraria*, 1.

The most abundant form is a *Gangamopteris*. The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to Lower Triassic forms. The species of *Gangamopteris, Glossopteris, Vertebraria*, and *Noeggerathiopsis* are allied to forms found in Australian strata.

Damuda.—The Damuda series consists of sandstones and shales with coal-beds; the floras of the different subdivisions present but few differences, and the following is the list of plants found:—[2]

CONIFERÆ.—*Rhipidopsis*, 1 sp.; *Voltzia*, 1; *Samaropsis*, 1; *Cyclopitys*, 1.
CYCADEACEÆ.—*Pterophyllum*, 2; *Anomozamites*, 1; *Noeggerathiopsis*, 3.
FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 4; *Pecopteris*, 1; *Merianopteris*, 1; *Macrotæniopteris*, 2; *Palæovittaria*, 1; *Angiopteridium*, 2; *Glossopteris*, 19; *Gangamopteris*, 7; *Belemnopteris*, 1; *Anthrophyopsis*, 1; *Dictyopteridium*, 1; *Sagenopteris*, 4; *Actinopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 1; *Phyllotheca*, 3; *Trizygia*, 1; *Vertebraria*, 1.

The only remains of animals hitherto recorded are an *Estheria* and two Labyrinthodonts, *Brachyops laticeps* and an undescribed form formerly referred to *Archegosaurus*. The only European genus allied to *Brachyops* is of Oolitic age.

The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria*. With the exception of *Noeggerathiopsis* all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation.

For many years European palæontologists generally classed this flora as Jurassic.[3] This was the view accepted by De Zigno and Schimper, and, though with more hesitation, by Bunbury. The species of *Phyllotheca, Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures (to which I shall refer presently) more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of

[1] Feistmantel, *Palæontologia Indica*, ser. xii. vol. iii.
[2] *Pal. Ind.* ser. ii. xi. xii. vol. iii.
[3] De Zigno, *Flora Fossilis Form. Ool.* pp. 50, 53; Schimper, *Traité de Paléontologie Végétale*, i. p. 645; Bunbury, *Q. J. G. S.* 1861, xvii. p. 350.

the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the middle or lower Jurassics more than any other.

One form, it is true, the *Schizoneura*, is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer,[1] if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

Panchet.—The uppermost series of the lower Gondwánas consists chiefly of sandstone, and fossils are rare. The most interesting are remains of *Reptilia* and *Amphibia*. The following is a list of the fossil animals and plants corrected to the present time:—

ANIMALS.

REPTILIA.

DINOSAURIA.—*Ancistrodon*, 1 sp.
DICYNODONTIA.—*Dicynodon* (*Ptychognathus*), 2.

AMPHIBIA.

LABYRINTHODONTIA.—*Gonioglyptus*, 2; *Glyptognathus*, 1; *Pachygonia*, 1.

CRUSTACEA.

Estheria, 1.

PLANTS.

CONIFERÆ.—*Samaropsis*, 1.
FILICES.—*Pecopteris*, 1; *Cyclopteris*, 1; *Thinnfeldia*, 1; *Oleandridium*, 1; *Glossopteris*, 3.
EQUISETACEÆ.—*Schizoneura*, 1.

The *Schizoneura* and the three species of *Glossopteris* are considered the same as Damuda forms. But with them are found two European Rhætic species, *Pecopteris concinna* and *Cyclopteris pachyrachis*. The *Oleandridium* is also closely allied to a European Rhætic form, and may be identical. The flora may thus be classed as typically Rhætic.

All the genera of *Labyrinthodonts* named are peculiar; their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India and South Africa, but some forms believed to be nearly allied have been described from the Ural mountains.[2] The Ural fossils were obtained from rocks now referred to the Permian.[3]

Upper Gondwánas.—The different series of the lower Gondwánas are found in the same area, resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwána groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmahals are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

Rájmahál.—The comparatively rich flora of the lowest upper Gondwána series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type. The following are the genera[4] of plants found:—

[1] Feistmantel, *Pal. Ind.* ser. xii. vol. iii. pp. 57, 129, &c.
[2] Huxley, *Q. J. G. S.* xxvi. p. 48.
[3] Twelvetrees, *Q. J. G. S.* xxxviii. p. 500.
[4] *Pal. Ind.* ser. ii; Feistmantel, *Rec. G. S. I.* ix. p. 39.

CONIFERÆ.—*Palissya*, 2 sp.; *Cunninghamites*, 1; *Chirolepis*, 2; *Araucarites*, 1; *Echinostrobus*, 1.
CYCADEACEÆ.—*Pterophyllum*, 9; *Ptilophyllum*, 1; *Otozamites*, 3; *Zamites*, 1; *Dictyozamites*, 1; *Cycadites*, 2; *Williamsonia*, 2; *Cycadinocarpus*, 1.
FILICES.—*Eremopteris*, 2; *Davallioides*, 1; *Dicksonia*, 1; *Hymenophyllites*, 1; *Cylopteris*, 1; *Thinnfeldia*, 1; *Gleichenia*, 1; *Alethopteris*, 1; *Asplenites*, 1; *Pecopteris*, 1; *Macrotæniopteris*, 4; *Angiopteridium*, 3; *Danæopsis*, 1; *Rhizomopteris*, 1.
EQUISETACEÆ.—*Equisetum*, 1.

The marked change from the lower Gondwána floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the lower Gondwánas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the lower Gondwána beds to European Mesozoic floras.

Of the Rájmahál plants[1] about fifteen are allied to Rhætic European forms, three to Liassic or Lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore as a whole on purely palæontological grounds be classed as Rhætic.

Kota-Maleri.—The deposits belonging to this series are found in the Godávari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of Maleri. That the two are closely connected is generally admitted.

From the Maleri beds the following remains have been recorded:—

ANIMALS.

REPTILIA.—*Hyperodapedon*, 1; *Parasuchus*, 1.
PISCES.—*Ceratodus*, 3.

PLANTS.

CONIFERÆ.—*Palissya*, 2; *Chirolepis*, 1; *Araucarites*, 1.
CYCADEACEÆ.—*Ptilophyllum*, 1; *Cycadites*, 1.
FILICES.—*Angiopteridium*, 1.

From the Kota fresh-water limestone 9 species of ganoid fish—viz. 5 of *Lepidotus*, 3 of *Tetragonolepis*, and 1 of *Dapedius*—have been described. An *Estheria*, a *Candona*, and some insects have also been found. The fish[2] are Liassic forms.

The reptilia of the Maleri beds are, on the other hand, Triassic,[3] and closely allied to Keuper forms. *Ceratodus* is chiefly Triassic (Keuper and Rhætic). The plants show relations with both the Rájmahál and Jabalpur floras, and, as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distant regions, the Kota-Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

Cutch and Jabalpur.—Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwána beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of

[1] Feistmantel, *Pal. Ind.* ser. ii. pp. 143, 187; *Manual Geol. Ind.* p. 145.
[2] *Pal. Ind.* ser. iv. pt. 2.
[3] *Q. J. G. S.* 1869, pp. 138, 152, &c.; 1875, p. 427; *Pal. Ind.* ser. iv. pt. 2; *Man. Geol. Ind.* p. 151.

uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant-remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin.

The following is a list of the Jabalpur plants:—[1]

CONIFERÆ.—*Palissya*, 2; *Araucarites*, 1; *Echinostrobus*, 2; *Brachyphyllum*, 1; *Taxites*, 1; *Gingko*, 1; *Phœnicopsis*, 1; *Czekanowskia*, 1.
CYCADEACEÆ.—*Pterophyllum*, 1; *Ptilophyllum*, 2; *Podozamites*, 3; *Otozamites*, 4; *Williamsonia*, 1; *Cycadites*, 1.
FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 3; *Macrotæniopteris*, 1; *Glossopteris*, 1; *Sagenopteris*, 1.

Of these thirty species nine are regarded either as identical with forms found in the Middle Jurassic (Lower Oolitic) of England or as closely allied.

The Cutch plants belong to the following genera:—[2]

CONIFERÆ.—*Palissya*, 3 sp.; *Pachyphyllum*, 1; *Echinostrobus*, 1; *Araucarites*, 1.
CYCADEACEÆ.—*Ptilophyllum*, 3; *Otozamites*, 3; *Cycadites*, 1; *Williamsonia*, 1; *Cycadolepis*, 1.
FILICES.—*Oleandridium*, 1; *Tæniopteris*, 1; *Alethopteris*, 1; *Pecopteris*, 1; *Pachypteris*, 2; *Actinopteris*, 1.

Of the twenty-two species enumerated four are identified with specific forms found in the Middle Jurassic of Yorkshire, and seven others are closely allied. The Cutch and Jabalpur beds, in short, are intimately related with European fossil floras.

One interesting fact should be mentioned. The Cutch flora occurs in the upper part of the Umia beds, the lower beds of which contain *cephalopoda* of Portlandian and Tithonian forms. In a lower subdivision of the Cutch Jurassic rocks, the Katrol group, shown by numerous Ammonites to be allied to Kimmeridge and upper Oxford beds of Western Europe, four species of plants have been found, of which three are met with in the Umia beds, and the fourth, an English oolitic form, in the Jabalpur series. This evidence seems in favour of the view that the flora underwent change more slowly than the marine fauna.

It will be as well, before leaving the subject of the Gondwána groups, to show in a tabular form the geological age assigned to the flora and fauna of each separately, on the evidence afforded by comparison with the plants and animals known from European formations.

		Plants	Animals
Upper Gondwána	Cutch	Middle Jurassic	Uppermost Jurassic ? Neocomian (marine)
	Jabalpur	Middle Jurassic	—
	Kota	—	Lower Jurassic (Liassic)
	Maleri	Middle or Lower Jurassic	Triassic
	Rájmahál	Rhætic	—
Lower Gondwána	Panchet	Rhætic	Triassic or Permian
	Damuda	Middle Jurassic	Middle Jurassic ?
	Karharbári, Talchir	Lower Triassic	—

Flora of Tonquin.—Quite recently M. Zeiller has described a series of plants

[1] *Pal. Ind.* ser. xi. pt. 2. [2] *Pal. Ind.* ser. xi. pt. 1.

from some coal-bearing beds in Tonquin.[1] This flora is very extraordinary in every respect. It consists of 22 species, and contains only two peculiar forms; ten, or nearly one-half, are European species found in the lower Lias or Rhætic; whilst of the remaining ten, five are Damuda forms—*Noeggerathiopsis hislopi*, *Macrotæniopteris feddeni*, *Palæovittaria kurzi*, *Glossopteris browniana*, and *Phyllotheca indica*, one species being common to the Newcastle beds and Carboniferous flora of Australia, and two others closely allied to the forms there occurring. The other five are said to be Rájmahál forms, four *Tæniopteris* or *Angiopteridium* and an *Otozamites*. M. Zeiller unhesitatingly classes the Tonquin beds as Rhætic. It is most singular that these coal-beds, although more distant from Europe by 18° of longitude than either the Damuda or Rájmahál beds of India, contain a larger proportion of European fossil species than any known Indian plant-beds; whilst the association in the same strata of upper and lower Gondwána forms, if well ascertained, shows how hopeless is the attempt to classify these deposits by plant evidence alone.

Australian Coal-Measures and Associated Beds.—In the notice of the lower Gondwána floras of India it was observed that there was a great resemblance between some of them and those found in certain beds of Australia. These latter present even a more remarkable instance of homotaxial perversity than do the Indian rocks. The Australian plant-bearing beds are found in Eastern and Southern Australia, Queensland, and Tasmania. For a knowledge of the geology of the country we are chiefly indebted to the writings of the late Mr. Clarke,[2] whilst the flora has been worked out by McCoy, Dana, Carruthers, and Feistmantel, the last having recently published a much more complete account than was previously available.[3]

The following are the fresh-water or subaërial beds of Australia, according to the latest classification:—

6. Clarence River beds, New South Wales (Mesozoic carbonaceous of Queensland, Victoria, and Tasmania.)
5. Wianamatta beds, N.S. Wales.
4. Hawkesbury beds, N.S. Wales (Bacchus Marsh sandstones, Victoria).
3. Newcastle beds, N.S. Wales.
2. Lower Coal-Measures with marine layers interstratified, N.S. Wales.
1. Lower Carboniferous beds, N.S. Wales.

To a still lower horizon probably belong some beds in Queensland, containing *Lepidodendron nothum* and *Cyclostigma*. They are considered Devonian by Carruthers, and there are some ancient plant-beds in Victoria that may be of the same period.

1. *Lower Carboniferous Beds.*—These underlie the beds with a Carboniferous marine fauna. The localities given are Smith's Creek, near Stroud, Port Stephens, and Arowa. The following plants are enumerated:—

LYCOPODIACEÆ.—*Cyclostigma*, 1 sp.; *Lepidodendron*, 2 or 3; *Knorria*, 1.
FILICES.—*Rhacopteris*, 4; *Archæopteris*, 2 (?); *Glossopteris*, 1.
EQUISETACEÆ.—*Calamites*, 2; *Sphenophyllum*, 1.

This flora contains several species identical with those in the Lower Carboniferous (Bernician) of Europe, corresponding to the Mountain Limestone. The agreement both in homotaxis and position is the more remarkable because of the startling contrast in the next stage. The only peculiarity is the presence of a *Glossopteris*. This comes from a different locality—Arowa—from most of the fossils, and the species is identical with one found in a much higher series. Under these circumstances it is impossible to feel satisfied that the specimen was really from this horizon. The evidence is not so clear as is desirable.

[1] *Bull. Soc. Géol.* ser. iii. vol. xi. p. 456.
[2] *Q. J. G. S.* 1861, p. 354, and *Remarks on the Sedimentary Formations of New South Wales*, 1878, besides numerous other works.
[3] *Palæontographica.—Pal u. mes. flora des östl. Australien* 1878-79.

2. *Lower Coal-Measures with Marine Beds.*—The following plants are recorded:—

CYCADEACEÆ.—*Noeggerathiopsis,* 1 sp.
FILICES.—*Glossopteris,* 4.
EQUISETACEÆ.—*Annularia,* 1; *Phyllotheca,* 1.

In the marine beds, which are interstratified, are found Lower Carboniferous (Mountain Limestone) marine fossils in abundance, such as *Orthoceras, Spirifer, Fenestella, Conularia,* &c. The plants belong to forms declared to be typically Jurassic by palæontologists. As the interstratification of the marine and plant-bearing beds has been repeatedly questioned by palæontologists, it is necessary to point out that the geological evidence brought forward by Mr. Clarke is of the clearest and most convincing character, that this evidence has been confirmed by all the geologists who are acquainted with the country, and has only been doubted by those who have never been near the place.

3. *Newcastle Beds.*—By all previous observers in the field these had been united to the preceding and the flora declared to be the same. Dr. Feistmantel has, however, pointed out important differences. Unfortunately, as he has been unable to examine the beds, it still remains uncertain whether the distinction, which has been overlooked by all the field geologists, is quite so great as it appears from the lists of fossils given. The following is the flora:—

CONIFERÆ.—*Brachyphyllum,* 1 sp.
CYCADEACEÆ.—*Zeugophyllites,* 1; *Noeggerathiopsis,* 3.
FILICES.—*Sphenopteris,* 4; *Glossopteris,* 8; *Gangamopteris,* 2; *Caulopteris* (?), 1.
EQUISETACEÆ.—*Phyllotheca,* 1; *Vertebraria,* 1.

The only animal known from the beds is a heterocercal ganoid fish, *Urosthenes australis,* a form with Upper Palæozoic affinities.

It will be noticed that the difference from the flora of the underlying beds associated with marine strata is chiefly specific, and by no means indicative of great difference of age, though the only species considered as common to the two by Dr. Feistmantel is *Glossopteris browniana,* found also in the Damuda series of India, in Tonquin, and in South Africa.

The plant fossils of the Newcastle beds and of the underlying series with marine fossils are those which exhibit so remarkable a similarity to the flora of the Indian lower Gondwánas, and especially to the Damudas. The same genera of plants, especially *Noeggerathiopsis, Glossopteris, Phyllotheca, Vertebraria,* prevail in both. But the lower beds of Australia, to judge by the marine fauna, are of Lower Carboniferous age, and it is impossible to suppose that the Newcastle beds are of very much later date. They are said to be conformable to the lower beds with marine fossils, and even to pass into them, and they should probably, if the lower beds are Lower Carboniferous, be classed as Middle or Upper Carboniferous. Thus if the evidence of marine faunas be accepted as decisive, the Damuda beds of India are homotaxially related to Jurassic strata in Europe and to Carboniferous in Australia.

But the Australian Newcastle flora has been quite as positively classed as Jurassic by European palæo-botanists as that of the Damudas. It would be easy to quote a long list of authorities—McCoy, De Zigno, Saporta, Schimper, Carruthers, and others—in support of the Jurassic age of the Australian beds. For years the testimony of Australian geologists was rejected, and doubts thrown upon their observations. There is, so far as I know, no case in the whole history of palæontology in which the conflict of palæontological evidence has been so remarkably displayed.

4. *Hawkesbury Beds.*—The fauna and flora are poor. Only two fish, *Clithrolepis granulatus* and *Myriolepis clarkei,* and one plant, *Thinnfeldia odontopteroides,* are known, and of the three forms two recur in the Wianamatta beds.

An important character of the Hawkesbury beds, to which further reference will be made presently, is the occurrence of transported boulders,[1] apparently brought thither by the action of ice.

Similar boulders have been observed in certain sandstones in Victoria known as the Bacchus Marsh beds. From these beds two species of *Gangamopteris* have been described by McCoy. *Gangamopteris*, it should be recollected, is a genus of ferns closely allied to *Glossopteris* and abundant in the Damuda and still more so in the Karharbári beds of the lower Gondwánas in India.

5. *Wianamatta Beds.*—These are the highest portion of the whole system in New South Wales. They contain the following organic remains:—

ANIMALS.

PISCES.—*Palæoniscus antipodeus, Clithrolepis granulatus.*

PLANTS.

FILICES.—*Thinnfeldia* (*Pecopteris*) *odontopteroides, Odontopteris microphylla, Pecopteris tenuifolia, Tæniopteris wianamattæ.*
EQUISETACEÆ.—*Phyllotheca hookeri.*

The fish from the Wianamatta, Hawkesbury, and Newcastle beds, four in number, were considered as a whole by Sir P. Egerton to be most nearly allied to the Permian fauna of Europe.

The Wianamatta plants, like those in the lower beds, are classed as Jurassic.

6. *Higher Mesozoic Beds.*—These, which do not appear to have been traced into connection with the Wianamatta and Hawkesbury beds, occur in widely separated localities, from Queensland to Tasmania. The correlation of these widely scattered deposits, and the assignment of them collectively to a position above that of the Wianamatta beds, appear solely founded upon the fossil flora, and it would be satisfactory to have in addition some geological evidence or some palæontological data derived from marine fossils. The Queensland flora is said to occur in beds overlying marine strata of Middle Jurassic age.

The following plants are recorded from these higher beds:—

CYCADEACEÆ.—*Zamites* (*Podozamites*), 3 sp.; *Otozamites*, 1.
FILICES.—*Sphenopteris*, 1; *Thinnfeldia*, 1; *Cyclopteris*, 1; *Alethopteris*, 1; *Tæniopteris*, 1; *Sagenopteris*, 1.
EQUISETACEÆ.—*Phyllotheca*, 1.

Tabulating, as in the case of the Indian Gondwána system, the age of the different Australian subdivisions as determined by their fossil plants and animals on purely palæontological grounds, we have the following result:—

	Plants	Animals
6. Higher Mesozoic beds	Jurassic	Jurassic (marine)
5. Wianamatta beds	Jurassic	Permian
4. Hawkesbury beds	Jurassic	Permian
3. Newcastle beds	Jurassic	Permian
2. Lower Coal-Measures	Jurassic	Lower Carboniferous (marine)
1. Lower Carboniferous beds	Lower Carboniferous	—

South Africa.—In connection with the later Palæozoic and older Mesozoic rocks of Australia and India it is of importance to mention briefly the corresponding fresh-water or subaërial formations of Southern Africa, although in that country there are not such marked discrepancies in the palæontological evidence,

[1] Wilkinson, quoted by Feistmantel, *Rec. Geol. Surv. Ind.* 1880, p. 257.

perhaps because the relations of the beds with remains of animals to the plant-bearing strata are less clearly known. It will be sufficient to notice some of the most prominent peculiarities of these formations here, as I hope that a fuller account will be given to the section by Professor Rupert Jones, who has made an especial study of South African geology.

In the interior of South Africa, occupying an immense tract in the northern parts of Cape Colony, the Orange Free State, Transvaal, and the deserts to the westward of the last two, there is a great system of sandstones and shales with some coal-beds, generally known as the 'Karoo formation.' The sequence of subdivisions is the following:—[1]

Stormberg	beds,	about	1,800	feet	thick
Beaufort	„	„	1,700	„	„
Koonap	„	„	1,500	„	„

The beds are but little disturbed in general, and form great plateaux. They rest partly on Palæozoic rocks (Carboniferous or Devonian), partly on gneissic formations. As in Australia, the underlying Palæozoic rocks contain a flora allied to the Carboniferous flora of Europe.

At the base of the Karoo formation are certain shales with coal, known as the Ecca beds, and remarkable for containing a great boulder-bed, the Ecca or Dwyka conglomerate,[2] like those in the Tálchir beds in India and the Hawkesbury sandstone in Australia, the boulders, precisely as in the Tálchir beds, being embedded in fine compact silt or sandstone, which in both countries has been mistaken for a volcanic rock. The Ecca beds are said to contain *Glossopteris* and some other plants, but the accounts are as yet somewhat imperfect. The whole Karoo system, according to the latest accounts, rests unconformably on the Ecca beds, whilst the Ecca beds are conformable to the underlying Palæozoic strata.

Unfortunately, although a considerable number of animals and a few plants have been described from the 'Karoo formation,' it is but rarely that the precise subdivision from which the remains were brought has been clearly known.

The known species of plants are very few in number; *Glossopteris browniana*, and two other species of *Glossopteris*,[3] *Rubidgea*, a fern nearly akin to *Gangamopteris* and *Glossopteris*, and a *Phyllotheca*-like stem are recorded, without any certain horizon, but probably from the Beaufort beds. There is no doubt as to the close similarity of these plants to those from the Damudas of India and the Newcastle beds of Australia.

From the Stormberg beds there are reported *Pecopteris* or *Thinnfeldia odontopteroides*, *Cyclopteris cuneata*, and *Tæniopteris daintreei*,[4] three of the most characteristic fossils of the uppermost plant-beds in Australia, and all found in the Upper Jurassic Queensland beds.

The animals found in the Karoo beds[5] are more numerous by far than the plants. The greater portion have been procured from the Beaufort beds. They comprise numerous genera of dicynodont, theriodont, and dinosaurian reptiles, two or three genera of labyrinthodont amphibians, some fish allied to *Palæoniscus* and *Amblypterus*, and one mammal, *Tritylodon*. Of the above the *Tritylodon* and some reptilian and fish remains are said to be from the Stormberg beds.

Tritylodon is most nearly related to a Rhætic European mammal. The relations of the reptiles called *Theriodontia* by Sir R. Owen are not clearly defined, but representatives of them and of the *Dicynodontia*, as already noticed, are said to be found in the Permian of Russia. The *Glossopteris* and its associates may of course be classed as Carboniferous or Jurassic, according to taste. Neither the fauna nor flora show sufficiently close relations to those of any European beds for any safe conclusions as to age, even if homotaxis and synchronism be considered identical.

[1] *Q. J. G. S.* xxiii. 1867, p. 142.
[2] Sutherland, *Q. J. G. S.* xxvi. p. 514.
[3] One classed by Tate as *Dictyopteris*, *Q. J. G. S.* xxiii. p. 141.
[4] Dunn, 'Report on Stormberg Coal-Field,' *Geol. Mag.* 1879, p. 552.
[5] Owen, 'Cat. Foss. Rept. S. Africa Brit. Mus. 1876,' &c.

On the other hand there are remarkable points of agreement with the faunas and floras of the Indian and Australian rocks.

Away from the typical Karoo area on the coast south of Natal there is found a series of beds, partly marine, sometimes called the Uitenhage[1] series. A few cycads (*Otozamites, Podozamites, Pterophyllum*), a conifer, and ferns (*Pecopteris* or *Alethopteris, Sphenopteris, Cyclopteris*) are quoted from them, and three or four of the forms are closely allied or identical with species found in the Rájmahál beds of India.

It was at first supposed that the plant-bearing beds were lower in position than those containing marine fossils, and the whole of the Uitenhage series was considered as of later age than the Karoo beds. The marine beds were considered Middle Jurassic. Subsequently, however, Stow[2] showed conclusively that a portion of the marine beds, judging by their fossils, are of uppermost Jurassic or even Neocomian age, and also that the relation of the plant-bearing beds to the marine strata are far less simple than was supposed.[3] Indeed, to judge from Stow's account, it is by no means clear that a portion of the wood-bed series or saliferous series, to which the plant-beds belong, is not higher in position than the marine Jurassic strata.

There is a very extraordinary similarity between the geology of the southern part of Africa and that of the peninsula of India. In both countries a thick freshwater formation, without any marine beds intercalated, occupies a large area of the interior of the country, whilst on the coast some marine Jurassic and cretaceous rocks are found, the former in association with beds containing plants. The coincidence is not even confined to sedimentary beds. As in India so in South Africa, the uppermost inland Mesozoic fresh-water beds are capped by volcanic rocks.

It has been assumed, but not apparently on any clear evidence, that the marine coast-beds and the associated plant-beds are in Africa much newer than the inland sandstone formation, but it is not impossible that the relations may really be the same as in India, and that the Stormberg beds of the inland formation may be the equivalents of the Upper Jurassic or even the Cretaceous marine beds on the coast. The discovery of plants identical with those of the Jurassic (probably Upper Jurassic) beds of Queensland in the Stormberg series may of course be taken for what it is worth; it is of quite as much importance in indicating the age of the rocks as the occurrence of dicynodont reptiles in the Permian of Russia and in the lower Gondwánas of India.

Altogether there is quite sufficient probability that the upper Karoo or Stormberg beds are of later age than Triassic to justify the protest which I made last year against a skull being described from these beds as that of a 'Triassic' mammal.[4] The practice, so common amongst palæontologists, of positively asserting as a known fact the geological age of organisms from beds of which the geological position is not clearly determined is very much to be deprecated.

I have called attention to the occurrence of boulders in the Tálchir beds in India, the Ecca beds of South Africa, and the Bacchus Marsh sandstones and Hawkesbury beds of Australia. The idea has occurred quite independently to several different observers that each of these remarkable formations affords evidence of glacial action; and although, in the case of India especially, the geographical position of the boulder-bed within the tropics seemed for a long time to render the notion of ice action too improbable to be accepted, further evidence has so far confirmed the view as to cause it to be generally received. Even before the Australian boulder-deposits had been observed it was suggested that the Tálchir beds and Ecca conglomerate might be contemporaneous,[5] and that the evidence in favour of a Glacial epoch having left its traces in the Permian beds of England[6] might possibly indicate that the Indian and South African boulder-beds are of the same geological epoch. The discovery of two similar deposits in Australia

[1] *Q. J. G. S.* xxvii. p. 144.
[2] *Q. J. G. S.* xxvii. p. 479.
[3] *L.c.* p. 505, 511, 513, &c.
[4] *Q. J. G. S.* xl. p. 146.
[5] *Q. J. G. S.* xxxi. p. 528.
[6] *Q. J. G. S.* xi. p 185.

adds to the probability that all may have resulted from the same cause and may record contemporaneous phenomena. It would be very unwise to insist too much on the coincidence.

It would be easy to call attention to further examples of discrepancies in palæontological evidence, but I should weary you, and nothing would be attained by going through instance after instance of deposits in distant parts of the world, the age of which has been solely determined by the examination of a few fossil forms of land and fresh-water animals and plants. I have, therefore, only taken a few with the details of which I have had occasion to become acquainted. In some of the most important cases I have mentioned, such as those of the Pikermi and Siwalik faunas, the Cutch (Umia beds) flora, and that in the lower coal-measures of Australia, the conflict is between the evidence of the marine and terrestrial organisms. Manifestly one or the other of these leads to erroneous conclusions.

The general opinion of geologists is in favour of accepting the evidence of marine organisms. The reason is not far to seek. So far as I am aware no case is known where such an anomaly as that displayed in the Gondwánas of India has been detected amongst marine formations of which the sequence was unquestioned. In the Gondwánas we have a Rhætic flora overlying a Jurassic flora, and a Triassic fauna above both. In Australia we find a Jurassic flora associated with a Carboniferous marine fauna, and overlain by a Permian fresh-water fauna. The only similar case amongst marine strata is that of the well-known colonies of the late M. Barrande in Bohemia, and in this instance the intercalation of strata containing later forms amongst beds with older types is disputed, whilst the difference in age between the faunas represented is not to be compared to that between Triassic and Jurassic.

There is, however, another and an even stronger reason for accepting the evidence of marine instead of that afforded by terrestrial and fresh-water animals and plants. If we compare the distribution of the two at the present day we shall find a very striking difference, and it is possible that this difference may afford a clue to the conditions that prevailed in past times.

Wanderers into what they fancy unexplored tracts in palæontology are very likely to find Professor Huxley's footprints on the path they are following. I have had occasion to turn to a paper of his on *Hyperodopedon*,[1] that very curious reptile already mentioned, of which the remains occur both in Great Britain and in India. and I find the following remarks, which appear so exactly to express a portion of the view to which I wish to call your attention, that I trust I may be excused for quoting them. Professor Huxley writes:—

'It does not appear to me that there is any necessary relation between the fauna of a given land and that of the seas of its shores. The land-faunæ of Britain and Japan are wonderfully similar; their marine faunæ are in several ways different. Identical marine shells are collected on the Mozambique coast and in the easternmost islands of the Pacific; whilst the faunæ of the lands which lie within the same range of longitude are extraordinarily different. What now happens geographically to provinces in space is good evidence as to what, in former times, may have happened to provinces in time; and an essentially identical land-fauna may have been contemporary with several successive marine faunæ.

'At present our knowledge of the terrestrial faunæ of past epochs is so slight that no practical difficulty arises from using, as we do, sea-reckoning for land-time. But I think it highly probable that sooner or later the inhabitants of the land will be found to have a history of their own.'

When these words were written more than fifteen years ago very few of the geological details to which I have called your attention were known. I need not point out how wonderful a commentary such details have afforded to Professor Huxley's views.

I have no desire to quote authority. I fear that in the facts I have been laying

[1] *Q. J. G. S.* xxv. p. 150.

before you my quotations of the most authoritative writers have been made less for the purpose of showing reverence than of expressing scepticism. My reason for calling attention to Professor Huxley's views is different. I entirely agree with them; but there is, I think, something to be added to them. There is, I believe, an additional distinction between land and marine faunas that requires notice, and this distinction is one of very great importance and interest. It appears to me that at the present day the difference between the land-faunas of different parts of the world is so vastly greater than that between the marine faunas, that if both were found fossilised, whilst there would be but little difficulty in recognising different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs, and that some would be more probably classed with those of a past period than with others of the present time.

I had proposed to enter at some length into this subject, and to attempt a sketch of the present state of our knowledge concerning the distribution of terrestrial and marine faunas and floras. But I found that it was impossible to do justice to the question without making this address far longer than is desirable, and I have already taken up more time than I ought to have done. I can therefore only treat the subjects very briefly.

As you are doubtless aware, the most important work upon the distribution of terrestrial animals yet published is that of Mr. Wallace. He divides the earth's surface into six regions—Palæarctic, Ethiopian, Oriental, Australian, Neotropical, and Nearctic. Some naturalists, with whom I am disposed to agree, consider Madagascar and the adjacent islands a seventh region, and it is possible that one or two other additions might be made.

These regions are essentially founded on the distribution of *vertebrata*, especially mammals and birds, and the following table, taken from Wallace's lists, shows the percentage of peculiar families of vertebrata and peculiar genera of mammalia in each region, mammalia being selected as more characteristic than birds and better known than reptiles, amphibians, or fishes:—

Regions	Total Families of Vertebrates	Peculiar Families	Percentage of Peculiar Families	Total Genera of Mammals	Peculiar Genera of Mammals	Percentage of Peculiar Genera
PALÆARCTIC .	137	3	2·2	100	37	37
ETHIOPIAN .	175	23	13·1	142	90	63
ORIENTAL .	163	12	7·4	118	54	46
AUSTRALIAN .	142	30	21·1	70	45	65
NEOTROPICAL .	168	45	26·8	131	103	79
NEARCTIC .	121	12	9·9	74	24	32

The marine mammals and reptiles are too few in number to be compared with the land-fauna, but whales, porpoises, seals, sirenians, turtles, and sea-snakes are for the most part widely diffused. The best class of the vertebrata for comparison is that of the fishes, and some details taken by Wallace from Günther's 'British Museum Catalogue' are very important. The whole class is divided into 116 families, of which 29 are exclusively confined to fresh water, whilst 80 are typically marine. Of these 80 no less than 50 are universally, or almost universally, distributed, whilst many others have a very wide range. Four families are confined to the Atlantic and 13 to the Pacific Ocean, whilst a few more are exclusively southern or northern. About 63 are found in both the Atlantic and Pacific.

Now, of the 29 fresh-water families 15, or more than one-half, are confined each to a single region, 9 are found each in two regions, 2 in three regions, and the same number in four; one only (*Cyprinidæ*) is found in five regions, whilst not one is met with in all six. It is impossible to conceive a greater contrast: 50 marine families, or 62·5 per cent., have a world-wide distribution, whilst not a single fresh-water family has an equally extended range, and more than one-half are confined each to a single region.

The regions adopted by Wallace, as already stated, are founded on the *vertebrata*; he considers, however, that the distribution of the invertebrates is similar. So far as the terrestrial mollusca are concerned, I am inclined to dissent from this view. But for one circumstance the mollusca would afford an admirable test of the theory that marine types—species, genera, and families—are much more widely spread than terrestrial. I am assured that this is the case, but the difficulty of proving it arises from the fact that the classification of pulmonate terrestrial mollusca, as adopted by naturalists generally, is so artificial as to be worthless. Genera like *Helix*, *Bulimus*, *Achatina*, *Pupa*, *Vitrina*, as usually adopted, are not real genera, but associations of species united by characters of no systematic importance, and the attempts that have hitherto been made at a natural classification have chiefly been founded on the shells, the animals not being sufficiently known for their affinities, in a very large number of cases, to be accurately determined. Of late years, however, more attention has been devoted to the soft parts of land mollusks, and in Dr. Paul Fischer's 'Manuel de Conchyliologie,' now being published, a classification of the Pulmonate Gasteropoda is given, which, although still imperfect for want of additional information, is a great improvement upon any previously available. In this work the first thirteen families of the *Pulmonata Geophila* comprise all the non-operculate land mollusca, or snails and slugs, and these 13 families contain 82 genera thus distributed:—

Peculiar to one of Wallace's land regions	54
Found in more than one, but not in both America and the Eastern hemisphere	12
Common to both hemispheres	16

The last 16 however include *Limax*, *Vitrina*, *Helix*, *Pupa*, *Vertigo*, and some other genera which certainly need further repartition. The operculated land-shells belonging to a distinct sub-order, or order, and closely allied to the ordinary Prosobranchiate Gasteropoda, are better classified, the shells in their case affording good characters. They comprise four well-marked families (*Helicinidæ*, *Cyclostomidæ*, *Cyclophoridæ*, and *Diplommatinidæ*), besides others less well marked or but doubtfully terrestrial. Not one of the families named is generally distributed, and the genera are for the most part restricted to one or two regions. The portion of Dr. Fischer's manual relating to these mollusca is unpublished, and the latest general account available is that of Pfeiffer, published in 1876.[1] From this monograph I take the following details of distribution. The number of genera enumerated is 64 (including *Proserpinidæ*).

Peculiar to one of Wallace's land regions	48
Found in more than one, but not in both America and the Eastern hemisphere	8
Common to both hemispheres	8

It is the distribution of the terrestrial operculate mollusca which induces me to suspect that the distribution of land mollusca differs from that of land vertebrates. One instance I may give. There is nowhere a better marked limit to two vertebrate faunas than that known as Wallace's line separating the Australian and Oriental regions, and running through the Malay peninsula between Java, Sumatra, and Borneo on the one hand, and Papua with the neighbouring groups on the other. There is in the two regions a very great difference in the vertebrate genera, and a considerable replacement of families. The Oriental *vertebrata* contain far more genera and families common to Africa than to Australia. Now, the operculate land-shells known from New Guinea and Northern Australia belong to such genera

[1] *Monographia Pneumonopomorum Viventium Supp.* iii.

as *Cyclophorus*, *Cyclotus*, *Leptopoma*, *Pupinella*, *Pupina*, *Diplommatina*, and *Helicina*, all found in the Oriental region, and mostly characteristic of it, whilst the only peculiar types known are *Leucoptychia*, closely allied to *Leptopoma*, from New Guinea, and *Heterocyclus*, apparently related to the Indian *Cyathopoma*, from New Caledonia. Farther east in Polynesia there are some very remarkable and peculiar types of land-shells, such as *Achatinella*, but these do not extend to Australia or Papua. On the other hand scarcely a single Oriental genus extends to Africa, the terrestrial molluscan fauna of which continent differs far more from that of the Oriental region than the latter does from that of tropical Australia.

The same is the case with plants. In an important work lately published by Dr. O. Drude, of Dresden, the tropics of the Old World are divided into three distinct regions—(1) tropical Africa; (2) the East African islands, Madagascar, &c.; (3) India, South-Eastern Asia, the Malay archipelago, Northern Australia, and Polynesia.

A very large proportion of the families and even of the genera of marine mollusca are almost of world-wide distribution, and even of the tropical and subtropical genera the majority are found in all the warmer seas. I have no recent details for the whole of the marine mollusca, but a very fair comparison with the data already given for land-shells may be obtained from the first 25 families of Prosobranchiate Gasteropoda, all that are hitherto published in Fischer's manual. These 25 families include *Conidæ*, *Olividæ*, *Volutidæ*, *Buccinidæ*, *Muricidæ*, *Cypreidæ*, *Strombidæ*, *Cerithiidæ*, *Planaxidæ* and their allies, and contain 116 living marine genera, the known range of which is the following—

Found only in the Atlantic Ocean	15	
Found only in the Pacific or Indian Ocean, or both . . .	28	
Found only in Arctic or Antarctic Seas, or in both . . .	12	
		—55
Found in the warmer parts of all oceans	34	
Widely, and for the most part universally, distributed . . .	27	
		—61

That is 52·6 per cent. are found in both hemispheres, whilst only 19·5 per cent. of the inoperculate, and 12·5 per cent. of the operculate land mollusca, have a similar distribution. This is, however, only an imperfect test of the difference, which is really much greater than these numbers named imply by themselves.

Some genera of fresh-water mollusca, as *Unio*, *Anodon*, *Cyclas*, *Lymnea*, *Planorbis*, *Paludina*, and *Bythinia*, are very widely spread, but a much larger number are restricted. Thus if *Unio* and *Anodon* are extensively distributed, all allied fresh-water genera, like *Monocondylæa*, *Mycetopus*, *Iridina*, *Spatha*, *Castalia*, *Ætheria*, and *Mülleria* inhabit one or two regions at the most. The same result is not found from taking an equally important group of marine mollusca, such as *Veneridæ* or *Cardiadæ*.

Throughout the marine invertebrata, so far as I know, the same rule holds good: a few generic types are restricted to particular seas; the majority are found in suitable habitats throughout a large portion of the globe. The marine provinces that have been hitherto distinguished, as may be seen by referring to those in Woodward's 'Manual of the Mollusca,' or Forbes and Godwin Austin's 'Natural History of the European Seas,' or Fischer's 'Manuel de Conchyliologie,' or Agassiz's 'Revision of the Echini,' are founded on specific distinctions, whilst the terrestrial regions are based on generic differences, and often on the presence or absence of even larger groups than genera.

Botany offers a still more remarkable example. I have just referred to Dr. Oscar Drude's work,[1] published within the last few months, on the distribution of plants. Dr. Drude divides the surface of the globe into four groups of floral regions (*Florenreichsgruppe*), and these again into floral regions (*Florenreiche*), 15 in number, which are again divided into sub-regions (*Gebiete*). The first group of floral regions is the oceanic, comprising all the marine vegetation of the world;

[1] Petermann's *Mittheilungen*, Ergänzungsheft No. 74, 'Die Florenreiche der Erde.'

and so uniform is this throughout that no separate regions can be established, so that there is but one oceanic to contrast with 14 terrestrial regions.

It is impossible to enter further into this subject now, and I can only allude to the evidence in favour of the existence of land-regions in past times. It is scarcely necessary to remind you of the proofs already accumulated of differences between the fauna of distant countries in Tertiary times. The Eocene, Miocene, and Pliocene vertebrata of North America differ quite as much from those of Europe in the same periods as do the genera of the present day; and there was as much distinction between the mammalia of the Himalayas and of Greece when the Siwalik and Pikermi faunas were living as there is now. In Mesozoic times we have similar evidence. The reptiles of the American Jurassic deposits present wide differences from those of the European beds of that age, and the South African reptilian types of the Karoo beds are barely represented elsewhere. But there is no reason for supposing that the limits or relations of the zoological and botanical regions in past times were the same as they now are. It is quite certain indeed that the distribution of land-areas, whether the great oceanic tract has remained unchanged in its general outlines or not, has undergone enormous variations, and the migration of the terrestrial fauna and flora must have been dependent upon the presence or absence of land communication between different continental tracts; in other words, the terrestrial regions of past epochs, although just as clearly marked as those of the present day, were very differently distributed. The remarkable resemblance of the floras in the Karoo beds of South Africa, the Damuda of India, and the coal-measures of Australia, and the wide difference of all from any European fossil flora, is a good example of the former distribution of life; whilst it is scarcely necessary to observe that the present Neotropical and Australian mammals resemble those of the same countries in the later Tertiary times much more than they do the living mammalia of other regions, and that the Australian mammal fauna is in all probability more nearly allied to the forms of life inhabiting Europe in the Mesozoic era than to any European types of later date. If the existing mammals of Australia had all become extinct, a deposit containing their bones would probably have been classed as Mesozoic.

The belief in the former universality of faunas and floras is very much connected with the idea once generally prevalent, and still far from obsolete, that the temperature of the earth's surface was formerly uniform, and that at all events until early or even middle Tertiary times the poles were as warm as the equator, and both enjoyed a constant tropical climate. The want of glacial evidence from past times in Spitzbergen and Greenland, where a temperature capable of supporting arboreal vegetation has certainly prevailed during several geological periods, is counterbalanced by the gradually accumulating proofs of Lower Mesozoic or Upper Palæozoic glacial epochs in South Africa, Australia, and, strangest of all, in India. Even during those periods of the earth's history when there is reason to believe that the temperature in high latitudes was higher than it now is, evidence of distinct zones of climate has been observed, and quite recently Dr. Neumayr,[1] of Vienna, has shown that the distribution of Cretaceous and Jurassic *cephalopoda* throughout the earth's surface proves that during those periods the warmer and cooler zones of the world existed in the same manner as at present, and that they affected the distribution of marine life as they do now.

The idea that fresh-water and terrestrial faunas and floras were similar throughout the world's surface in past times is so ingrained in palæontological science that it will require many years yet before the fallacy of the assumption is generally admitted. No circumstance has contributed more widely to the belief than the supposed universal diffusion of the Carboniferous flora. The evidence that the plants which prevailed in the coal-measures of Europe were replaced by totally different forms in Australia, despite the closest similarity in the marine inhabitants of the two areas at the period, will probably go far to give the death-blow to an hypothesis that rests upon no solid ground of observation. In a vast number

[1] 'Ueber klimatische Zonen während der Juras- und Kreidezeit,' *Denkschr. Math. Nat. Cl. Akad. Wiss. Wien*, vol. xlvii. 1883.

of instances it has been assumed that similarity between fossil terrestrial faunas and floras proves identity of geological age, and, by arguing in a vicious circle, the occurrence of similar types, assumed without sufficient proof to belong to the same geological period, has been alleged as evidence of the existence of similar forms in distant countries at the same time.

In the preceding remarks it may perhaps have surprised some of my auditory that I have scarcely alluded to any American formations, and especially that I have not mentioned so well known and interesting a case of conflicting palæontological evidence as that of the Laramie group. My reason is simply that there are probably many here who are personally acquainted with the geology of the American Cretaceous and Tertiary beds, and who are far better able to judge than I am of the evidence as a whole. To all who are studying such questions in America I think it will be more useful to give the details of similar geological puzzles from the Eastern hemisphere than to attempt an imperfect analysis of difficult problems in the great Western continent.

Perhaps it may be useful, considering the length to which this address has extended, to recapitulate the principal facts I have endeavoured to bring before you. These are—

1. That the geological age assigned on homotaxial grounds to the Pikermi and Siwalik mammalian faunas is inconsistent with the evidence afforded by the associated marine deposits.

2. The age similarly assigned on the same data to the different series of the Gondwána system of India is a mass of contradictions; beds with a Triassic fauna overlying others with Rhætic or Jurassic floras.

3. The geological position assigned on similar evidence to certain Australian beds is equally contradictory, a Jurassic flora being of the same age as a Carboniferous marine fauna.

4. The same is probably the case with the terrestrial and fresh-water faunas and floras of South Africa.

5. In instances of conflicting evidence between terrestrial or fresh-water faunas and floras on one side, and marine faunas on the other, the geological age indicated by the latter is probably correct, because the contradictions which prevail between the evidence afforded by successive terrestrial and fresh-water beds are unknown in marine deposits, because the succession of terrestrial animals and plants in time has been different from the succession of marine life, and because in all past times the differences between the faunas and floras of distant lands have probably been, as they now are, vastly greater than the differences between the animals and plants inhabiting the different seas and oceans.

6. The geological age attributed to fossil terrestrial faunas and floras in distant countries on account of the relations of such faunas and floras to those found in European beds has proved erroneous in so large a number of cases that no similar determinations should be accepted unless accompanied by evidence from marine beds. It is probable in many cases—perhaps in the majority—where the age of beds has been determined solely by the comparison of land or fresh-water animals or plants with those found in distant parts of the globe, that such determinations are incorrect.

The following Papers were read:—

1. *Results of past experience in Gold Mining in Nova Scotia.* *By* Edwin Gilpin, Jun., *A.M.*, *F.G.S.*, *F.R.S.C.*

The gold fields of Nova Scotia stretch along the whole Atlantic coast of the province, and occupy an area of about 7,000 square miles.

The auriferous measures may be divided into two series, an upper one consisting of black pyritous slates with occasional bed of quartzite and some auriferous veins and a lower one made up of alternating beds of slates and quartzites and compact sandstone, sometimes felspathic. The upper series is estimated to be 3,000 feet thick, the lower 9,000 feet.

Granite rocks stretch irregularly the whole length of the gold fields. The granite is evidently intrusive, and is older than the carboniferous period.

The auriferous veins vary in thickness up to six feet; the usual size of those worked is only four to fifteen inches. The quartz is often crystalline and banded. The veins have the same strike as the enclosing rocks and were at first considered to be beds, similar to those known to be auriferous in the Carolinas and elsewhere; but the fact of their containing portions of the enclosing slate, and of occasionally cutting obliquely across the bedding, proves that they are true veins.

The distribution of the gold in the veins may be termed capricious. While the veins for a long distance may be auriferous, there is generally one zone or several zones of quartz much richer than that on each side. These zones or 'pay streaks' do not appear to be the effect of any law that has yet been applied to our mines.

Judging from the available fossil evidence, which however is small, the gold-bearing beds appear to be of Cambrian age.

The quartz mills of Nova Scotia are similar to those in general use in Australia and California. The cost of mining varies from eighty cents in the open cast slate belts, carrying auriferous quartz, up to fifteen dollars a ton in small veins, three or four inches wide, in very hard rock. The cost per ton of crushing with water-power varies from sixty cents to one dollar; with steam power the cost is somewhat higher.

Attention is now being turned to low grade ores, that is to say, beds of auriferous slate with veins of quartz, yielding averages of four to eight pennyweights of gold to the ton.

During the year 1883 the miners averaged two dollars eighty-four cents a day from 25,954 tons of quartz, yielding ten pennyweights and twenty-one grains of gold per ton, and looking at the large extent of country containing proved auriferous strata, the author anticipates a permanent and profitable future for the gold mines of Nova Scotia.

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2. *A Comparison of the Distinctive Features of Nova Scotian Coal-fields.* *By* EDWIN GILPIN, Jun., *A.M., F.G.S., F.R.S.C.*

The Carboniferous Rocks of Nova Scotia cover a large part of the northern side of the province, and are exposed in unusually good sections. The presence of workable coal-seams has led to many surveys, &c., which have resulted in a good knowledge of their structure. The best known and most continuous sections are those of the Joggins in Cumberland county, and of the Cape Breton coal-field. There are numerous coal-fields, the most important being those of Cumberland, Pictou, and Cape Breton.

The presence of east and west synclinal folds is noticeable in each of these districts. In the Sydney coal-field these foldings are on the prolongation of the ranges of the pre-carboniferous rocks, and die out as they recede from them. In all these coal-fields these flexures are not accompanied by serious faults, except where the older measures have interrupted or complicated them. Thus on the north side of the Cumberland coal-field the measures are comparatively free from disturbances where no pre-carboniferous strata appear, while numerous dislocations are found on the south side, where they rest almost directly on the Silurian slates of the Cobequid mountains.

In the Sydney coal-field the sections show the ancient centre of the coal-field where the maximum of coal and the minimum of strata occur, from which it would appear that the distributing currents carried material principally from the north and the south; the source of part of the detritus being the bordering Lower Carboniferous strata. The slight difference of deposition, however, is marked by the presence of beds of bituminous and fossiliferous limestone, which, chiefly developed in the centre, extend almost from end to end of the district.

In the Pictou district a noticeable point is a horizon in the lower part of the section containing 1,500 feet of shale, and coal in beds up to 38 feet in thickness. This curious formation is referred to the presence of a contemporaneous barrier-reef of shingle formed from the Millstone Grit, and allowing under its shelter an immense accumulation of argillaceous and carbonaceous sediment. In the Cumberland coal-field a long-continued alternation of shale and sandstone allowed the formation of sixty-seven coal beds, only two of which in the 'Joggins Section' are of workable size.

It is noticeable that in the Pictou and Cumberland coal-fields the most productive horizon is at the base of the coal-measures, and comparatively speaking, of limited thickness. Thus at Pictou, the lower 1,300 feet hold fifteen beds, yielding 119 feet of coal. At Springhill, in the Cumberland district, the lower 1,000 feet of the coal measures hold twelve beds, containing 51 feet of coal. The overlying measures are more arenaceous, and hold a much smaller proportion of coal in both districts. In the Cape Breton coal-field there are now exposed only 1,300 feet of productive measures immediately overlying the Millstone Grit, and holding the workable seams.

The question naturally arises if it might not be considered that at one time the Cape Breton coal-field may not have had a total thickness of strata equalling that recorded in Pictou and Cumberland, and that possibly the upper section was similar in development.

The coals from these districts present several points of difference. Thus the slightly higher ash contents of the Pictou and Cumberland coals may be connected with the predominance of the including beds of shale as compared with the more arenaceous measures of Cape Breton, and a low ash percentage in the coals.

Other differences between the districts may be referred to conditions of deposition, foldings, drainage, &c.

As yet the study of the fossils of the three districts does not show any points of difference calling for remark, but this subject has not yet received a share of attention equal to that bestowed on the points of economic interest.

The above and other differences between the districts are perhaps more justly considered due to local differences of the deposition extending over large areas than as marking distinctions between individual and isolated coal-fields.

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3. *On the Coals of Canada.* *By* H. A. Budden.

Coal is widely distributed over the Dominion; from the extreme eastern point on the Atlantic, in the Island of Cape Breton, it occurs, and through a portion of Nova Scotia and New Brunswick; from thence a wide blank exists, until about the ninety-seventh parallel is reached; from it to the base of the Rocky Mountains extensive fields are being developed; it is also met at various points in British Columbia, but Vancouver Island on the Pacific contains the most valuable deposits.

Central Canada, although deprived of coal, is contiguous to the immense fields of Pennsylvania, Ohio, &c., and through the medium of the great lakes and the railways, is readily served at moderate cost.

The principal fields are five in number. Those in Nova Scotia are carefully described by Sir William Dawson, in his 'Acadian Geology,' but among others, Sir Charles Lyell, Sir William Logan, Messrs. Brown, Hartley, Robb, and gentlemen in the service of the Geological Survey of Canada, have given much attention to the subject. The North-West fields have been surveyed partially by the Geological Survey, Dr. George Dawson doing the principal work. Vancouver Island and British Columbia are indebted to the late Mr. Richardson and Dr. George Dawson for the results from their surveys; their reports are to be found in the records of the Geological Survey.

Cape Breton.—The coal-field is carboniferous, the measures consist of an accumulation of strata, comprising shale, sand-stone and fire-clay, with numerous valuable seams of bituminous coal. The principal field is about thirty-one miles long, bounded on the north by the ocean, on the south by the Millstone Grit, the outcrops of the seams are found on the shores of the deep bay. The measures lie at an easy angle, dipping under the sea.

Pictou County has the next important field, and is widely known on account of the immense thickness of the seams, they are more irregular in their dip than those of Cape Breton, with an angle of from 10° to 30°. The total area is about thirty-five square miles, but owing to the extent of faults, a large portion of the coal is cut off; the whole field forms an irregular basin, let down on all sides, among rocks of older age.

Cumberland County.—This important field has only recently been developed on a large scale, the productive measures extend from the Joggins, on the shore of the Bay of Fundy, for more than twenty miles easterly, towards the base of the Cobequid Hills. On the shore of the Bay of Fundy, the exposure is of immense thickness, estimated at 14,000 feet, extending from the Marine Limestones of the Lower Carboniferous to the top of the Coal Formation. Its extent has not yet been arrived at.

North-West.—The ninety-seventh meridian separates pretty exactly, the coal-bearing formations of America into two classes. To the east, Carboniferous; in the west, the coals and lignites are found at various horizons in the Secondary and Tertiary rocks. Their development has only commenced; but when it is considered that outcrops of valuable seams are found eastward of the Rocky Mountains, from the United States boundary, for hundreds of miles to the north, no anxiety may be felt as to their extent.

British Columbia.—Very little exploration has been made in the mainland, the coals of Vancouver Island being easily accessible and of excellent quality. The best known fields are those of Comox and Nanaimo, on the eastern shore of the island. The measures dip mostly under the sea; they are variable, however, and require the diamond drill to be used extensively; the coals are bituminous and are considered the best on the American Pacific Coast. Two companies, the Wellington and Vancouver, work extensive mines.

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4. *On the Geology of Halifax Harbour, Nova Scotia.* *By the* Rev. D. Honeyman, *D.C.L., F.R.S.C.*

Halifax Harbour owes to its geology very many of the features by which it is characterised. Its formations are: 1st. *Archæan.* 2nd. *Lower Cambrian-metamorphosed.* 3rd. *Glacial.*

(1) Opposite McNab's Island and west of the main entrance the principal rocks are *Granites.* Genner regarded these as primary, Professor Hind considers them to be *Laurentian Gneisses,* the author, unstratified rocks of Archæan age.

(2) *Gneissoid Rocks and Schists.*—The former, andalusitic and pyritous, are associated with the granites. They are seen lying on the granites, abutting against them, dipping towards them, having an east and west strike, and a southerly dip, and in no case dipping away from them; some of them appear to cross the harbour, outcropping near the lighthouse and on the island, and appearing at the eastern passage.

(3) The *argillites* of Halifax city occupy the west side of the harbour, appearing fully at Pleasant Park. At Three Gun Battery Point there is a syncline on either side. The argillites have only one feeble outcrop on the eastern side. The only other rocks to be seen are quartzites. These are at a considerable distance from the harbour, reaching Dartmouth on the same side. The Halifax argillites are seen to have crossed over in great force, and continue so until we come opposite Richmond. At this place the *Quartzites* of Bedford Basin connect with the Halifax *Argillites,* and also cross over to the Dartmouth side. Bedford Basin has *Quartzites* with interbedded shales and greenish slates on all sides. Occasionally they appear as ledges on the shore. The metamorphism of the Cambrian seems to have been effected in Upper Cambrian and Lower Silurian times. Simultaneously the harbour evidently had its beginning.

(3) *Glacial.*—The argillites of Halifax and Dartmouth are universally glaciated; exposed surfaces of rocks indicate the intensity of the action and the course of movement in a very striking manner. The author mentioned instances. Some of the *ruts* show that the agent moved in a southerly direction. The general direction

of the striation is S. 20° E., N. 20° W., magnetic, or S. 40° E., N. 40° W., true. This is also approximately the course of the harbour.

Produced *northerly* the striation of Point Pleasant touches the brow of Blomidon on the Minas Basin. Still farther it passes through the Cobequid Mountains. Produced *southerly*, it passes through the harbour close to Thrum-Cap, the extremity of McNab's Island and into the Atlantic.

Transportation.—In the 'Transactions of the Nova Scotian Institute of Natural Science,' 1881–2, and in the 'Canadian Science Monthly,' July number, the author has given a list of nearly all the accumulations of 'Glacial Drift' that he has examined in and around Halifax Harbour. The following, however, have been re-examined recently:—

1. Thrum-Cap and the beach which connects it with McNab's Island. The boulders in the drift were: (1) Boulders of Amygdaloidal rocks with zeolites, which were transported from Blomidon, and Syenites, Syenitic gneisses, Diorites, &c.; from the Archæan rocks of the Cobequid Mountains was observed also a great mass of quartzite grooved and striated in a striking manner, an obvious part of the machine which ploughed the rocks of Point Pleasant. On the beach, besides the abundant quartzite boulders, were boulders of common basalt, basalt with olivine and amygdaloids from Blomidon. (2) Granites, micaceous, normal, and hornblendic; Syenites, hornblendic; Gneisses, with magnetite; Diorites, with magnetite, and Porphyrites from the Cobequid Mountains. (3) Sandstones from the carboniferous formation of Hants and Colchester counties.

2. In the drift at Point Pleasant were found a fine amygdaloid boulder of large size with plenty of smaller ones, and Archæan boulders. Another large mass of quartzite, strikingly grooved and furrowed, was also found. This accumulation is almost in a line with the Prince of Wales' Tower.

3. On Navy Island in Bedford Basin, eight and a half miles above Thrum-Cap, were collected (1) basalts, common and chrysolitic, amygdaloids. (2) Syenites, Diorites with magnetite, hornblendic gneisses, &c.

4. On the opposite side were collected (1) common basalt and basalt replete with large crystals of olivine and amygdaloids. (2) Hornblendic gneisses with magnetite.

5. Not far from the top of the basin on the same side with Navy Island, and two miles above it, were collected from the drift, basalt, hornblendic gneiss with magnetite, porphyrites, &c.

The Archæan boulders of these accumulations have not come from the Cobequid Mountains to the Halifax Harbour over the same course as the Blomidon (triassic) boulders. They are a portion of the transportation which had a sub-parallel course, which had been diverted from the general course S. 40° E. to S. as is seen by the glaciation at Wellington Station, Intercolonial Railway. It consequently encountered the triassic transportation before it reached the harbour. The united freight was carried along the harbour to the Atlantic and discharged at Thrum-Cap or beyond, and then when the glacier retreated, McNab's Island, Point Pleasant, George's Island, Navy Island, and other accumulations, were discharged in succession. Thrum-Cap is the *ultima thule* of the great S.E. glacial transportation of Eastern Canada.

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5. *Gleanings from Outcrops of Silurian Strata in Red River Valley, Manitoba.* *By* J. HOYES PANTON, *M.A.*

The country north of Winnipeg is apparently a very level prairie, but there are several places where Silurian beds crop out—sometimes from beneath the drift on the banks of the Red River and Cook's Creek; sometimes as rocks projecting above the prairie level. The beds exposed are Limestones, which are worked for ornamental and other purposes.

There are four localities on the river banks, sixteen to twenty-one miles north-east of Winnipeg, which the author groups together as yielding much the same fauna; these are between St. Andrews (North) and East Selkirk. The fossils found here are *Palæophycus*, numerous Corals, and Cephalopods, some Brachiopods and Trilobites.

The localities north and north-west of Winnipeg give a rather different fauna. Stony Mountain rises in a horseshoe shape, about sixty feet above the prairie on the north and north-west sides, sloping gradually down to the prairie-level on the east. There is here also some drift, beneath which are very distinct glacial striæ running north-north-west. Brachiopoda are very numerous here. At Stonewall the glacial striæ are also very distinct, running in the same direction.

The author gives lists of fossils from the different localities. In many cases only the genera are as yet determined. The species will be numerous. The following table gives the chief characteristics:—

	Selkirk, &c.	Stony Mountain		Stonewall
		Lower beds	Upper beds	
Condition . .	Rather soft .	Soft	Very hard . .	Hard and flinty
Action with cold acid	Much effervescence	Effervescence	None or slight	Slight effervescence
Colour . . .	Mottled, dark, and light grey	Reddish-grey .	Light grey and ochreous	Very white
Fossils . . .	Numerous .	Many . . .	Few	Several
Type . . .	Corals and Cephalopods	Brachiopods .	Corals . . .	Corals

The relative positions of these, and their equivalents, appear to be as follows, in descending order:—

Stonewall.		Niagara limestone.
Stony Mountain	Upper beds	? ?
	Lower beds	Hudson River.
Selkirk, &c.		Trenton.

6. *The Apatite Deposits of the Province of Quebec.* By G. C. Brown.

Apatite is worked for commercial purposes only in the county of Ottawa.

One type of its deposits is that in which it occurs as a constituent of the rock, in much the same sense that quartz is a constituent of granite; always remembering that apatite-bearing rock is found in small masses compared with granite. In such a type there may be present five, ten, or fifteen per cent. of apatite disseminated in particles and in pieces from the size of a pea to that of a hazel-nut, inclosed in greenish pyroxenite. Mica is not always present. One of these apatite-bearing pyroxenites has been observed to occupy the greater part of a surface of four or five acres, having the general strike of the neighbourhood, the lesser part being foreign rocks, and both with a length of four or five times the breadth. There are seldom clear walls of separation between the particles of apatite and the inclosing rock, such as occur with crystals. In detaching a piece some of the mineral may be left attached to the pyroxenite or some pyroxenite may come away with the apatite.

A further development of this type shows much fewer but larger masses of apatite, some exceeding a thousand tons, leaving the same indistinct walls of separation and containing pyroxenite masses (from a few pounds to a few hundred pounds in weight) more generally rounded than roughly angular, with the same indistinct walls of separation, and rarely containing disseminated pyroxenite grains. Massive iron-pyrites is generally met with in the larger deposits but seldom in disseminated grains. In the case of a rock not pyroxenite forming one wall of the deposit, the apatite separates cleanly from it. The presence of massive apatite indicates the presence of pyroxenite; but the latter is often found without the former.

The apatite extracted from these deposits varies greatly in quantity; some yielding a few hundred pounds, others a few tons, and so up to over 7,000 tons from the largest worked deposit, which is still being worked.

It has been met with in pyroxenite having a schistose structure in masses of from a few pounds to a few tons between the irregular layers.

Deposits of apatite have been met with which, on the surface soil being removed, showed a length of, say, ten times the width; where the width is, say, four feet the length would be, say, forty feet, narrowing towards the ends. On being worked it generally happened that both the width and the length gradually decreased until the deposit ran out or left only a narrow streak of apatite; giving one the impression that the deposit was the segment of an irregular circular form, of which the greater part had been cut off. The strike is generally that of the neighbourhood, and the mineral usually separated cleanly from one wall, but seldom from both. One might fancy such a deposit had been squeezed into a bed-like form.

Mining has extended to a depth of 130 feet, but by far the greater quantity has been taken from surface workings—workings open to daylight.

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7. *On the Occurrence of the Norwegian 'Apatitbringer' in Canada, with a few notes on the microscopic characters of some Laurentian Amphibolites.* *By* Frank D. Adams, *M.Ap.Sc.*

The author first gave a short account of the investigations which have been made on this amphibole-scapolite rock in Norway, where all the principal deposits of apatite either traverse it or occur in its immediate vicinity. The deposits of apatite in Canada generally occur associated with some variety of highly pyroxenic rock, often holding orthoclase and quartz.

The 'Apatitbringer' has, however, recently been found in the vicinity of the town of Arnprior on the River Ottawa. It closely resembles the Norwegian rock, both in external appearance and in its microscopic characters, containing hornblende, scapolite, and pyroxene as essential constituents. A number of amphibolites in the museum of the Geological Survey of Canada, which resemble this rock in appearance, have been sliced and examined with the microscope, and one of them found to contain scapolite in large amount. It was collected at Mazinaw Lake, in the township of Abinger, and is from the same belt of hornblendic rocks as that in which Arnprior is situated. The paper closed with a short account of some of these amphibolites.

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8. *On the Acadian Basin in American Geology.* *By* L. W. Bailey, *M.A.*, *F.R.S.C.*

The Acadian Basin, embracing the region bordering on and including the Gulf of St. Lawrence, together with the provinces of New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island, constitutes one of the natural physical divisions of the continent of North America, and exhibits many marked peculiarities of climate and floral and faunal distribution. In its geological structure, and in the history which this reveals, its individuality is not less clearly marked, being often in strong contrast with that of other portions of the continent farther west; and in some periods and features even exhibiting a closer relationship with the geology of Europe. In the present paper, the facts bearing upon this individuality are summarised and discussed; including the consideration of the varying land-surfaces of Acadia in different eras, the time and nature of its physical movements, its climate and its life. A review of recent progress in the investigation of its geological structure is also given.

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9. *Pennsylvania before and after the Elevation of the Appalachian Mountains. By* Professor E. W. CLAYPOLE, *B.A., B.Sc.Lond., F.G.S.*

The paper, of which the following notes are an abstract, is intended as an attempt to handle, in a necessarily imperfect manner, and only to first approximations, a difficult but important and interesting geological subject. The method of treatment is, in the writer's opinion, one that has not hitherto been employed for the same purpose.

The object in view is to form some estimate, as near to the truth as possible, of the amount of compression or shortening produced at the surface by the corrugation of the upper layers of the coast into mountain chains, with especial reference to the American Atlantic seaboard.

In order to confine the paper within due limits, certain propositions must be taken as proved. The principal of these are:

1. That central contraction has developed tangential pressure in the crust.
2. That the tangential pressure has produced crumpling of the crust.
3. That to this crumpling are due long ranges of mountains.
4. That the Appalachian Mountains came into being in this manner in the later portion of the Palæozoic era.

These admitted, the conclusion necessarily follows that during the formation of the Appalachian Mountains a considerable contraction of the crumpled area ensued, in a direction at right angles to that of the chain.

The following points constitute the main features of the paper:

1. A short account was given of the mountains of Middle Pennsylvania in plan and section with diagrams, and the field of study limited to eleven great ranges crossing the State from N.E. to S.W. These were

Blue Mountain	Blue Ridge
Bower Mountain	Jack's Mountain
Conecocheague Mountain	Standing Stone Mountain
Tuscarora Mountain	Tussey Mountain
W. Shade Mountain	Bald Eagle Mountain
Black Log Mountain	

2. A line of sections at right angles to these ranges was chosen and its position as given from near Warrior's Mark, in Huntingdon, to near Carlisle, in Cumberland, sixty-five miles in length.

3. An attempt was made to estimate the length of the original contorted bed of Meania Sandstone of which all these mountains consist, aud after making ample allowance for all necessary deductions for the flattened tops of the arches and bottoms of the synclines, and assuming for the ranges an average dip of 45°, the conclusion was reached that the first portion of the section of forty-nine miles in length represented about sixty miles of horizontal stratum before it was corrugated. The second portion being more strongly plicated and its folds overlapping gives yet higher results, and the whole sixty-five miles of the section line were considered to represent about one hundred miles of surface before corrugation took place.

4. Such mass-motion as this involves the displacement of whole counties, and the shoving of their superficial strata over those below them, to an extent seldom fully realised. The travelling of a whole county in this manner for thirty or forty miles is a view in geology not easily pictured to the mind; yet the south-east line of Cumberland county must have moved over at least this distance. Toward the north-west this movement diminished, until the sliding, yielding mass was arrested against the beds of the Midland district, which formed the great buffer-plate on which the earth pressure spent itself.

In conclusion allusion was made to some suggestions which have been put forward to account for this crumpling, none of which are sufficient, for some cause yielding a much larger amount of contraction is required to explain the facts here brought forward.

10. *On the Occurrence, Localities, and Output of the Economic Minerals of Canada.* *By* William Hamilton Merritt, *F.G.S.*

In this paper an endeavour was made to collect from the maps of the Geological Survey the number of localities where the various economic minerals found in Canada are situated, and the geological formation in which the occurrences exist.

From the trade and navigation returns, and the annual mining report of Nova Scotia, the mineral output for the past year has been compiled in order to show the present condition of mining industry in Canada.

The lack of encouragement and assistance to mining industry from the non-existence of any department in the Central Government for collecting reports and statistics on mining was alluded to forcibly.

The paper was accompanied by a list of the principal localities of the economic minerals of Canada, and the geological formation in which they occur. This list showed that indications of valuable ores are very numerous and widespread from Newfoundland on the Atlantic to British Columbia on the Pacific Ocean. The chief yield is shown to be from coal, gold, iron, gypsum, apatite and copper.

It was also pointed out that it was not intended to convey the idea that the different minerals were limited to the localities mentioned. They ought more to be looked upon as a few indications of an exceptionally large mining development which is hopefully looked forward to in the near future.

FRIDAY, AUGUST 29.

The following Papers and Report were read:—

1. *Phases in the Evolution of the North American Continent.* *By* Profesor J. S. Newberry, *M.D.*

As the day had been assigned to papers bearing on the ice period, Dr. Newberry limited his remarks to the condition of North America during the Tertiary and the Glacial age. He exhibited a map of North America on which the areas where glacial debris or inscriptions had been found, were coloured white. This showed that more than half of the Continent in the Glacial epoch was covered with perpetual snow or ice. The margin of the drift area passed from Newfoundland by George's Bank to Cape Cod, thence traversed the middle of Long Island, crossed Staten Island near its southern extremity, and New Jersey near Trenton. Thence it was deflected northward through Pennsylvania, forming an angle in the southern part of Western New York, thence passing diagonally across Ohio to Cincinnati, reaching (as recently shown by Prof. G. F. Wright) into Kentucky, thence running north-westerly or westerly through the States of Indiana and Illinois into Missouri, whence it followed nearly the course of the Missouri River to the Canada line. All the country included in and north of this semicircle has been glaciated, its topography profoundly modified, and the surface of a belt surrounding the Canadian Highlands 2,000 miles in length by nearly 500 in breadth, covered with a sheet of débris which after much erosion is still from 30 to 50 feet in thickness.

On the mountain ranges of the West, conspicuous evidence of glacial action is visible as far south as the north line of New Mexico. These phenomena afford conclusive proof of the reality of the ice period, and that the present climate and physical conditions of Greenland reached in that age as far south as New York and Cincinnati. The elevation of the Continent was at that time less than at present, since the Champlain Clays—the fine material ground up by the glaciers and washed down to the ocean—reach the sea level about New York. At Croton Point on the

Hudson they rise to 1,000 feet, at Albany 200, in the Champlain Valley, 350, at Montreal 500, in Labrador 800, at Davis Strait 1,000, and at Polaris Bay, as reported by Dr. Bissell, 1,600 feet above the ocean level. These clays contain Arctic shells from New York to Greenland, and hence are shown to have been deposited during the ice period.

The elevation of the northern position of the continent during the Tertiary—when land connection existed between America and Asia and between America and Europe, while a mild climate prevailed at the north—and the depression of the northern half of the Continent during the ice period make it impossible to accept the Lyellian hypothesis of topographical changes as causes of these differences of climate, and compel us to look to some extraneous influence for the cause of the cold of the ice period.

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2. *Marginal Kames.* *By* Professor H. Carvill Lewis, *M.A.*

During his exploration of the extreme southern edge of the ice-sheet in Pennsylvania the author had an opportunity of studying certain short ridges of stratified drift which appeared to represent in many cases a *backward drainage* of the melting edge of the glacier, and for which he proposed the name *marginal kames.*

After describing the general characters of kames, eskers, and osars, as studied in different parts of the world, the author reviewed the researches of American geologists upon this subject, and discussed the various theories as to the origin of these curious deposits. He then described in detail a number of marginal kames in Pennsylvania, indicating their relationship to the great terminal moraine (from which they are clearly to be distinguished), and to the lines of the present drainage. He showed that these kames are made of stratified sand and gravel, finest within and often coarse without, that they have a rude anticlinal structure, that boulders and till often lie on top of them, that they contain no shells or other indications of having been shore-lines of any kind, and that while bearing no relation to the movement of the glacier, their courses coincide with the general drainage of the region in which they lie.

It was argued that marginal kames are due to sub-glacial streams draining the edge of the ice-sheet. When the terminal moraine rested against an upward slope this sub-glacial drainage was backward or into the ice. A study of the terminal moraine had led the author to the same conclusion, and a number of examples were given to show in certain places the absence of any drainage outwards from the glacier.

Finally, the sub-glacial drainage of the modern glaciers of Greenland and of Alaska was alluded to, as also the aqueous nature of much of the till in the lowlands, all of which strengthened the conclusion arrived at concerning marginal kames, and concerning an extended sub-glacial drainage of the American ice-sheet.

(The paper was illustrated by a number of lantern views of kames and moraines, most of them from photographs taken in the field.)

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3. *Twelfth Report on the Erratic Blocks of England, Wales, and Ireland.*

See Reports, p. 219.

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4. *On Fluxion-Structure in Till.*[1] *By* Hugh Miller, *A.R.S.M.*, *F.G.S.*

It has long been recognised as one of the characteristics of the till that its long-shaped boulders are striated lengthwise. They have, as it has been concisely expressed, been 'launched forward end-on.' From the minute and magnifiable striæ upon the smaller (*e.g.* almond-sized) boulders it also appears that these at

[1] Published as part ii. of a Paper 'On Boulder Glaciation,' *Royal Physical Society of Edinburgh*, 1884.

least have been carried forward involved in the matrix, and glaciated chiefly by its particles. Under the microscope the particles exhibit most of the varieties of form and glaciation that are found among larger boulders. The structure of the till in many open situations shows that the axes of its stones have been turned by a common force in the direction of glaciation; exhibiting a rough arrangement comparable to the fluxion-structure of igneous rocks, the smaller boulders dividing around and apparently drifting past the larger, like the tide round an anchored skiff. This structure, which has been found by the author over many hundreds of square miles, chiefly in the North of England, indicates that at least a surface-layer of the till was dragged along, with a shearing movement of particle upon particle, producing intimate glaciation within its mass. Proofs are adduced that this moving layer was in general a surface-layer only, and that the till did not, as has often been supposed, move forward *en masse*, licking up its additions from beneath. This appears to be the only intelligible explanation of the order (as well as the structure) of the boulder-clays of which the author has any practical knowledge. In up-lying situations, where the drift consists of raw material, fluxion-structures are seldom to be detected. In sheltered spots they are not generally developed. They are characteristic of well-kneaded till in open situations, liable, however, to obscuration by contortions within the mass. Of twelve experimental attempts made near the watershed of England in East Cumberland, 600–900 feet above the sea, to determine the ice-movement from this structure alone, eight were correct, three indeterminate, and only one misleading. The pressure and movement capable of producing this widespread fluxion-structure seem to have been that of some mass vast and far-spreading—closely investing, slow-moving, and heavily dragging—such as glacier-ice. It needs only to be assumed that the confluent glaciers communicated something of their own movement and structure to the ground-moraine below.

5. *On the Glacial Origin of Lake Basins.* *By* Alfred R. C. Selwyn, *LL.D., F.R.S.*

As we are all aware, a great deal has been said and written on the manner in which the numerous rock basins now holding lakes have been formed, and that they have been assigned by Ramsay and many other geologists to the scooping power of ice.

In 1876, Ramsay, Hull, James Geikie, Judd, Fisher, Bonney, and Hugh Miller took part in the discussion of this question.[1]

On December 20, 1876, following the very interesting remarks on this subject by the authors above named, I wrote as follows:[2]

'In reading the correspondence and remarks on the origin of Lake basins, in the November and other numbers of the 'Geological Magazine,' it has occurred to me that the glacial origin of these basins may be explained without supposing the ice to have scooped them out of *solid rocks*, such as we now see around them. I have been led to this idea by a study of the phenomena connected with the decomposition of rocks *in situ* in southern latitudes—Australia and Brazil.

'Similar facts, I am informed, may likewise be seen in South Carolina, Georgia, &c.

'In these southern regions, which have never been glaciated, the surface over more or less extensive areas consists of quite soft decomposed rock, and mining operations have shown that the decomposition has been, from some unexplained cause, very irregular in its action, and that often great masses resembling boulders are quite unchanged though completely surrounded by the decomposed material; and the varying depth to which the decomposition has extended has resulted in producing an underlying *solid rock* surface, as full of hollows and depressions of all shapes and sizes as can be found in any of our northern lake regions. And if we admit that prior to the Glacial period these northern lake regions were similarly

[1] *Geological Magazine*, vols. iii. and iv., 1876 and 1877.
[2] *Geological Magazine*, vol. iv., p. 93.

covered with a mantle of decomposed rock, then the ice would not require to exert any very extraordinary power in order to scoop out any number of lake basins, and to leave enormous—apparently water-worn—boulders scattered over the face of the country as we now find them.

'In Brazil these, what may be called, "boulders of decomposition," with their surrounding decomposed matrix, were mistaken by Agassiz for glacial boulder drift. Their true value, however, having been subsequently pointed out by Professor Hartt, I examined some of these supposed glacial drifts in 1869, and from personal observation can endorse Professor Hartt's view of their nature.'

The letter above quoted seemed at that time—1876—to close the discussion; nor, so far as I am aware, has the theory I then advanced in explanation of the origin of these rock basins been since alluded to by any one. Therefore I thought it was not inappropriate or without interest, on this occasion, and surrounded as we are by a vast region of such lakes and lakelets, to again refer to the subject.

I have now nothing to add to the facts stated in my letter written eight years ago. I have, however, since then had considerable opportunities for studying the lakes of our great Laurentian region, as well as the action of winter ice around our coasts, and I am more than ever convinced of the inadequacy of ice, however thick, to scoop out solid hard rocks, or to produce the phenomena of lakes and boulders which our great northern glaciated regions now present. While if the explanation I have advanced is admitted, and as yet I have heard no objection to it, all difficulty seems to disappear.

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6. *On Points of Dissimilarity and Resemblance between Acadian and Scottish Glacial Beds.* By RALPH RICHARDSON, *F.R.S.E.*

Mr. Richardson said that, in his 'Acadian Geology,' Principal Dawson gave the following as a typical section of the superficial geology of Acadia—that is, Nova Scotia, New Brunswick, and Prince Edward Island—and as, in some respects, also applicable to Canada and Maine, viz.: At the bottom, peaty deposits; then unstratified boulder-clay; then stratified Leda-clay, indicating deep water; and, lastly, gravel and sand-beds, the Saxicava-sand indicating shallow water. Mr. Richardson pointed out wherein such a section differed from and resembled the glacial beds of Scotland. He said the latter showed no such orderly arrangement as the Acadian, and could not, as a rule, be divided into deep and shallow waterbeds. The marine shells in the Scottish beds are all mixed up together, regardless, as a rule, of the province—whether Arctic or British, or both—to which they properly belong; regardless of the depths which they usually tenant, and regardless of the deposit (whether clay, gravel, or sand) in which they are now found fossil. They are likewise met with at all heights, from the level of the sea to more than 500 feet above it. No system of dispersion of boulder-erratics from definite centres in Scotland seems as yet ascertained. The peaty deposits occurring in Principal Dawson's section *below* the boulder-clay or till, occur in Scotland above it. With regard to points of resemblance, the facies of the shells in Acadia and Scotland is similar, being of the Arctic and British-Arctic type. Again, both in Acadia and Scotland, all the shelly glacial beds occur above the unstratified boulder-clay or till. Mr. Richardson cited various Scottish sections to prove this, and remarked that the belief in earlier and later boulder-clays is of long standing in Scotland. He concluded by pointing out that, in their cardinal features, the Acadian and Scottish glacial beds seemed to coincide. In both Acadia and Scotland that great mass of unstratified clay known as *till* existed; and, doubtless, the geologists of the New World were, like those of the Old, puzzled to account for its origin with certainty and satisfaction. The question was left unsolved by the meeting of the British Association in Edinburgh in 1850, although then discussed by Hugh Miller and Professor John Fleming. The author hoped that during the present meeting some advance would be made in solving this great problem, as well as in correlating and arranging the glacial beds of Canada, Acadia, and Britain.

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7. *On the improbability of the theory that former Glacial Periods in the Northern Hemisphere were due to Eccentricity of the Earth's Orbit, and to its Winter Perihelion in the North. By* W. F. STANLEY, *F.G.S., F.R.Met.Soc.*

The theory of Dr. Croll, accepted by many geologists, is that former glacial periods in the Northern hemisphere were due to greater eccentricity of the earth's orbit, and to this hemisphere being at the time of glaciation in winter perihelion. This theory is supported upon conditions that are stated to rule approximately at the present time in the Southern hemisphere, which is assumed to be the colder. Recent researches by Ferrel and Dr. Hann, with the aid of temperature observations taken by the recent Transit of Venus expeditions, have shown that the mean temperature of the Southern hemisphere is equal to, if not higher than, the Northern, the proportions being 15·4 C. Southern, 15·3 C. Northern. The conditions that rule in the South at the present time are a limited frozen area about the South Pole, not exceeding the sixtieth parallel of latitude; whereas in the North frozen ground in certain districts, as in Siberia and North-Western Canada, extends beyond the fiftieth parallel; therefore by comparison the North, as regards the latitude in which Great Britain is situated, is at present the most glaciated hemisphere. As it is very difficult to conceive that the earth had at any former period a lower initial temperature, or that the sun possessed less heating power, glaciation in the North could never have depended upon the conditions argued in Dr. Croll's theory. The author suggested that glaciation within latitudes between 40° to 60° was probably at all periods a local phenomenon depending upon the direction taken by aërial and oceanic currents; as, for instance, Greenland is at present glaciated, Norway has a mild climate in the same latitude, the one being situated in the predominating Northern Atlantic currents, the other in the Southern. Certain physical changes briefly suggested in the distribution of land might reverse these conditions, and render Greenland the warmer climate, Norway the colder.

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8. *On Ice-Age Theories. By the* Rev. E. HILL, *M.A., F.G.S.*

On the Montreal Mountain, in the neighbouring quarries, at the mouth of the Saguenay River, and more or less everywhere over all Canada and all the north and north-west of this continent, are seen phenomena which imply a former vastly extended action of ice. The like are found over Europe and Asia, thus completely encircling the pole. Many theories have been propounded to account for these facts. It is proposed to pass these before you in review.

Any explanation ought to account not only for cold greater than the present, but for accumulations of snow and ice. A kindred phenomenon is the greater size of the Antarctic ice-cap. The supposed interglacial warm periods, and the unquestioned luxuriance of Miocene vegetation in Greenland, ought also to find their causes in any thoroughly satisfactory theory.

The theories which have been propounded fall into three groups, as Cosmical, Terrestrial, and Astronomical (or Periodical).

The Cosmical theories are Poisson's Cold-Space theory—incomprehensible; and the Cold-Sun theory of S. V. Wood and others—lacking any evidence.

The Terrestrial theories are numerous. Lyell's suggestion of Polar-continent and Equatorial-ocean is opposed by evidence that continents and oceans lay on much the same areas as now. The contrary view, Polar-ocean and Equatorial-land, would deserve consideration but for the same opposing evidence. The elevation view (Dana, Wallace), which alleges greater altitude of mountain-chains, disagrees with the strong evidence for land-depression during the period. The submergence view of Dr. Dawson agrees with this evidence, but requires elucidation. Alteration of ocean-currents (Gunn, J. S. Gardiner) is a most powerful agency, but would act locally rather than universally round the pole. Alteration of prevalent winds, hitherto worked out by no one, deserves attentive consideration. Conditions are conceivable which would produce over an area winds from cold quarters almost permanently. However, this seems open to the same objection as the preceding theory.

Last come the Astronomical or Periodical theories. A tilt of the earth's axis was suggested by Belt, but suggested as owing to causes which are wholly insufficient. Tilting from astronomical agencies is slight, though its action would be in the direction required. Herschel suggested the Eccentricity theory, but abandoned it. Adhémar's Precession theory, as explained by himself, involved an absolute fallacy. The celebrated view of Dr. Croll combines the Precession and Eccentricity theories into one. It exactly agrees with the Antarctic greater extension of ice, and provides an explanation of interglacial warm periods. The great difficulty in its way is to see how a mere difference in distribution through the year of an unchanged total heat-receipt can produce consequences so vast. The laws of radiation explain but a very minute part, the laws of evaporation perhaps rather more; but, so far as can at present be seen, both together are inadequate. Another serious objection is that the theory seems to require the climate of the northern hemisphere to be now in a state of change for the better, of which at present there appears no evidence.

Dr. Croll's elaborate explanations of the reaction of one effect upon another—fogs, deflection of currents, and the like—have no special connection with his own theory. They would act in all cases, and support all theories equally. The arguments, if admitted, would only prove that the earth's climates are in a state of highly unstable equilibrium, in which a slight cause may produce an enormous change. Nor are his arguments universally admitted.

In conclusion, Dr. Croll's theory seems inadequate: alteration of currents and winds are the most powerful causes suggested hitherto: further investigations ought to be made as to the nature and extent of the last series of changes in the outlines of the continents of the globe.

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9. *On the recent Discovery of new and remarkable Fossil Fishes in the Carboniferous and Devonian Rocks of Ohio and Indiana. By* Professor J. S. NEWBERRY, *M.D.*

The fishes described by the author consisted of:—

1. Two new species of *Dinichthys* from the Huron Shale (Upper Devonian) of Northern Ohio. Of these one is considerably larger than either of the two gigantic fishes described in the Geological Report of Ohio under the names of *Dinichthys Herzeri* and *D. Terrelli*, the cranium having a breadth of 3 feet 8 inches. This is about one-third larger than the largest specimen of *Dinichthys* before known, and two or three times as large as *Asterolepis* of Hugh Miller and *Heterostens* of Pander, its congeners. Another is a small species of *Dinichthys* of which the dorso-median plate is only 5 inches in breadth and 6 in length. The mandibles are not more than 6 to 8 inches in length, but are much worn by long use, indicating maturity.

2. The pavement teeth of a gigantic ray, *Archæobatis gigas*, Newb., from the lower Carboniferous of Indiana; the largest tooth is over 6 inches long by 4 inches wide and one and a half thick. These teeth formed several rows in the mouth above and below. In shape they resemble the teeth of *Psamodus*, but the enamelled surface was strongly ridged to prevent the slipping of molluscs, crustacea, &c., which formed the food of the fish.

3. *Diplognathus mirabilis*, Newb., a new genus and species in which the mandibles, set along the anterior portion with conical teeth, diverge at the symphysis, forming a fork which carries another row of strong, acute, recurved teeth. As such a forked jaw would be liable to be split, the rami were united at the symphysis by a strong ligament, deeply inserted in each bone. This apparatus, admirably adapted for catching slender and slippery fishes, is different from anything hitherto known among vertebrates.

4. The teeth of several species of *Mylostoma*, Newb., a new genus of fishes, probably allied to *Dinichthys* on the one hand and to *Ctenodus* on the other, in which the under jaw was provided with one or more pairs of powerful crushing

teeth, somewhat like a shoe-last in form, which played upon strong, flattened, bony plates that covered the roof of the mouth. These, like *Diplognathus*, are from the Huron shale of Ohio.

5. *Ctenodus Wagneri*, Newb., of which a remarkably large and finely preserved palate tooth was exhibited, discovered by Mr. Frank Wagner in the Cleveland shale near the base of the Carboniferous system at Cleveland, Ohio.

6. Spines of two species of *Edestus*, Leidy, from the Coal Measures of Indiana and Illinois, which show distinctly the structure and mode of growth of these remarkable defensive weapons. They are from 10 to 18 inches in length, very massive and strong, and consist of a series of sheathing segments firmly soldered together, each carrying a triangular, crenulated, and enamelled denticle from 1 to 2 inches in length. The spines are symmetrical and were therefore located on the median line like the spines of *Trygon*, and were probably the defences of large sharks or rays which inhabited the inland waters of the Continent in the Carboniferous age.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Papers and Report were read:—

1. *On the Fossil Reticulate Sponges constituting the Family Dictyospongidæ. By* Professor JAMES HALL, *LL.D.*

Our knowledge of these forms in America dates back to 1842, when Mr. Conrad described a peculiar fossil body under the name Hydnoceras (in the belief of its relation to Orthoceras). Subsequently in the same year another form by Vanuxem as a marine plant, and in 1862 Dawson as Algæ, and followed by Hall in 1863, who described several of the species under the name Dictyophyton; adopting Vanuxem's name Uphantænia for other forms.

In 1879 Mr. C. D. Walcott described a form referable to this group of fossils, from the Utica State, as Cyathophycus. In 1881 Mr. R. P. Whitfield published observations on the structure of Dictyophyton and its affinities with certain sponges, accompanied by a note from Dr. J. W. Dawson, on the structure of a specimen of Uphantænia, &c. (D. Walcott on the Nature of Cyathophycus.)

In the same year R. P. Whitfield (with note by Dr. J. W. Dawson) described two species of Dictyophyton and one of Uphantænia. (Bulletin of the American Museum of Natural History.)

In 1882, James Hall upon Dictyophyton, Phragmodictya, and similar forms with Uphantænia. (American Association for the Advancement of Science.)

In the European literature, the first notice of which was observed by the writer, of any fossil resembling Dictyophyton, is in Murchison's Silurian System (1839), where *Cophinus dubius* is described and figured.

(In Morris' Catalogue this fossil is placed in the category of *incertæ sedes*.)

In 1845, Mr. Coy, in his 'Synopsis of British Palæogoric Fossils,' describes *Tetragonis Danbyi* (*Receptaculites Danbyi*, Salter in MS.)

In 1874 (43) Mr. Salter, in his Catalogue of the Cambrian and Silurian Fossils in the Cambridge Museum, places *Tetragonis Danbyi* under the Spongidæ.

In 1880, Dr. Ferdinand Roemer has described the genera Dictyophyton and Uphantænia (Lethea geog. Thiel, p. 126 and 128), placing them among the Algæ. At a later date the same author places *Tetragonis Murchisoni*, *T. Danbyi*, and *T. Eifelensis* among the Spongidæ.

In 1883 the same author ('Zeitschrift der Deutschen Geologischen Gesellschaft,' Bd. XXXV., p. 704) has discussed the relations of *Tetragonis Eifelensis*, with Dictyophyton, describing and illustrating *Dictyophyton Gerolsteinensis.*

This group presents a great variety of form in the mode of growth. The structure of the frond which characterises every member of this family, may be described as a reticulation of tubular spicules forming rectangular meshes. In the simpler forms these meshes alternate in size and strength, owing to the regular alternation in the size of the bundles of spicules which determine the meshes. In the prismatic and nodose forms, certain bundles of spicules become very much developed and produce the characteristic form and ornamentation of the cup. The middle layer is uniformly reticulate; while the inner and superficial layer show an oblique and sometimes a radiate arrangement of spicules. In the highly-ornamented species, the outside layer of spicules is often produced into tufts, spines, and intersecting fimbria or laminæ of greater or less prominence.

In the foreign literature accessible to the writer, there are six species of this family described. In preparing a memoir on the subject he has been able to recognise, from personal examination, thirty-seven American forms, the oldest geologically being from the Utica State, and the latest form from the Keokuk limestone of the Carboniferous system. These thirty-seven species have been described under the following genera, viz.:—Cyathophycus, Walcott; Dictyophyton, Ectenodictya, Lyrodictya, and Physospongia, Hall; and Uphantænia, Vanuxem.

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2. *On the Lamellibranchiata Fauna of the Upper Helderberg, Hamilton, Portage, Chemung and Catskill Groups (equivalent to the Lower, Middle and Upper Devonian of Europe); with especial reference to the Arrangement of the Monomyaria and the Development and Distribution of the Species of the Genus Leptodesma. By* Professor JAMES HALL, *LL.D.*

The investigation of the fossil Lamellibranchiate shells has been carried on as a part of the work of the palæontology of the State of New York. Already ninety plates have been lithographed, and these with their explanations giving the names of the fossils have been distributed to the principal scientific societies of Europe and America. The full text of the descriptions of the species of the Monomyaria, 268 pages and plates I.–XXXIII. and LXXXI.–XCII., have been published complete. The remaining portions of the work are well advanced.

The Monomyaria are described under twenty-one genera and 284 species. The remaining portion of the work contains illustrations of about 215 species under thirty-three genera.

The author has found it necessary to make subdivisions among the forms usually referred to Aviculopecten, and it has seemed equally important to propose other generic names for forms which have heretofore been indiscriminately referred to Avicula, Pterinea, Pteronites, &c. While the essential internal characters have been regarded as of primary importance, such an arrangement has been made of the species, that the student may determine their generic relations from the general form and exterior markings alone. Since, in all forms of the fossil Lamellibranchiata the interior surface usually remains attached to the matrix, a reliable means of identifying the genera by external characters becomes a consideration of primary importance.

Among the new genera proposed, Leptodesma presents some features in its development and distribution which may be of more than ordinary interest. The upper part of the Chemung group exhibits such physical features as might be expected from a gradually shallowing sea and the approach of estuarine conditions. Numerous circumscribed areas appear to have existed, and these, while often characterised by an abundant fauna, contain few species, and these forms are extremely limited in their geographical range. The species of the genus Leptodesma are often abundant and very characteristic of certain horizons within limited areas, but rarely have a general distribution through the strata, as some species of the Brachiopoda.

They seem to have been developed in shallow lagoons, and the characteristic species of one of these areas rarely appear in another. At the same time the physical condition or other causes have operated to develop a remarkable variety in form, and as it does not seem possible to separate these forms generically, it becomes necessary to arrange them in distinct groups or sections.

These sections have been made with reference to the most prominent characteristic of the forms. Of those already known and described, nineteen species are conspicuously marked by a posterior spiniform extension of the hinge-line, and form the section Spirifera. In another group, where the spiniform extension is not conspicuous, the umbo is remarkably prominent, and ten species are arranged under the section *Umbonata.* In other forms, the anterior extremity becomes nasute or rostrate, and seventeen species are placed under the section *Rostrata.* Other forms are nearly flat and spreading, with little or no extension of the hinge beyond the body of the shell, and these forms are placed in the section *Patulata.* Other forms have the hinge-line shorter than the width of the shell, the anterior end rounded or truncate, and having the general form of *Arca.* Of these, six species are placed under the section *Arcoidea.* Still, a few other forms have the aspect of Mytilus, and two species are placed under the section *Mytiloidea.* Here we have a group of shells among which we find no means of generic separation; and yet within its limits the species are developed in the direction of several other genera, so far as regards form and other external characters. The studies of this genus have been made from collections of many hundreds of specimens with the result stated. An examination of a more limited number of examples could easily have led to the reference of some forms to the genus Mytilus, some to Arca, and others to new and distinct genera.

The forms of this genus, as at present limited, certainly exhibit evidences of a most remarkable development in form and external characters; and are well worthy the study of the specialist in this department of Palæontology.

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3. *On the Archæan Rocks of Great Britain. By* Professor T. G. Bonney, *D.Sc., LL.D., F.R.S., Pres.G.S.*—See Reports, p. 529.

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4. *The Eozoic Rocks of North America.*[1] *By* T. Sterry Hunt, *LL.D., F.R.S.*

Among the pre-Cambrian strata of North America there is an invariable succession of crystalline stratified rocks, the constituents of which become progressively less massive and less crystalline, until we reach the sediments of palæozoic time; of which the Cambrian is regarded as the basal member. Since all of these pre-Cambrian rocks, with the exception, perhaps, of the lowest or fundamental gneiss, present evidences, direct or indirect, of the existence of organic life at the time of their deposition, it seems proper to include them under the general title of Eozoic, proposed by Sir William Dawson. The term Archæan appears too indefinite in its signification, and moreover is not in accordance with the nomenclature generally adopted for the great divisions succeeding.

The following are the subdivisions adopted by the author:—

Taconian . . .	Quartzite, limestones, and micaceous and argillaceous schists (including the *Animikie* series of Lake Superior) 4,000 to 10,000 feet thick.
Montalban . .	Fine grained white gneisses, passing into granulites, or into coarse-grained mica-schists, over 20,000 feet thick.
Huronian . .	(= Pebidian) schistose rocks, with stratified 'Gabbros;' 18,000 feet.
Arvonian . . .	Halleflintas, passing into quartziferous porphyry; many thousand feet thick.

[1] Printed in full in *Geol. Mag.* dll III. vol. i. pp. 506–510.
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Norian . . . Quartzless granitoid or gneissoid rocks, with plagioclase felspars (Norites); 10,000 feet.

LAURENTIAN.

Grenville Series. Granite, with hornblendic gneiss, quartzite, pyroxenite, serpentine, magnetite, and crystalline limestone, containing *Eozoon*; 15,000 to 20,000 feet.

Ottawa Gneiss . Granitoid gneiss.

All these are unconformable to each other, save perhaps the Arvonian and Norian.

The Arvonian or petrosilex group intervenes between the Laurentian and the Huronian, but the peculiar characters of the Norian, and its localisation to some few limited areas in Europe and North America, make it difficult for us, as yet, to define its precise relations to the Arvonian. The Norian, however, probably like the Arvonian, occupies a horizon between Laurentian and Huronian. Much time may pass, and many stratigraphical studies must be made before the precise relations of the Huronian and the succeeding Montalban can be defined. It seems probable, in the present state of our knowledge, that the Montalban series was, in many cases, deposited over areas where the Huronian had never been laid down. Notwithstanding the great geographical extent, and the importance of these two series, neither can claim that universality which probably belonged to the primitive granitic substratum, a universality soon interrupted by the appearance of dry land; an event which preceded Huronian time.

The author sketched the history of opinion regarding the relations of the lower Palæozoic to the Eozoic rocks; he stated that recent researches have shown that the Transition Greywacke of Eaton, which was the Upper Taconic of Emmons, and includes the primordial or Cambrian fauna, rests in unconformable stratification upon the various crystalline Eozoic rocks. The Quebec group of Logan, as well as what he called the Potsdam group, is this same Cambrian or Transition Greywacke. The Hudson River group also, as first described by Vanuxem and by Mather, and later by Logan up to 1860 (when he changed its name to that of the Quebec group) is nothing else than this same Cambrian Greywacke, with the addition, in certain localities, of a portion of Taconian, and in other of schistose beds containing the second or Ordovician fauna (Utica and Loraine shales). The above explanation becomes necessary for the reason that the Canadian geologists (Logan and the present writer) formerly described certain crystalline schists, chiefly Huronian, as altered rocks of the Hudson River group, and later (from 1860 to 1867) as of the Quebec group.

The cupriferous series of the basin of Lake Superior (the distinctness of which was maintained by the writer in 1873, when he called it the Keweenaw group, a name which he subsequently changed to Keweenian), which has a thickness probably greatly exceeding 20,000 feet, was also by Logan referred to the Quebec group. It has, however, been shown by later observers that the fossiliferous sandstones which rest in horizontal layers upon the inclined strata of the Keweenian, belong to the Cambrian, and hold the fauna of the Potsdam. The conglomerates of the Keweenian cupriferous series contain portions alike of Laurentian Arvonian, Huronian, and Montalban rocks, and appear, according to the latest observations, to overlie the schists which we have referred to the Taconian. The sandstones and argillites of the Keweenian, which are interstratified with great masses of melaphyre, are uncrystalline. It remains to be determined whether the intermediate Keweenian series has greater affinities with the Taconian than with the Cambrian.

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5. *First Impressions of some Pre-Cambrian Rocks of Canada. By* Professor J. F. Blake, *M.A.*, *F.G.S.*

The author had examined the Huronian rocks in their typical locality on the north shore of Georgian Bay, and the rocks referred to the same group in some of the other localities. He saw no relation whatever between the typical Huronians and the British 'Pebidian,' and other rocks which had been compared to them, though the latter had some resemblance to the 'Animike' group of Port Arthur. He drew special attention to the volcanic nature of a great part of the Hastings series, and compared these with the so-called 'Arvonian' portion of the Pre-Cambrian of Great Britain.

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6. *On the Southward Ending of a great Synclinal in the Taconic Range.*[1] *By* Professor JAMES D. DANA, *LL.D.*

The Taconic Range, which gave the term 'Taconic' to geology, lies in Western New England, between Middlebury, in Vermont, on the north, and Salisbury, in Connecticut, on the south. In former papers, published in the 'American Journal of Science,' the author has shown, first, that the rocks constituting the range vary as we go from north to south, from roofing-slate and hydromica (or sericite) schist to true chloritic and garnetiferous mica schists; secondly, that these schists lie mostly in a synclinal or compound synclinal; thirdly, that the crystalline limestone along the eastern foot is one with that along the western, the limestone passing under the schist as a lower member of the synclinal; and, fourthly, that since the limestone contains in Vermont (according to the discoveries of the Vermont Geological Survey, and also of Mr. A. Wing), and in the State of New York, fossils of the Lower Silurian, ranging from the inferior divisions to the higher, the Taconic schists are probably of the age of the Hudson River group or Llandeilo flags.

The author's papers further show that while a large part of the Taconic Range has an eastward dip on both the east and west sides, a southern portion about twelve miles long, consisting of Mount Washington in south-western Massachusetts and its continuation into Salisbury, Connecticut, is a broad tray-shaped synclinal, the dips of the two sides being toward one another, like the sides of an ordinary trough. The width of the broad synclinal between the limestone belt on either side is about five miles.

As the result of investigation during the last two years, the synclinal character of this Mount Washington part of the Taconic Range is illustrated in the paper by new sections, and by facts connected with the dying out of the great synclinal (or compound synclinal) in the town of Salisbury.

The mean height of Mount Washington above the sea-level is about 2,000 feet, and above the wide limestone region on either side and to the south, about 1,250 feet. The synclinal virtually ends along an east and west line through the village of Lakeville, in the town of Salisbury, where a beautiful lake lies within the limestone area. The surface of the mountain region descends 1,000 feet in the southern, or last, three miles; and in the latitude of Lakeville the width, as the map presented shows, diminishes abruptly from five miles to a narrow neck of six-tenths of a mile. The area south is of limestone, and the neck of schists referred to is hardly 150 feet in height above it.

The limestone may in some places be seen emerging from beneath the schist at a small angle; and at one locality a low oven-shaped anticlinal of limestone has the schist covering all but a narrow portion at top; the quarrymen had to remove the schist to work at the limestone. Several narrow strips or belts of limestone, S. 15° W. in direction, corresponding with the direction of this part of the range, show out through the sides of the mountain where local anticlinals have had their tops worn off. Further, the dip of the schist over much of the southern slope is southerly and at a small angle, but with many local anticlinals and synclinals. In addition, there are small areas of schist *in the limestone* region, like straggling portions of the dwindled mountain, which appear in general to be remains of local flexures.

There is the plainest evidence that the limestone formation of southern and

[1] Printed in full in *American Journal of Science*, Ser. 3, vol. xxviii. pp. 268–275, with map and six woodcuts; 1884.

south-eastern Salisbury comes out from beneath the dwindled, flattened-out and worn-off mountain synclinal. And the reason why this limestone is exposed to view over plains miles in width, east and west of the Taconic Mountain, as well as to the south, is simply this, that the once overlying schist has been removed because in badly broken anticlinals and synclinals.

The paper closed with an allusion to the orographic, stratigraphical and lithological interest of the facts, and to their important bearing on the question of the origin and chronology of certain kinds of crystalline rocks, such as chloritic, garnetiferous and staurolitic mica schists, as well as others less coarsely crystalline.

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7. *Notice of a Geological Map of Monte Somma and Vesuvius.* *By* H. J. Johnston-Lavis, *M.D., F.G.S.*

Vesuvius (using this term for the whole volcanic pile) is of all known volcanoes that one which has been most studied and written about, its phenomena more investigated than any of its rivals, and although its early history is not so complete as that of its fellows, Etna and Stromboli, yet its eruptions during the Christian Era are so intimately connected with the ill-fated cities of Pompeii, &c., and thus with archæology, that this alone is sufficient to make it most prominent.

But beyond this its geological structure is so varied, its products so numerous, its past and present historic activity permitting the comparative study of these to be carried on, together with its convenient size and accessibility, led the author some years since to conceive the idea of minutely investigating its phenomena and structure, which it is his intention to publish in the form of a monograph and a geological map.

The two out of six sheets forming the splendid map constructed in 1876, by the students of the Italian School of Military Topography, on the large scale of 1 : 10,000, have been coloured in seven different tints, indicating the various products of different eruptive periods [1] with indications of dykes, of lateral craterlets, of springs simple, or thermo-mineral, blowing caverns, buried antiquities (of geological interest), &c. The work has now extended over four summers, and the examination of about half, including the most complicated part of the mountain, has been completed, and the author hopes that if he is able to continue the work during the present and next summer, to finish it by the autumn of 1885. This long time occupied in the work is dependent on various causes. 1st. The great intricacy of the geology. 2nd. The thick vegetation requiring very numerous traverses. 3rd. The author, for professional reasons, being only able to devote the summer months to the work, the hot Neapolitan sun of this season is so exhausting that not more than four field days a week are possible, and even then at a considerable sacrifice of health. In the two sheets exhibited are a few blanks that require further study or have been left for various reasons. The work on the other four sheets is of so scattered a nature at present that it was not thought advisable to exhibit them till in a more complete state.

Besides the actual mapping, a large amount of notes of a descriptive character have been collected, and all the important features and sections photographed on a large scale. Specimens of the various lavas, ejected blocks, tufas, pumices, &c., have been carefully selected as the work went on, so that the author has now in his possession by far the most complete geological collection from the mountain yet extant, which is open to the study of anyone who should care to investigate its contents.

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8. *Report on the National Geological Surveys of Europe.*—See Reports, p. 221.

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[1] See Memoir by the author in *Quarterly Journal of the Geological Society*, January 1884.

9. *The Value of detailed Geological Maps in relation to Water-supply and other Practical Questions.* *By* W. Whitaker, *B.A., F.G.S.*

Those maps of the Geological Survey of England in which various divisions of the Drift have been coloured tell us, as a rule, a very different tale from the corresponding sheets in which the Drift is ignored, and it is only these Drift maps that really give us a true idea of the nature of the surface. Indeed in many districts a geological map that does not show the Drift is comparatively useless for most practical purposes, at all events in a populous country like England, where in some cases such a map is even misleading. Moreover, it is not enough merely to mass Drift as such, but its constituent members should be fairly distinguished, not merely with regard to their classification or relative age (and therefore their order of superposition), but also as to their composition, whether of clay, loam, or gravel and sand. To illustrate this there were exhibited copies of the two versions of many of the Geological Survey Maps of the London Basin, with and without Drift, from which the following important points could be at once seen:—

1. Large tracts, shown as Chalk on one version, really consist, at the surface, of the generally impervious Boulder Clay, whilst over others the Chalk is covered by Brickearth and Clay-with-flints; all these beds being such as give a character to the country very different from what we find where the Chalk is bare.

2. Parts of the wide-spreading area of the London Clay (of the Driftless maps) are really quite altered, and deprived of their clayey character, by the sheets, long strips, and more isolated patches of gravel and sand that occur so often, whether along the river-valleys or over the higher plains.

3. The sandy permeable Crags are in great part hidden by Drift, which, though often consisting of sand and gravel, is sometimes of Boulder Clay. Indeed so widespread is the Glacial Drift in the greater part of Norfolk and Suffolk that only a Drift edition of the Geological Survey Maps of the eastern parts of those counties has been issued; a map without Drift would necessarily be a work of fiction.

To illustrate the important bearing which these Drift maps have on a great question, that of water-supply from the Chalk, the author also exhibited some special maps, which he has made to show the areas over which rain-water has access to the Chalk, as distinguished from those over which the surface-water cannot sink down into the Chalk, or can only do so very partially. These maps were more particularly noticed in Section G.

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10. *On the Mode of Occurrence of Precious Stones and Metals in India.* *By* V. Ball, *M.A., F.R.S.*

For full 3,000 years India has been known as the source of precious stones and metals, but scarcely 200 years have elapsed since other countries yielding precious stones have entered into competition with her; and it is only within the present century that she has ceased to hold a pre-eminent position as a supplier of the markets of the world.

In order to arrive at a full and satisfactory elucidation of this subject, two branches of inquiry must be undertaken, one based upon what has been actually ascertained by careful geological exploration of the country, and the other upon such historical records as are available of the former production of the minerals in question, and of the indications of the sites where they were mined.

By means of our present knowledge of the geology, it has become possible to give definite form to many vague statements by early writers, and to recognise the actual positions of mines which are now, by the people of the localities themselves, forgotten and deserted. In the majority of these cases, had the geologist not got the historical hand to guide him he would be unwilling to predicate the presence of such minerals from mere superficial examination.

As a collateral result, many of the widespread myths and fables connected with mining have proved to have originated in peculiar local customs. They rest, therefore, on more substantial bases of facts than could have been suspected by any one unacquainted with these customs.

This method of combining the results of geological research with historical records the author has found on previous occasions to have the advantage of bringing the geologist into touch with the rest of humanity, attracting as it does the interest of historians, linguists, and others, who find in the facts so presented to them pabulum applicable to the requirements of their own particular pursuits.

In this paper it will not be necessary or suitable to enter at length into details —the author having done so elsewhere.[1] His object is rather to direct attention to the subject generally, and to make known the fact that much has been accomplished of late years, which has not as yet found its way into manuals and encyclopædias. Most of the information to be found in such works is far behind our present knowledge; and, where not actually incorrect, has been superseded by fuller and more accurate observations. The subjects taken for special consideration are the following:—Diamond, ruby, sapphire, spinel, beryl, emerald, lapis-lazuli, gold, silver. The steel of India, or *wootz*, might be included here, since at least 2,000 years ago it was one of the most precious productions of India.

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11. *What is a Mineral Vein or Lode?* *By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

The author quoted briefly the definitions of a mineral vein given by Werner, Carne, B. von Cotta, Grimm, A. von Groddeck, Geikie, Sandberger, and Serlo, who, in common with most geologists, have looked upon mineral veins as 'the contents of fissures.' While admitting that a very large number of veins may be so described, the author contended that the exceptions are sufficiently important and numerous to warrant a change in the definition. He is of opinion that many of the principal and most productive tin-lodes in Cornwall are simply tabular masses of altered granite adjacent to fissures; and he brought forward the opinions of other geologists to show that certain veins in the English Lake district, the Tyrol, Nova Scotia, Nevada, Colorado, California, and Australia are not filled-up fissures. In conclusion, he proposed the following definition: 'A mineral vein or lode is a tabular mineral mass formed, more or less entirely, subsequently to the enclosing rocks.'

TUESDAY, SEPTEMBER 2.

The following Papers and Reports were read:—

1. *Plan for the Subject-Bibliography of North American Geology.* *By* G. K. Gilbert.

The United States Geological Survey is engaged on a Bibliography of North American Geology. The work when completed will give the title of each paper, with the title-page of the containing book, and the number of plates, the whole being arranged alphabetically by authors.

There is in contemplation also the simultaneous preparation of a number of more restricted bibliographies, each covering a division of geologic literature. The plan includes abbreviated titles of papers, with reference to the pages on which the special subjects are treated, the entries in each bibliography being arranged alphabetically by authors.

The selection of topics for treatment in this manner involves the classification of geologic science, and the author submitted a tentative classification, requesting the criticisms of geologists.

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[1] 'Economic Geology of India,' and 'A Geologist's Contribution to the History of India,' *Proc. Roy. Dub. Soc.* 1883.

2. *On some remains of Fish from the Upper Silurian Rocks of Pennsylvania.* *By* Professor E. W. CLAYPOLE, *B.A.*, *B.Sc.* (*Lond.*), *F.G.S.*

The earliest vertebrate animals yet known from any part of the world are some remains of fish in the Upper Silurian rocks of England. They are for the most part of three types. First, short fin-spines, named by Agassiz *Onchus tenuistriatus*; second, fragments of shagreen, or the skin of a placoid fish (*Thelodus* and *Sphagodus*), belonging probably to the same that carried the spine; and third, ovate, finely striated plates or shields, supposed to be the defensive armour of some fish, unlike any now living.

No one has doubted the ichthyic nature of the first and second of these three forms. But as regards the third there has been much controversy. Evidently allied to *Cephalaspis,* its right to the name of fish has been called in question, and suspicion has been raised in regard to the whole family of the Cephalaspids.

On the whole, however, it seems best to retain them in the class of fishes, and to this conclusion Professor Huxley evidently inclines in the conclusion of his 'Essay on the Classification of the Devonian Fish.' One may expect some, or even considerable, divergence of structure from the usual ichthyic types in such early forms.

These English fossils occur in the lowest beds of the Devonian (Cornwall), and in the highest beds of the Silurian (Shropshire and Hereford). The well-known Upper Ludlow 'bone bed' has yielded them in considerable quantity, and one specimen is reported by Sir C. Lyell in his 'Elements of Geology' (1865) as 'discovered from the Lower Ludlow, beneath the Aymestry limestone.' Below this horizon I have never heard of their occurrence.

The English Ludlow, taken as a whole, has been usually correlated with the Lower Helderberg of North America, and on good grounds, both containing *Eurypterus* and *Pterygotus.* The English Lower Ludlow and the Water-Lime or basal beds of the North American Lower Helderberg are the lowest strata containing these fossils. On both sides of the Atlantic they range from this level upwards into the Devonian.

The oldest vertebrate fossils yet announced from America are those found in the Corniferous limestone or Lowest Devonian of Ohio. Possibly the beds at Gaspé on the Gulf of St. Lawrence are somewhat lower; as they have yielded *Cephalaspis,* which is not yet known from Ohio, and *Coccosteus,* of which Ohio has yielded only a single specimen. No authenticated fish-fossil has yet been announced from the Upper Silurian rocks of America.

It is true that reports of the discovery of such remains have been published at various times, but investigation has proved them all erroneous. (See 'Palæontology of New York,' vol. ii. pp. 319, 320, pl. lxxi.; 'American Journal of Science,' second series, vol. i. p. 62; 'Palæontology of Ohio,' vol. ii. p. 262.)

During his recent work on the Palæontology of Perry County, Pennsylvania, the author came upon some fossils which at once suggested relationship to the Ludlow group above described. Among them were a few spines recalling *Onchus tenuistriatus,* but with some differences. He has named them *Onchus Pennsylvanicus.* With them he discovered abundance of specimens bearing a strong resemblance to *Scaphaspis,* but larger, and differing in some other respects. These he named *Palæaspis* (*P. elliptica* and *P. bitruncata*).

Comparing these with *Scaphaspis* we find them much thinner, not exceeding one-fortieth of an inch in thickness; whereas specimens of *Scaphaspis* in the author's possession from Cornwall are in some places much thicker. The striation on both is equally fine, but is rather less regular on the American specimens. These also show no trace of the spine in which the shield of *Scaphaspis* terminates, as shown by Murchison in 'Siluria.'

No traces of the English fossil shagreen—*Thelodus* and *Sphagodus*—have been found in the Pennsylvanian beds, though it abounds in the Ludlow rocks.

The fossils were found in a bed of sandstone about 200 feet below the base of the Water-Lime in Perry county, Pennsylvania; near the top of the great mass of variegated shale composing the Fifth Group of Rogers in the First Survey of

Pennsylvania. This shale in New York immediately overlies the Niagara limestone, which is correlated on satisfactory evidence with the Wenlock limestone of England. Ten or twelve species are common to the two beds.

It seems, therefore, that the great mass of coloured shale, near the top of which these fossils were found, and which is a continuation of the Onondaga group of New York, has no representative in the British series, but corresponds to an interval between the Upper Wenlock and the Lower Ludlow. (For details regarding the correlation of these beds in Pennsylvania with those in New York, see a paper by the author in 'Proc. Amer. Phil. Soc.' for 1884.)

It is consequently a necessary inference that the beds yielding *Palæaspis* and *Onchus* in Pennsylvania are somewhat older than those containing *Scaphaspis* and *Onchus* in England.

Microscopic examination of the specimens, and a comparison of their structure with that of *Scaphaspis* and *Cephalaspis*, are in progress, and the details will be given below. Other fossils in the author's possession indicate the possible existence of fish at a still earlier date, but the material is not yet worked out.

The microscopic structure of *Palæaspis* corresponds in all important points with that of *Scaphaspis* as figured by Huxley ('Q. J. G. S.' vol. xiv., pl. xv., fig. 1). The basal cellular and vascular layers are present in both, but the latter presents a regularity of structure to which *Scaphaspis* affords no parallel. A section parallel with the striation presents a beautiful forest-like appearance produced by the rise and divergence of the tubules from the larger vessels. The most remarkable anatomical peculiarity of these fossils is also one in which they coincide with the Pteraspids of England. All the species belonging to this group are distinguished by the total absence of the bone cells (*lacunæ*) and the connecting tubules (*canaliculi*) characteristic of all other bone-structure in all classes of the animal kingdom. This absence was the greatest objection to the admission of the fossil to this class of fishes. Though now overruled, its importance is in no wise diminished. To receive these forms the group of Heterostracans was established by Professor Lankester in 1869 as a sub-division of Huxley's family of Cephalaspids. So profound a difference, however, forming a distinct line of demarcation between the fossils of the family seems to demand bolder recognition, and it was proposed to raise Lankester's sub-family of Heterostracans into a distinct family under the name of Pteraspids (*Pteraspidæ*) and the name of Cephalaspids (*Cephalaspidæ*) be retained for those forms exhibiting true bony tissue, and composing the sub-family of the Osteostracans of Lankester.

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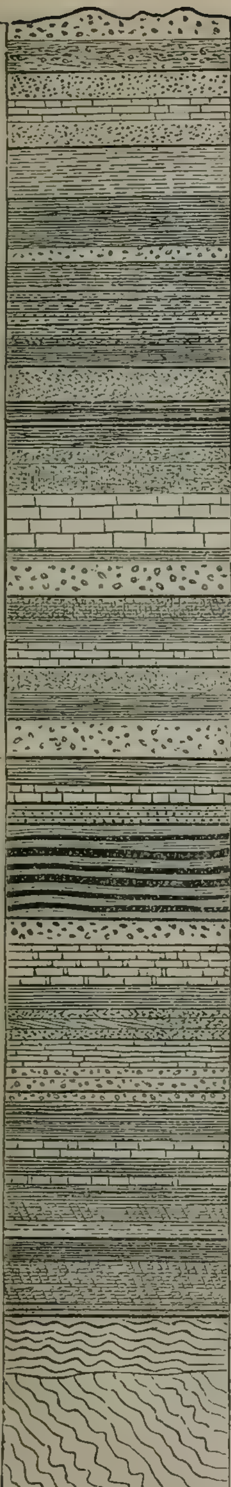
3. *On American Jurassic Mammals.* *By* Professor O. C. Marsh.

The first Jurassic Mammals discovered in this country were found in 1878, in the Atlantosaurus beds of Wyoming Territory, and described by the author. Other discoveries in the same region soon followed, and a systematic exploration of this geological horizon has been continued by the author up to the present time.

This horizon in the upper Jurassic, with its characteristic fossils, has been traced by the author along the flanks of the Rocky Mountains for a distance of more than three hundred miles. Its position is shown in the geological section on page 735. The deposits are lacustrine, and the accompanying fossils are dinosaurs, pterodactyles, crocodiles, lizards, and fishes.

Remains of Mammals have been found by the author at several points along the line of this horizon for two hundred miles or more, but the most productive locality is in the region where the first discovery was made. At one point, from a space scarcely larger than the room in which the author was speaking, remains of more than three hundred individuals of Jurassic Mammals have been obtained, a good indication of the wonderful richness of the fauna here entombed.

Other localities have yielded many important specimens, so that up to the present time, the author has secured the remains of nearly or quite four hundred individuals of Jurassic Mammals. So far as known, no other specimens of this class have been secured from this formation in America.



Era	Period	Epoch	Beds	Vertebrates
CENOZOIC.	Recent. Quaternary.			Tapir, Peccary, Bison, Llama. *Bos, Equus, Megatherium, Mylodon.*
	Tertiary.	Pliocene.	Equus Beds.	*Equus, Tapirus Elephas.*
			Pliohippus Beds.	*Pliohippus, Tapiravus, Mastodon, Aceratherium, Bos, Morotherium.*
		Miocene.	Miohippus Beds.	*Miohippus, Diceratherium, Thinohyus.*
			Oreodon Beds.	*Oreodon, Eporeodon, Hyænodon, Hyracodon.* Edentates (*Moropus*).
			Brontotherium Beds	*Brontotherium, Menodus, Mesohippus.*
		Eocene.	Diplacodon Beds.	*Diplacodon, Epihippus, Amynodon.*
			Dinoceras Beds.	*Dinoceras, Tinoceras, Uintatherium, Palæosyops, Orohippus, Helaletes, Colonoceras.*
			Green River, or Heliobatis, Beds.	*Heliobatis, Amia, Lepidosteus.*
			Coryphodon Beds.	*Coryphodon, Eohippus.* Lemurs, Tillodonts, Rodents, Serpents.
MESOZOIC.	Cretaceous.		Laramie Series, or Hadrosaurus Beds.	*Hadrosaurus, Dryptosaurus* (*Lælaps*).
			Fox Hill group.	
			Colorado Series, or Pteranodon Beds.	Birds with Teeth (*Odontornithes*), *Hesperornis, Ichthyornis.* Mosasaurs, Pterodactyls, Plesiosaurs.
			Dakota Group.	
	Jurassic.		Atlantosaurus Beds. Baptanodon Beds.	Dinosaurs, *Brontosaurus, Diplodocus, Stegosaurus, Allosaurus.* Turtles. Crocodiles. Mammals (*Dryolestes, Stylacodon, Tinodon, Ctenacodon*).
	Triassic.		Otozoum, or Conn. River, Beds.	First Mammals (*Dromatherium*). Dinosaur Foot-prints, *Amphisaurus.*
PALEOZOIC.	Permian.		Nothodon Beds.	Reptiles (*Nothodon, Sphenacodon*).
	Carboniferous.		Coal Measures, or Eosaurus Beds.	First Reptiles (?) *Eosaurus.*
			Subcarboniferous, or Sauropus Beds.	First known Amphibians (Labyrinthodonts), *Sauropus.*
	Devonian.		Dinichthys Beds.	*Dinichthys.*
			Schoharie Grit.	First known Fishes.
	Silurian.		Upper Silurian.	No Vertebrates known.
			Lower Silurian.	
	Cambrian.		Primordial.	
	Archæan.		Huronian.	
			Laurentian.	

Section to illustrate Vertebrate Life in America.

These interesting fossils have been only partially investigated, but the author has already described, from the more interesting forms, eight genera and seventeen species, representing at least two widely different groups.

The first genus described was *Dryolestes*, of which five species are now known. The second genus was *Stylacodon*, with two species. The third was *Tinodon*, represented by four species. *Ctenacodon*, with two species, and *Diplocynodon*, with a single species, were next described, and, subsequently, *Allodon* and *Docodon*, each having only a single species.

All these genera are apparently quite distinct from any European forms, yet they are clearly allied to those described from the Jurassic of England.

One species alone appears to be identical, generically, with *Triconodon* of Owen.

The genus *Ctenacodon*, related to *Plagiaulax* of Falconer, differs widely from all the others, and these two genera have been referred by the author to a new order, *Allotheria*. They resemble the Marsupials in many respects, but are apparently distinct from that group.

The remaining known Jurassic Mammals have been placed by the author in a distinct order, *Pantotheria*. They differ from the Marsupials in many important characters, and appear to belong to a more generalised group, having many characters of the Insectivors.[1]

No Cretaceous Mammals are known, and from the Triassic deposits of this country, only a single species (*Dromatherium Sylvestre*, Emmons) has been brought to light.

The author is still engaged in the investigation of American Mesozoic Mammals, and, when this is completed, the results will be brought together in a memoir on the subject.

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4. *On the Geology of South Africa.*
By Professor T. Rupert Jones, *F.R.S.*, *F.G.S.*

The contour of the South coast is parallel with the outcrop of the strata in the interior, from Oliphant's River (31° 40′ S. Lat.) on the West coast, southward to the Cape, and then eastward to about 33° 30′ S. Lat. Here the edges of the strata, formerly bending round to the north, have been swept away to a great extent; but their outcrop is again seen on the East coast at St. John's River (31° 40′ S.Lat.), where they strike north-eastwardly through Natal, probably far up the country.

1. Gneissic rock and the *Namaqualand Schists* apparently underlie the others, coming out on the north-west, and exposing a narrow strip on the South coast. 2. Micaschists and Slates, interrupted by Granites here and there, form a curved maritime band, from about 30 to 70 miles broad, and are known as the *Malmesbury Beds* (Dunn). These and the beds next in succession (the *Bokkeveld Beds*, 3) are overlain unconformably by the *Table-Mountain Sandstone* (4), 4,000 (?) feet thick, which forms patches and extensive ridges, and possibly dips over No. 3, to join No. 5, the *Witteberg Beds*. Nos. 3 and 5, together about 2,100 feet thick, lie parallel, and form a concentric inner band. The former contains *Devonian* fossils; the latter is probably of *Carboniferous* Age (with *Lepidodendron*, &c.), and forms the Wittebergen and Zwartebergen in the Cape District, and the Zuurbergen in Eastern Province.

The *Ecca Beds* (6) come next; Lower Series, 800 feet; Conglomerate Beds (*Dwyka*), 500 feet; Upper Series, 2,700 feet; conformable with No. 5; in the south much folded, and in undulations throughout, until it passes under the next set of beds, No. 7, in some places 50 miles to the north. The Ecca Beds have fossil wood and plant remains in abundance here and there, but these have not been clearly determined. This series has not been well defined until lately, and even now its limits are not fully determined. It includes the Karoo Desert, and therefore takes in the lowest members of Bain's great *Karoo Formation*, Nos. 12

[1] *American Journal of Science*, vol. xx. p. 235, September 1880. See also vol. xxi. p. 511, June 1881.

and 14 of his map (1856), or the 'Ecca,' 'Koonap,' and part of the 'Beaufort' Beds of Jones (1867). The series No. 7, horizontal and unconformable on the Ecca Beds at the Camdeboo and elsewhere, retains the name of *Karoo Sandstones*; and after a width of about 40 miles is conformably surmounted by a set of somewhat similar Beds (8) in the Stormberg; and thus No. 7 should be regarded as the *Lower*, and No. 8 the *Upper Karoo Sandstones*. The latter end off northwards in the Draakensberg, Natal, Orange-Free-State, the Transvaal, and Zululand, with the still horizontal *Cave Sandstone* and associated beds. The *Lower Karoo Sandstones* probably thin away northwards beneath the others. Below the *Karoo Sandstones*, and dying out southwards near the Camdeboo (Prof. Green), are the Shales (7*), which constitute the country around Kimberley, described as the 'Olive Shales of the Karoo Formation,' by G. W. Stow. These die out northward against the old rocks of Griqualand-West and the Transvaal. They contain Glacial Conglomerates in their lowest (earliest) beds, in Griqualand-West, just as the Ecca series has its great Glacial Conglomerate (the *Dwyka Conglomerate* in No. 6) in its lowest portion. As the *Stormberg Beds* (8) lie upon the *Olive* or *Kimberley Shales* (7*) in the Orange-Free-State, the *Lower Karoo Sandstones* (7) must die out northwards. The *Kimberley Shales* contain some Reptilian bones and plant remains, and some coal on the Vaal; the *Karoo Sandstones* are rich with Dicynodont and other Reptilian bones, and have some Fish remains; and their upper portion (*Stormberg*) contains Ferns and Cycadeous leaves, and some seams of coal. A fossil mammal also has been found in this series. Throughout its range the *Karoo Series* is traversed with igneous dykes.

Limestones and sandstones (9) with fossils of nearly pure Jurassic, but with some of Cretaceous type, occur unconformably in the Eastern Province. Their fossil Flora is like that of the *Stormberg Beds*. Cretaceous strata (10) are known on the Natal coast; and Tertiary and post-Tertiary deposits (11) form several patches on the East, South, and West coasts.

THE SOUTH-AFRICAN FORMATIONS.

11. Tertiary and Post-Tertiary, 100′?

~~~~~~~~ (Unconformable on several different rocks.)

10. Cretaceous.

~~~~~~~~ (Unconformable on Carboniferous?)

9. Jurassic.	Uitenhage Formation.	Trigonia Beds, Wood-bed, Saliferous Beds, Zwartkop Sandstone	400′?
		Enon Conglomerate, 300′.	

~~~~~~~~ (Unconformable on Devonian and other old rocks in Albany.)

Triassic.	Karoo Beds.	8. Upper.	Cave Sandstone, 150′
			Red Beds, 600′
			Stormberg Beds, 1,000′.
		7. Lower.	Sandstones and Shales, 5,000′
			7*. Kimberley or Olive Shales and Conglomerates, 2,300′.

~~~~~~~~ (Unconformable on Ecca Beds in the South, and on the old Vaal and Kaap series in the North.)

Carboniferous?	6. Ecca Beds.	Upper Ecca Beds, 2,700′
		Dwyka Conglomerate, 500′
		Lower Ecca Beds, 800′.
	5. Witteberg and Zuurberg Quartzites, 1,000′?	
	4. Table-Mountain Sandstone, 4,000′.	

		(Unconformable on the Old Cape Schists and Slates and on the Bokkeveld Beds.)
Devonian.		3. Bokkeveld Beds, 1,100′.
		(Probably unconformable to the Malmesbury Beds.)
Silurian ?		2. Malmesbury Beds, Micaschists and Slates of the Cape.
		(Probable unconformity.)
		1. Namaqualand Schists and Gneiss.

Mr. Stow's Old Rocks of the Vaal, and his Kaap or Campbell-Randt series, in Griqualand-West and the Transvaal, are probably Lower-palæozoic, or even of greater age (like Nos. 1 and 2).

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5. *On the more Ancient Land Floras of the Old and New Worlds.*
By Principal Sir W. DAWSON, *C.M.G., LL.D., F.R.S.*

In the Laurentian period vegetable life is probably indicated, on both sides of the Atlantic, by the deposits of graphite found in certain horizons. There is good evidence of the existence of land at the time when these graphitic beds were deposited, but no direct evidence as yet of land plants. The carbon of these beds might have been wholly from sub-aquatic vegetation; but there is no certainty that it may not have been in part of terrestrial origin, and there are perhaps some chemical arguments in favour of this. The solution of the question depends on the possible discovery of unaltered Laurentian sediments.

The Silurian land flora, so far as known, is meagre. The fact that *Eopteris* has been found to be merely a film of pyrite deprives us of the ferns. There remain some verticillately-leaved plants allied to *Annularia*, the humble Acrogens of the genus *Psilophyton*, and the somewhat enigmatical plants of the genera *Pachytheca*, *Prototaxites*, and *Berwynia*, with some uncertain Lycopods. We have thus at least forerunners of the families of the *Asterophylliteæ*, the *Lycopodiaceæ*, and the *Coniferæ*.

The comparison of the rich Devonian or Erian flora of the two sides of the Atlantic is very interesting. On both continents it presents three phases, those of the Lower, Middle, and Upper Erian, and there is a remarkable correspondence of these in countries so wide apart as Scotland, Belgium, Canada, Brazil, and Australia. Examples of this were given in the Rhizocarps, at this period very important, in the Lycopods, the Equisetaceæ, the Ferns, and the Conifers. The number of coniferous trees belonging to *Dadoxylon* and allied genera, and the abundance of ferns, often arborescent, were especial features of the Middle and Later Erian.

The flora of the Erian age culminated and then diminished. In like manner that of the succeeding Carboniferous period had a small commencement quite distinct in its species from the Erian; it culminated in the rich vegetation of the true coal formation, which was remarkably similar over the whole world, presenting, however, some curious local differences and dividing lines which are beginning to become more manifest as discovery proceeds. In the Upper Carboniferous the flora diminishes in richness, and the Permian age is, so far as known, one of decadence rather than of new forms. Great progress has recently been made by Williamson and others in unravelling the affinities of the coal-formation plants, and we are on the eve of important discoveries in this field.

Throughout the Silurian, the conditions do not seem to have been eminently favourable to plants, but the few forms known indicate two types of Acrogens, and one leading to the Gymnosperms, and there is no reason to doubt the existence of insular land richly clothed at least with the few forms of vegetation known to have existed.

In the Erian and Carboniferous there seem to have been two great waves of plant-life, proceeding over the continents from the north, and separated by an interval of comparative sterility. But no very material advance was made in them, so that the flora of the whole Palæozoic period presents a great unity and even monotony of forms, and is very distinct from that of succeeding times. Still the leading families of the *Rhizocarpeæ*, *Equisetaceæ*, *Lycopodiaceæ*, *Filices*, and *Coniferæ*, established in Palæozoic times, yet remain; and the changes which have occurred consist mainly in the degradation of the three first-named families, and in the introduction of new types of Gymnosperms and Phænogams. These changes, delayed and scarcely perceptible in the Permian and Early Mesozoic, seem to have been greatly accelerated in the Later Mesozoic.

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6. *On the Relative Ages of the American and the English Cretaceous and Eocene Series.* *By* J. STARKIE GARDNER, *F.L.S.*, *F.G.S.*[1]

The paper is a contribution towards the determination of the ages of the American Cretaceo-Eocene rocks, relative to those of Europe.

It briefly describes the chief characteristics of the various stages of the series in America. The lowest beds there are distinguished by the presence of well-developed dicotyledonous leaves, associated with *Ammonites* and other Cretaceous mollusca, considered to warrant their correlation with the Gault and Chalk of England. Newer beds thought to be intermediate in age between Secondary and Tertiary are distinguished by the incoming of palms and a new flora of Dicotyledons, associated with *Mosasaurus*. The rest are correlated with the various divisions of the Tertiary series recognised in Europe. The entire series seems to have been deposited without any considerable break in continuity, but reveals a sudden transition from a temperate to a subtropical flora, and from a Cretaceous to a Tertiary vertebrata. The high development of the flora is, however, quite irreconcilable with the accepted correlation.

In further comparing the American series with that of Europe, it is observed that the subdivisions of the Cretaceous series were first determined for a limited area, when different ideas of evolution and gradual passage prevailed, and subsequently extended to embrace areas at a distance which may be, rightly or wrongly, correlated with those of England and western France. The comparisons now drawn are only between the rocks of the original and typical area and of America, excluding the Cretaceous rocks of other countries.

Thus restricted, the Neocomian of Europe comprises only shore deposits, characterised by a Cretaceo-Jurassic fauna and a Jurassic flora. The Gault is a deeper sea-deposit, comparable to the 'Blue mud' of the 'Challenger,' with a typically Cretaceous fauna and a Jurassic flora. The Upper Greensands are more or less the equivalents of the Gault, deposited under differing physical conditions, corresponding to the 'Greensands' of the 'Challenger,' and have been assumed to represent the shore or shallower water conditions preceding the Chalk. The Chalk itself is described with a view to prove that it is a truly oceanic deposit, formed at a distance from shore and at a considerable depth, corresponding in all respects with the existing 'Globigerina Ooze.' The arguments against this view are refuted in detail, and the suggestion made that the alleged shallower habitats in the tropics of the few surviving Mollusca may be due to the lower temperature prevailing now in the abyssal depths of the ocean having driven heat-loving types from the depths at which they were able to live in the Chalk period.

The whole Cretaceous series in the British area is the result of a gradual conversion of land into sea, owing to subsidence. The process commenced with the Neocomian, became more serious with the Gault, and continued until the close of the Chalk. The focus of the depression, so far as its results are accessible, was the English Channel, whence it spread in an easterly direction across Central Europe. As the land subsided, the gulf increased in magnitude, and Blue and Green Muds were formed on a wider and wider area, to be succeeded in due time by chalky Ooze. The nearer the focus of subsidence, the older the Greensands and Gault, and the farther we recede from it, the newer in age they become. The zones of increasing depth travelled outward and forward, and though now represented by continuous bands of the same lithological characters, extending over

[1] Printed in full in *Geological Magazine*, Dec. III., vol. i., pp. 492-506, 1884.

many countries, it would be rash in the extreme to infer the synchronism of portions of these when separated by degrees of latitude. The time required for these zones to travel from Kent to the Crimea, and to accumulate a mass, mainly composed of minute organisms, of over a thousand feet in thickness, must have been sufficient to account for a very sensible progress in the evolution of organic forms.

The deposition of the Chalk commenced in the English area at a period when the land floras were still of Jurassic character. By the time it had reached Limburg, Saxony, and Bohemia, Dicotyledons had become developed. The period required for the chalk ocean to encroach but 300 to 400 miles must thus have been very vast. The question may however arise, whether plant development at this stage followed the otherwise universal law of evolution, or was exceptionally rapid. The fauna has to be examined to see whether it discloses an equally appreciable progress. The conclusion arrived at is, that while the groups with which the author is less acquainted apparently do so, the progress in the Mollusca is unmistakable. The helicoid, turbinate, and patelloid groups are archaic and stationary, but the fusiform shells betray a tendency to elongate their canals, and the relative abundance of such, and gradual dropping out of now extinct genera, furnish an unmistakable index of the relative ages of the more littoral deposits. From this point of view we are able to demonstrate that the Greensands of Aix-la-Chapelle are far younger than their lithological structure and sequence would indicate, while the appearance of such distinctly new developments as cone and cowry shells further support the views of the relatively almost tertiary, or, at least, transition age of the Cretaceous series in Denmark. While, therefore, denudation on a truly colossal scale has produced one of the most considerable gaps in the whole geological record between Cretaceous and Tertiary over the British area, beds of intermediate age may successfully be sought for at a distance from this centre. The erroneous correlation of these, bed by bed almost, with the typical Cretaceous series, as developed in England, has led to a still more untrustworthy correlation of the American series with ours.

The Cretaceous series of America contains at its very base a flora composed of angiosperms so perfectly differentiated that they are apparently referable to existing genera. One of the oldest floras in Europe containing angiosperms is that of Aix-la-Chapelle, and even this we have seen is relatively modern: but these are not referable in at all an equal degree to existing genera, and even the Coniferæ are embarrassing on account of their highly transitional characters. The oldest Cretaceous flora of America, so far from possessing any Cretaceous characters, agrees in a remarkable manner with that of the English Lower Eocene, while the Laramie, or supposed Cretaceo-Eocene, flora has very much in common with that of our Middle Eocene, and marks a similarly sudden rise in temperature. The question is whether the evidence of the fauna in favour of the Cretaceous age of the series is so conclusive that the floral evidence must be set aside. Taking the Cretaceous series as represented in California, the older stages possess Mollusca of definitely Cretaceous aspect, but those of the newest have a decidedly Eocene facies. To be Cretaceous a fauna must have some elements which did not survive to a later period; but are we in a position to state that the Ammonitidæ, the Belemnites, and Inocerami did not do so? Even our present limited knowledge is entirely opposed to such a view. It must be remembered that the Eocenes in their typical area, England and France, were deposited under peculiar local conditions, and it would be as logical to infer from the absence in them of Cretaceous types that these existed nowhere else, as it would be, were the bed of the English Channel now upheaved, to class as extinct all forms of life not met with in its sands and muds. If, as there is evidence to show, America was isolated at the time, the survival there of forms of Reptilia, elsewhere extinct, would be in accordance with ordinary observation at the present day.

The flora of the American series is Eocene; the fauna of its earlier stages is Cretaceous. We are compelled, therefore, to choose whether we will believe that a large Eocene flora was developed there during the Cretaceous, or that some members of a Cretaceous fauna lived on to an Eocene date. The former supposition demands greater rapidity of evolution than we are accustomed to admit, and no external evidence is advanced to support it. The latter is more conceivable from the standpoint of evolution, and is not contradicted by any evidence that has yet come under the author's observation.

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7. *On the Structure of English and American Carboniferous Coals. By* Edward Wethered, *F.G.S., F.C.S.*

The author had examined several seams of coal from England and America. He pointed out that they were not always made up of one continuous bed of coal, but often comprised several distinct beds. In the case of the well-known Welsh 'four feet' seam there were four distinct strata of coals, separated by clay beds of a few inches thick. In the case of the 'Splint Coal' from Whitehill Colliery, near Edinburgh, the seam presented three clearly defined beds of coal, but these were not separated by partings of any kind.

With a view of testing the 'Spore Theory' of the origin of coal, as propounded by Professor Huxley, the author had obtained a portion of the 'better bed' seam intact for a thickness of 10 inches from the top. He had examined this inch by inch, by preparing thirty-three microscopic sections. At the top was $3\frac{1}{2}$ inches of dull lustrous coal, termed 'laminated coal.' This the author found to be practically a mass of macrospores and microspores. Below this there was a change in the character of the seam. Spores became less numerous; in places they were scarce, the mass being made up of vegetable tissue and a substance to which the author gives the term 'hydrocarbon.' He could not, therefore, support Professor Huxley in saying that the 'better-bed' coal was 'simply the sporangia and spore cases of plants.' The assertion would, however, apply to the first $3\frac{1}{2}$ inches of the seam. The 'splint coal' from Whitehill Colliery was a better example of a spore coal than the 'better-bed.' The bottom stratum was 4 inches thick, and presented a dull lustre with thin bright layers traversing at intervals. The dull portion was a mass of spores and spore cases, but these did not enter the bright layers. A vertical section cutting a bright layer, bounded on either side by dull lustrous coal, showed plenty of spores in the dull coal, but in the bright not one was detected. The second bed in this seam was 1 foot thick; it was of a brighter lustre than the 4 inches below, but two layers could be distinctly made out, one more lustrous than the other. In the dullest of the two spores were found, which, however, were less numerous than in the bed below, and were, also, of a different variety. In the bright layers the spores were absent. The top bed of the seam was also 1 foot thick, and might be defined as a mass of spores, chiefly microspores, except in the bright layers. The American coals examined were collected by the author from the Warrior Coalfields of Alabama, and from near Pittsburg, Pennsylvania. The same structural affinities were noticed as in the English coals, and the author therefore came to the conclusion that the English and American Carboniferous coals had a common origin.

The spores in the coal from both countries were closely allied. Some microspores from Alabama were identical with those which occur in the lower bed of the Welsh 'four feet' seam. A feature in spores obtained from all the coals was the triradiate markings which they exhibited. Whether this was to be regarded as superficial or not, it was very characteristic of them, and was, therefore, to be considered in attempting to ally them with modern vegetation.

The author regarded peat in the light of post-tertiary coal; lignite as peat in a transition state to coal; and coal as the remains of carboniferous bogs.

The author referred to the practical application of a knowledge of the microscopic structure of coal, as enabling an expert to judge of the nature of a coal from an examination of it with a pocket lens.

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8. *Second Report on the Fossil Phyllopoda of the Palæozoic Rocks.*

See Reports, p. 75.

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9. *A preliminary Examination of the Silicious Organic Remains in the Lacustrine Deposits of the Province of Nova Scotia, Canada. By* ALEXANDER HOWARD MACKAY, *B.A., B.Sc.*

Many of the lakes of Nova Scotia contain large deposits abounding in these remains which consist of the silicious skeletons of upwards of sixty species of diatomaceæ, and of the silicious spicules of at least seven species of fresh-water sponges. The deposits from different lakes are generally marked by a difference in the species present or in their relative proportion. In lakes which are not agitated by large streams bearing earthy sediments during times of freshets, the deposits generally consist of a light slimy brownish mud, sometimes of a depth beyond twenty feet, into which a pole can be easily driven by the hand. This mud when treated so as to eliminate the carbonaceous vegetable matter, leaves a variable percentage of exquisitely sculptured diatom cells and various forms of sponge spicules. In some places this percentage is very high and the deposit correspondingly whiter and firmer, in some cases consisting nearly of the pure silicious valves and spicules. The diatomaceæ grow not only in the waters of these lakes but in the streams flowing into them, so that these deposits are not all developed *in situ*. The sponges, on the other hand, affect the stiller waters of the lake. They attach themselves to and grow upon portions of submerged wood, stone or even sand, sometimes forming extensive incrustations several inches in thickness, some species extensively lobed and even branching. The sponge-flesh dying away each winter, innumerable microscopic spicula which formed its skeleton are thus scattered in the waters, so that in some localities the sponge spicules form a greater proportion of the deposits than the valves of the diatomaceæ.

Some of these deposits may prove to be of industrial importance, the material being regarded as capable of use as polishing powder for various purposes, and in the manufacture of dynamite.

The lakes upon which these preliminary observations have been made include Ainslie, in Cape Breton; Lochaber, in Antigonish Co.; Mackay, Black Brook, Garden of Eden, Grant, M'Lean, Calder, Forbes, Ben, and Toney Lakes in Pictou Co.; Mackintosh, Earltown, and Gulley lakes, in Colchester Co.; the lakes which supply the city of Halifax with water, Grand Lake and Dartmouth Lakes in Halifax Co.; and Kempt Lake, in King's Co.

Lists of the species of diatomaceæ and spongidæ detected in the several deposits were given in the paper, which was accompanied by microscopical slides and specimens. The author has not yet concluded his researches.

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10. *Tenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations.*—See Reports, p. 96.

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11. *Fifth and last Report on Fossil Polyzoa.*—See Reports, p. 97.

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12. *Report on the Exploration of the Raygill Fissure in Lothersdale, Yorkshire.*—See Reports, p. 240.

WEDNESDAY, SEPTEMBER 3.

The following Papers and Reports were read:—

1. *The Geological Age of the Acadian Fauna. By* G. F. MATTHEW, *A.M., F.R.S.C.*

In this sketch an attempt is made, by comparison with the Cambrian fauna of other countries, and especially of Wales, to fix more exactly than has hitherto been done the position of the assemblage of organisms found near the base of the Saint John group. The trilobites are taken as a criterion for this purpose. A brief statement of the position and thickness of the beds is given, showing the relation of the fauna to the formation as a whole.

It is shown that the genera and species of the Acadian trilobites do not agree with those of the Menevian, in the restricted application of that term now in vogue; the great *Paradoxides* with short eyelobes, and the genera *Anopolenus, Agraulos* (= *Arionellus*), *Erinnys*, and *Holocephalina* being, so far as known, absent from it. On the other hand, it shows very close relationships in its genera to the Solva group fauna, especially in the following species:

Solva Group.	*Acadian Fauna.*
Conocoryphe solvensis (Hicks).	*Ctenocephalus Matthewi* (Hartt sp.).
Conocoryphe bufo (Hicks).	*Conocoryphe elegans* (Hartt sp.).
Paradoxides Harknessi (Hicks).	*Paradoxides cteminicus* (Matthew).

As bearing on the question of the age of the Acadian fauna, the development of the eyelobe in *Paradoxides* is referred to, and it is shown that while in the Cambrian rocks of Wales the length of the eyelobe is in direct relation to the age of the strata, the *Paradoxides* of the Acadian fauna, having continuous or nearly continuous eyelobes, are more primitive in their facies than those of the Menevian, and agree with the species found in the Solva group.

The family of Conocoryphidæ, restricting the name to such species as those described by Corda under *Conocoryphe* and *Ctenocephalus*, are a marked feature of this early fauna; and *Conocoryphe* has a characteristic suture not observed in the Menevian genera. The Acadian *Ctenocephalus* also differs in this respect from the Bohemian species.

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2. *The Primitive Conocoryphean.* *By* G. F. Matthew, *A.M., F.R.S.C.*

Relates to the development of the species *Ctenocephalus Matthewi* and other Conocorypheans of the Acadian fauna, and is considered under the three heads, viz., the Development of the Glabella; the Acquisition of Sensory Organs; and the Decoration of the Test.

Under the first head, it is shown that the peculiar glabella of the species above referred to is closely related to the early history of the trilobite. The glabella, in its earliest stage, is very different from that of the adult, and in outline is not unlike that of *Paradoxides*: it also resembles this species in the position of the ocular fillet. At the next stage the glabella or axial lobe becomes trumpet-shaped, as in *Carausia*, and in the third the glabella proper is developed by the segmentation of the axial lobe: the glabella and ocular fillets now resemble those of *Ptychoparia*. In the following stages the family characters of the Conocorypheans begin to assert themselves, especially the widening of the base of the glabella, the appearance of the canals connected with the ocular ridges, and the development of spines.

2. *The Acquirement of Organs of Sense.*—The ocular fillet appears, in the second stage of growth, as a faint, narrow ridge, close to the anterior marginal fold, and extending but a short distance from the glabella. It is not until the fifth stage of growth that the ramifying branches which spread from the ocular ridge to the anterior margin make their appearance. The ocular lobe and sensory apparatus connected with it are more distinctly visible on the under than on the outer surface of the test, and the canalets connected with the lobe spread over the anterior slopes of the shield and extend to the anterior margin. In the tuberculated species they connect by hollow spines with the outer surface. In one species they cover a wider space than in the others, extending some distance behind the ocular ridges and over the front of the glabella.

3. *Decoration of the Test.*—In all the Acadian species of this group but one, the surface of the test at maturity is covered with tubercles and spines similar to the surface-markings of *Conocoryphe Sulzeri*, &c. In the earliest stages, however, no such tubercles are found, but the surface appears smooth or scabrous. In *Cteno-*

cephalus Matthewi the surface, in the first three stages of growth, appears smooth; in the fourth, tubercles begin to appear, and about the fifth stage all projecting parts of the test are studded with them. Those on the glabella and frontal lobe are arranged in transverse rows; those on the cheeks in interrupted rows conforming more or less to the periphery of these protuberances. Towards the adult stage these tubercles and spines become more irregular in position and number, conforming in this respect to the law of development in the Ammonites, expounded by Professor Alphonso Hyatt.

3. *Report on the Rate of Erosion of the Sea Coasts of England and Wales.*—See Reports, p. 238.

4. *Fourth Report on the Earthquake Phenomena of Japan.* See Reports, p. 241.

5. *The Geology of Palestine. By* Professor E. HULL, *LL.D., F.R.S.* See p. 272.

6. *Notes on Niagara. By* P. HALLETT, *M.A.*

These notes may be expressed in abstract in the following propositions, and are submitted to the Section as questions for its consideration.

1. That, assuming the principle of the gradual formation of the cataract, the condition of existence of the present overhanging precipice is the superimposition of the hard Niagara limestone—corresponding to the Wenlock limestone—upon the friable Niagara shale, the latter being undermined, and the former left overhanging; that the condition of existence of the rapids above the precipice is the succession of hard rocks simply, and that these differences of condition probably differentiate overhanging Falls from Rapids generally.

2. Hence, in case of the precipice receding to a position above the shale, the Fall would disappear and become a Rapid.

3. That the course of the water in the Rapids as an effect of increasing velocity is convergent to mid-channel; and hence the Rapids, instead of being a source of danger to Goat Island and the small islands in their current, are actually a protection to them by determining the water from their banks.

4. That the water of the Fall undergoes a continuous disintegration from summit to base, breaking up into smaller and smaller masses and spreading out as it descends. The 'continuous roar' of Niagara is really a succession of impulses.

5. That this disintegration is a consequence of the collision between the falling water and the column of air beneath it; and that the compressed air in its descent is propelled inwards and outwards: inwards forming the well known rush of winds behind the Falls, and driving the heading of excavation in the shale; outwards sending up the cloud mist that continuously hangs over the Falls.

6. That this collision between the air and falling water is really a conservative influence, distributing the direct force of the fall and partly transmitting it both directly and by reaction along the currents of the gorge.

7. That besides the force of the air propelled against the shale face of the precipice as a cause of its excavation, attention is also to be directed to the continuous drainage from the shale, as evidenced by springs, &c. Even along the gorge where there are no falls this appears to determine an undermining action or recession of the banks below, with overhanging rocks above.

8. That retrocession of the Falls, evident as it is, is not to be regarded as the operation of a mechanical force necessarily continuous, but as a movement to equilibrium. Hardly any retrocession has occurred in parts of the American Fall during the time that the Canadian one has gone back some 500 yards. Retrocession

would follow from any cause increasing the amount or velocity of the water, elevation of the land, increased rainfall, &c., and each retrocession would increase the discharging power of the river, thus tending to carry off the increased water supply. The relation between the increased supply and the discharging power thus tends through retrocession to equality and to balance.

9. All the features of Niagara being dependent on the force of the waters, every attempt to diminish this force by what is known as the utilisation of the Falls would change these features, and if the utilisation were carried to the extent sometimes proposed these features would be destroyed. Abstract the *vis viva* from the water and we have only a mass of inert matter.

10. It may be questioned whether even the material argument in favour of utilisation, great as it is, is so conclusively in favour of the utiliser as is often supposed. It is admitted that Niagara has played no mean part in the geographical evolution of this part of the continent, and it may be asked does it not now play an equally important part in its preservation? In the Niagara descent is generated the impulse which commands the circulation both of the upper and lower lakes, and hence to some extent the drainage, rainfall, and cultivation of their adjacent areas of country. The Niagara impulse, some four and a half million horse-power, tends to move the waters down from Erie and to drive them through Ontario. If this impulse be wholly or even largely withdrawn in the manner proposed, what may be the effect on the circulation of this continental district. If this is not now a practical question the proposals now in the air may soon make it one.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION—Professor H. N. MOSELEY, M.A., LL.D., F.R.S., F.L.S., F.R.G.S., F.Z.S.

THURSDAY, AUGUST 28.

The PRESIDENT delivered the following Address:—

IN appointing the phenomena of pelagic and deep-sea life as one of the subjects specially selected for consideration at the present meeting of this Section, the Organising Committee have, I think, done wisely. Our knowledge of the subject is at present in most active progress. It is one of the widest and deepest interest to the physiologist as well as the zoologist, and in some features claims a share of attention from the botanist. And the proximity here of the United States, to which science is indebted for so many important discoveries on deep-sea matters, is a strong argument in favour of the subject being brought forward at a British Association meeting on this side of the Atlantic. I have naturally been led to choose the consideration of some deep-sea biological questions as the subject of my address by the special interest which I have been led to take in deep-sea phenomena generally, owing to my long participation in actual deep-sea research during the voyage of H.M.S. 'Challenger.'

Unfortunately, the physiology of the deep-sea life has until lately received but little attention from professed physiologists. No physiologist has, as far as I am aware, as yet set forth comprehensively and dwelt upon the numerous difficulties which are encountered when the attempt is made to understand the mode in which the ordinary physiological processes of vertebrata and other animals are carried on under the peculiar physical conditions which exist at great depths.

Whilst I was on the 'Challenger' voyage, absorbed principally in the zoological discoveries daily resulting from the dredging operations, I received a letter from my revered teacher, Professor Ludwig, of Leipzig, which brought deep-sea phenomena before me in a very different light. The Professor naturally regarded deep-sea questions mainly from a physiological point of view, and asked a series of most suggestive questions bearing on it. I am much indebted to him for this and recent letters on the same subject. One of the first questions he asked was, naturally, as to the amount of oxygen present in deep-sea water. A knowledge of the conditions under which gases occur in a state of absorption in the ocean-waters is of primary importance to the physiologist. With regard to this subject most valuable information is contained in the report by the distinguished chemist, Professor Dittmar, on 'Researches into the Composition of the Ocean-Water collected by H.M.S. "Challenger,"' which has appeared during the present year, and which embody Mr. J. Y. Buchanan's results.[1] It appears from his results that, contrary to what was before suspected, the presence of free carbonic acid in sea-water is an exception. What carbonic acid is present occurs as a bicarbonate, in general more or less incompletely saturated. In surface-waters the proportion of carbonic acid increases when the temperature falls, and *vice versâ*. Deep-sea water does not contain an abnormal proportion of loose or free carbonic acid.

Hence, with regard to Mr. John Murray's interesting discovery that after

[1] 'Official Report on the Scientific Results of the Voyage of H.M.S. "Challenger,"' *Physics and Chemistry*, vol. i.

certain depths are reached *Pteropod* shells are dissolved and disappear from the sea-bottom, and at certain further depths *Globigerina* shells suffer the same fate, Professor Dittmar holds the opinion that the solution is not due to the presence of free acid, but to the solvent action of the sea-water itself, which will, even when alkaline, take up additional carbonate of lime if sufficient time be given. Thus the amount of carbonic acid normally present throughout the ocean cannot be inimical to life; but, according to the Professor, there must be in the depths of the ocean numerous bodies of richly carbonated water, for he regards the principal supply of carbonic acid to the sea-water as derived from volcanic springs and discharges issuing from the ocean-bed, the quantity derived from the decay of marine plants and animals being insignificant in comparison with this. Possibly the 'Challenger,' when it dredged from deep water off the Azores immense quantities of dead and blackened coral, encountered an area which had thus been visited by a carbonic acid discharge.

With regard to the absorbed oxygen and nitrogen, the theoretical maximum quantity of oxygen absorbed at normal surface-pressure by a litre of sea-water should range, according to Professor Dittmar's experiments and calculations, from 8·18 c.c. in cold regions at 0° C. to 4·50 c.c. in the tropics, with a temperature of 30° C. The results experimentally obtained from samples of surface-water collected during the voyage differ considerably in detail from the calculated estimates from various causes explained, and especially because of the reduction of the amoumt of oxygen by oxidation and respiration. The main and almost sole source of the nitrogen and oxygen present in deep-sea water lies in the atmosphere and is absorbed at the surface, its quantity being thus dependent on surface conditions of temperature and pressure and not those of the depths. A given quantity of water, having absorbed its oxygen and nitrogen at the surface, may be supposed to sink unmixed with surrounding water to the depths. During the process its amount of contained nitrogen remains constant, whilst its oxygen-supply becomes gradually diminished, owing to the process of oxidation, which in the depths go on without compensation. That the amount of absorbed oxygen present in sea-water diminishes with the depth had been shown already by Mr. Lant Carpenter's experiments. It is not yet possible to formulate in any precise terms the relation between the depth and the diminution of the oxygen present, but Mr. J. Y. Buchanan's previous conclusion that a minimum of oxygen is attained at a depth of about 800 fathoms is not confirmed by the summing up of the whole of the evidence now available. This result is not without biological significance, since the existence of this supposed zone with a minimum of oxygen has been used as an argument in favour of the occurrence of especially abundant life at this depth below the ocean-surface.

Professor Dittmar finds that there is nothing characteristic of bottom-waters as such in regard to their absorbed gases, nothing to distinguish them from waters from intermediate depths. This, it seems to me, is not quite what might have been expected, as the concentration of the food supply, and consequently of life, on the actual bottom might have led to a different result.

If there were absolute stagnation of the water at great depths the oxygen might be reduced there to zero, but the fact that in no case has oxygen been entirely absent from any sample of deep-sea water examined proves that a certain motion and change must occur. The smallest amount of oxygen found at all was in a sample of water from a depth of 2,875 fathoms, and amounted to 0·65 c.c. per litre only, a result long ago published by Mr. Buchanan. Even this, however, may well be sufficient to support life, since Humboldt and Provencal[1] found that certain fish could breathe in water containing only one-third of that quantity of oxygen per litre. In another sample, from 1,645 fathoms, it was 2·04 c.c. On the other hand, as much as 4·055 c.c. was found in a sample from 4,575 fathoms, and 4·39 c.c. in one from 3,025. Most remarkable, in one instance water from a depth of only 300 fathoms yielded only 1·65 c.c. of oxygen. Professor Dittmar admits that there was no lack of anomalous results, some, no doubt, due to some extent to imperfection in the apparatus employed in collecting the water.

[1] 'Sur la Respiration des Poissons,' *Journ. de Physique, de Chimie et d'Histoire Naturelle*, t. lxix., October 1809, p. 268.

In connection with the valuable investigations carried on in the 'Travailleur' and the 'Talisman' by Professor Milne Edwards and his associates, French physiologists have lately commenced researches on some of the problems of deep-sea life.

Experiments have been made by M. Regnard[1] with a view of determining the effects of high pressures, corresponding with those of the deep sea, on various organisms. Yeast, after being exposed to a pressure of 1,000 atmospheres, equal to a depth of about 6,500 fathoms of sea-water, for an hour, was mixed with a solution of sugar. An hour elapsed before any signs of fermentation appeared, and a mixture of yeast and sugar solution did not ferment at all, whilst under a pressure of 600 atmospheres, equal to a depth of about 3,900 fathoms. Algæ, seeds of a phanerogamic plant, infusoria, and even mollusca and leeches, were found to be thrown into a sort of state of sleep or latency by exposure to similar pressures, recovering from this condition after a shorter or longer period of return to normal conditions. A fish without a swimming bladder, or one with the bladder emptied of air, may be submitted to a pressure of 100 atmospheres, equivalent to a depth of 650 fathoms, without injurious effect. At 200 atmospheres, equivalent to a depth of 1,300 fathoms, it becomes torpid, but soon revives when the pressure is removed. At 300 atmospheres, equivalent to a depth of about 2,000 fathoms, the fish dies.

These experiments are of the highest interest. The pressure made use of was obtained by means of water in the absence of air other than that absorbed at the normal atmosphere pressure, and thus the physical conditions produced were closely similar to those actually existent in the deep sea. They are the first of their kind.

Professor Paul Bert's[2] somewhat similar experiments related to a different question altogether—namely, the effect on aquatic organisms of water subjected to the pressure of compressed air. He found that young eels were rapidly killed when subjected to a pressure of only 15 atmospheres, and could not survive one of even 7 atmospheres for any considerable time.[3] He pointed out the essential difference between the conditions produced in such experiments and those existing in the deep sea, where the charge of oxygen contained by the water has been taken up at the surface under a pressure of one atmosphere only.

In the experiments on animals made by M. Regnard's method there is the obvious difficulty that the supply of oxygen in the water compressed cannot be renewed during the experiment, but must be gradually reduced by respiration, and for this reason it would probably be useless, unless a large quantity of water would be employed, to try the effect on a fish of a very gradual application of pressure, extending over many hours. It is probable that the results would be greatly modified if plenty of time could be given for the fish to accommodate itself to the change of pressure, and the conditions in which it moves in nature slowly from one depth to another be imitated. The results of M. Regnard's further experiments will be looked forward to with great interest.

A question of the utmost moment, and one that has received a good deal of attention, is that as to the source of food of the deep-sea animals. Certainly a large proportion of this food is derived from the life on the ocean-surface. The débris of pelagic animals sinks slowly downwards, forming on its passage a sparsely scattered supply of food for any animals possibly living at intermediate depths, but becoming concentrated as it were on the bottom. The pelagic animals depend for their ultimate source of food, no doubt, largely on the various pelagic plants, the range of which in depth is limited by the penetration of sea-water by the sunlight, and probably to an important extent is dependent on the symbiotic combinations of radiolarians with zooxanthella. But a large part of their food-supply is also constituted by animal and vegetable débris derived from the coasts, either directly from the littoral zone or by rivers and the action of the tides from terrestrial life. Immense quantities of shore-débris have been dredged from deep water near coasts, and deep-sea life appears to diminish in abundance as coasts are

[1] P. Regnard, 'Recherches Expérimentales sur l'Influence des très-hautes Pressions sur les Organismes Vivants,' *Comptes-Rendus*, No. 12, 24 mars 1884, p. 745.

[2] *La Pression Barométrique*, Paris, 1878, p. 814.

[3] *Ibid.* p. 1151.

receded from. Unfortunately our knowledge of pelagic vegetable life is very imperfect, and it is to be hoped that botanists may be led to take up the subject and bring together what is known with regard to the geological ranges and abundance of the various larger seaweeds, trichodesmium, diatoms, and other algæ by which the sea-surface is inhabited. It will, then, be possible to form a nearer estimate of the extent to which these plants are capable of forming a sufficient ultimate food-source for the greater part of the pelagic fauna, and through it of deep-sea life. The question is of importance, because if the deep sea, having no ultimate source of food in itself, derived its main supply from the coasts and land-surfaces in the early history of the habitation of the globe by animals, there can have existed scarcely any deep-sea fauna until the littoral and terrestrial faunas and floras had become well established.

Whether the littoral and terrestrial plants or the pelagic be proved to have the larger share in composing the ultimate food-source of the deep sea, it seems certain that the food as it reaches the deep sea is mostly in the form of dead matter, and I imagine that the long but slender backwardly directed teeth of many deep-sea fish, resembling those of snakes, are used rather as aids for swallowing whole other fishes which have fallen from above dead, and thus making the best of an occasional opportunity of a meal, than for catching and killing living prey. In a lecture on 'Life in the Deep Sea,' delivered in 1880,[1] I suggested that putrefaction of organic matter, such as ordinarily occurs elsewhere, may possibly be entirely absent in the deep sea, the bacteria and other microphytes which cause it being possibly absent. Some interesting experiments with regard to this question have lately been made by M. A. Certes.[2] He added to sterilised solutions of hay-extract, milk, broth, and other organic nutrient fluids mixed with sea-water, with the usual necessary precautions, small quantities of deep-sea mud, or deep-sea water, procured by the 'Travailleur' and 'Talisman.' In some experiments air was present; others were made in vacuo. In nearly all the former putrefaction occurred after some time, especially after application of warmth, and micro-organisms were developed, whilst the latter remained without exception sterile, apparently indicating that the microbes which live where air is absent are not present in the deep sea. The others which developed in the presence of oxygen may possibly have sunk from the surface to the bottom, and have retained their vitality, although it is not improbable that they may be incapable of active existence and multiplication under the physical conditions there existing. M. Certes is to make further experiments on this question under conditions of pressure and temperature as nearly resembling those of the deep sea as possible. In the deep sea the ordinary cycle of chemical changes of matter produced by life is incomplete, there being no plants to work up the decomposition products. These, therefore, in the absence of any rapid change of the deep-sea waters, must accumulate there, and can only be turned to account when they reach the surface-waters on the littoral regions.

Many interesting results may be expected to be obtained when the histology of animals from great depths comes to be worked out, and especially that of the special sense-organs. At present very little has been attempted in this direction, principally, no doubt, because deep-sea specimens are too precious to be used for the purpose. In a remarkable scopelid fish dredged by the 'Challenger' from deep water, *Ipnops Murrayi* of Dr. Günther, the eyes are curiously flattened out and occupy the whole upper surface of the mouth. They are devoid of any trace of lens or iris, and, as appears from observations by Mr. John Murray and my own examination of his preparations, the retina consists of a layer of long rods, with a very thin layer indeed of nerve-fibres in front of it, and apparently no intervening granular ganglionic or other layers. The rods are disposed in hexagonal bundles, the free ends of which rest on corresponding well-defined hexagonal areas, into which the choroid is divided. It is probable that aberrant structures may be found

[1] Lecture delivered at the Royal Institution, March 5, 1880, *Nature*, April 22, p. 592.

[2] 'Sur la Culture, à l'abri des Germes Atmosphériques, des Eaux et des Sédiments rapportés par les Expéditions du "Travailleur" et du "Talisman," 1882, 1883,' *Comptes-Rendus*, No. 11, 11 mars 1884, p. 690.

in the retinas of deep-sea fish, which may conceivably help towards physiological conclusions as to the functions of the various components. With regard to the all-important question of the nature of the light undoubtedly present in the deep sea, it is hardly possible to accept Professor Verril's recent startling suggestion that sunlight penetrates to the greatest depths with perhaps an intensity at from 2,000 to 3,000 fathoms equal to that of some of our partially moonlight nights. Such a conjecture is entirely at variance with the results of all experiments on the penetration of sea-water by sunlight as yet made by physicists, results which have prevented other naturalists from adopting this solution of the problem.

The progress of research by experts on the deep-sea fauna confirms the conclusions early formed that it is impossible to determine any successive zones of depth in the deep-sea regions, characterised by the presence of special groups of animals. Within the deep-sea region the contents of a trawl brought up from the bottom give no evidence which can be relied on as to the depth at which the bottom lies within a range of at least 2,500 fathoms. Some groups of animals appear to be characteristic of water of considerable depth, but representatives of them struggle up into much shallower regions. Thus of the remarkable order of Holothurians Elasipoda nearly all the representatives occur at very considerable depths, and their numbers diminish shorewards, but one has been found in only 100 fathoms. Again, the Pourtalesidæ range upwards into about 300 fathoms, and the Phormosomas, which Loven considers as eminently deep-sea forms, range up to a little over 100 fathoms depth, and are nearly represented in shallow water at a depth of only five fathoms by *Asthenosoma.* As has often been pointed out before, there are numerous genera, and even species, which range even from the shore-region to great depths.

The fact that zones of depth cannot thus be determined adds seriously to the difficulties encountered in the attempt to determine approximately the depths at which geological deposits have been formed. Dr. Theodore Fuchs,[1] in an elaborate essay on all questions bearing on the subject, has attempted to determine what geological strata should be considered as of deep-sea formation, but, as he defines the deep-sea fauna as commencing at 100 fathoms and extending downwards to all depths, his results may be considered as merely determining whether certain deposits have been found in as great a depth as 100 fathoms or less, a result of little value as indicating the depths of ancient seas or the extent of upheaval or depression of their bottoms. Mr. John Murray has shown that the depths at which modern deep-sea deposits have been formed can be approximately ascertained by the examination of their microscopical composition and the condition of preservation of the contained pelagic and other shells and spicules.

The most important question with regard to life in the ocean, at present insufficiently answered, is that as to the conditions with regard to life of the intermediate waters between the surface and the bottom. It is most necessary that further investigations should be made in extension of those carried out by Mr. Alexander Agassiz with similar apparatus—a net, or vessel, which can be let down to a certain depth, whilst completely closed, then opened, lowered for some distance, and again closed before it is drawn to the surface. The greatest uncertainty and difference of opinion exist as to whether the intermediate waters are inhabited at all by animals, and, if they are inhabited, to what extent; and these intermediate waters constitute by far the greatest part of the ocean. If we estimate roughly the depth of the surface-zone inhabited by an abundant pelagic fauna at 100 fathoms, and that of the zone inhabited by the bottom animals at 100 fathoms also, the average depth of the ocean being about 1,880 fathoms, it results that the intermediate waters, concerning the conditions of life in which we are at present in the utmost uncertainty, really represent more than eight-ninths of the bulk of the entire ocean. Great care should be exercised in drawing conclusions from the depths ascribed to animals in some of the memoirs in the official work on the 'Challenger' expedition. The scientific staff of the expedition merely recorded on

[1] 'Welche Ablagerungen haben wir als Tiefseebildungen zu betrachten?' *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, 11. Beilage, Bd. 1882.

each bottle containing a specimen the depth from which the net in which the specimen was found had been drawn up. In many instances, from the nature of the specimen, it is impossible that it can have come from anywhere but the bottom, but in many others it is quite possible that a particular specimen may have entered the net at any intermediate depth, or close to the surface, and this is a matter on which the author of the monograph in which the specimen is described can form the best conclusion, if one can be formed at all from his knowledge of the animal itself. In all doubtful cases the mere record of the depth must be received with caution.

Just as before the commencement of the present period of deep-sea research there was a strong tendency amongst naturalists, owing to the influence of the views of Edward Forbes, to refuse to accept the clearest evidences of the existence of starfish and other animal life on the sea-bottom at great depths, so there seems now to have sprung up in certain quarters an opposite tendency, leading to the assignment of animals possibly of surface origin to great depths on inconclusive evidence.

With regard to the constitution of the deep-sea fauna, one of its most remarkable features is the general absence from it of Palæozoic forms, excepting so far as representatives of the Mollusca and Brachiopoda are concerned, and it is remarkable that amongst the deep-sea mollusca no representatives of the *Nautildæ* and *Ammonitidæ*, so excessively abundant in ancient periods, occur, and that *Lingula*, the most ancient Brachiopod, should occur in shallow water only.

There are no representatives of the most characteristic of the Palæozoic corals, such as *Zaphrentis*, *Cystiphyllum*, *Stauria* or *Goniophyllum*. Possible representatives of the *Cyathonaxidæ* have indeed been obtained in *Guynia*, described by Professor Martin Duncan, and *Haplophyllia* and *Duncania*, described by the late Count Pourtales, but the *Cyathonaxidæ* are the least aberrant and characteristic members of so-called *Rugosa*. Pourtales justly felt doubtful whether the arrangement of the septa in four systems instead of six could in itself be considered as a criterion of the *Rugosa*,[1] and in the cases of *Haplophyllia* and *Duncania* the septa may be described rather as devoid of any definite numerical arrangement than exhibiting any tetrameral grouping. Further, I have lately examined by means of sections the structure of the soft parts of *Duncania* in a specimen kindly given to me by Mr. Alexander Agassiz for the purpose, and find that with regard to the peculiar arrangement of the longitudinal septal muscles and the demarcation of the directive septa the coral agrees essentially with the Hexactinian *Caryophyllia* and all other modern Madreporaria the anatomy of which has been adequately investigated.

There are further no representatives of the ancient *Alcyonarians*, forming massive coralla, the *Helioporidæ* and their allies, in deep water, no *Palæocrinoids*, *Cystidea*, or *Blastoidea*, no *Palechinoidea*, no *Trilobites*, no allies of *Limulus*, no *Ganoids*. Further, other ancestral forms, certainly of great antiquity, although unrecorded geologically, such as *Amphioxus*, do not occur in deep water. It might well have been expected that, had the deep sea been fully colonised in the Palæozoic period, a considerable series of representative forms of that age might have survived there in the absence of most of the active physical agents of modification which characterise the coast regions.

From the results of present deep-sea research it appears that almost all modern littoral forms are capable of adapting themselves to the conditions of deep-sea life, and there is no reason why Palæozoic forms should not have done so if the abyssal conditions were similar to those now existing, just as a considerable number of forms of the chalk period have survived there. In fact, however, most of survivals of very ancient forms—*Heliopora, Limulus, Amphioxus, Dipnoi, Ganoids*—occur in shallow seas or fresh water.

With regard to the origin of the deep-sea fauna, there can be little doubt that it has been derived almost entirely from the littoral fauna, which also must have

[1] 'Zoological Results of the Hassler Expedition.' See *Cat. Mus. Comp. Zool. Harvard*, No. viii. 1874, p. 44.

preceded, and possibly given rise to, the entire terrestrial fauna. Although the littoral, and even its offspring, the terrestrial faunas, have undoubtedly, during the progress of time, contributed to the pelagic fauna, and although it is very likely that first traces of life may have come into existence in the shallow waters of the coast, it is not improbable that we should look to the pelagic conditions of existence as those under which most of the earliest types of animal life were developed. Nearly all the present inhabitants of the littoral zone revert to the pelagic free-swimming form of existence in their early developmental stages, or in cases where these stages have been lost can be shown to have once possessed it. And these pelagic larval forms are in many cases so closely alike in essential structure, though springing from parents allied but widely differentiated from one another in the adult form, that it is impossible to regard them as otherwise than ancestral. Had they been produced by independent modification of the early stages of the several adult forms as a means of aiding in the diffusion of the species, they must have become more widely differentiated from one another. The various early pelagic free-swimming forms, represented now mostly only by larvæ, gradually adapted themselves to coast life, and underwent various modifications to enable them to withstand the beating of the surf on the shores and the actual modifying alterations of the tides, which, together with other circumstances of coast life, acted as strong impulses to their further development and differentiation. Some developed hard shells and skeletons as protections; others secured their position by boring in the rocks or mud; others assumed an attached condition, and thus resisted the wash of the waves. A remarkable instance in point, about the circumstances of which there can be little doubt, is that of the *Cirripedia*. The *cypris* larva of *Balanus*, evidently of pelagic origin, sprung from a *Nauplius*, fixes itself by its head to the rocks and develops a hard conical shell, by means of which it withstands the surf in places where nothing else can live. In the same way the *Planula* larva, the Palæozoic cœlenterate form, produces the reef coral and various other forms specially modified for and by the conditions of littoral existence. Similarly echinoderms, mollusca, polyzoa, crustacea, recapitulate in their ontogeny their passage from a pelagic into a littoral form of existence.

It is because the ancestors of nearly all animals have passed through a littoral phase of existence, preceded mostly by a pelagic phase, that the investigations now being carried on on the coasts in marine laboratories throw floods of light on all the fundamental problems of zoology. From the littoral fauna a gradual migration must have taken place into the deep sea, but probably this did not occur till the littoral fauna was very fully established and considerable pressure was brought to bear on it by the struggle for existence. Further, since a large share of the present food of deep-sea animals is derived from coast-débris, life must have become abundant in the littoral zone before there could have been a sufficient food-supply in the deeper regions adjoining it. Not until the development of terrestrial vegetation and animal life can the supply have reached its present abundance. Such a condition was, however, certainly reached in the Carboniferous period. From what has been stated as to the general absence of representatives of Palæozoic forms from the deep sea, it is just possible that if deep oceans existed in Palæozoic periods they may not have been colonised at all, or to a very small extent, then, and that active migration into deep waters commenced in the secondary period. Very possibly the discharges of carbonic acid from the interior of the earth, which Professor Dittmar believes may have been sufficient to account for the vast existing deposits of coal and limestone, may have been much more abundant than at present over the deep-sea beds in the Palæozoic period, and have rendered the deep waters more or less uninhabitable.

In his splendid monograph on the *Pourtalesia*,[1] which has recently appeared, Professor Loven has dwelt on the peculiar importance of the littoral region, and of the infinity of agencies present in it 'competent to call into play the tendencies to vary which are embodied in each species.' He treats of the origin of the deep-sea fauna from that of the littoral region. It is impossible here to follow

[1] *On Pourtalesia, a Group of Echinoidea*, by Sven Loven. Stockholm, 1883.

him in his most valuable speculations. In one matter, however, I would venture to express a difference of opinion. He regards the littoral forms of invertebrates as migrating into the deep sea by the following process: Their free-swimming larvæ are supposed to be carried out by currents far from land, and then, having completed their development, to sink to the bottom, where a very few survive and thrive. It is hardly to be conceived that any animal, especially in a young and tender condition, could suddenly adapt itself to the vast change of conditions entailed in a move from littoral to deep-sea life. It seems to me much more likely that the move of animals from the shallow to the deep sea has been of the most gradual kind and spread over long series of generations, which may have migrated downwards, perhaps a fathom or so in a century, partly by very slight migrations of the adults, partly by very short excursions of larvæ. Thus alone by almost insensible steps could animals, such as those under consideration, be enabled to survive an entire change of food, light, temperature, and surroundings.

The following Papers were read:—

1. *On the Geographical Distribution of the Macrurous Crustacea.* *By* C. Spence Bate, *F.R.S.*

The *Macrura* may conveniently be classified into three natural groups of apparently equal importance in size and structural character. These differ from each other in anatomical details, even where they approximate in external form; and they are essentially distinct in consanguinity by a large history in their development and growth.

The distinction is more conveniently exhibited in the structure of the branchial apparatus, which differs importantly, and assumes three different forms.

In the *Astacidea*—the lobster and crayfish division—the branchiæ are formed as a mass of cylindrical tubes varying in length, but thickly grouped together in a greater or less number of rows opening from one central stalk.

In the *Penæidea* the branchiæ consist of filaments dividing into branches, sometimes dichotomously and sometimes unequally. These filaments are generally cylindrical in form, but in some genera they are so closely arranged that they become compressed into plates of considerable tenuity, still retaining, however, their divided or branching character.

In the *Caridea*—the prawn and shrimp section—the branchiæ are in the form of broad plates of extreme tenuity, arranged similarly to those that exist in crabs or the short-tailed crustacea, the entire plume being suspended by the centre to that portion of the animal to which it belongs.

With each of these there is a corresponding condition of the walking legs.

In the *Astacidea* all have a tendency to possess a chelate condition, of which the first pair is the largest and the third the smallest, while the posterior is usually chelate only in the females.

A departure from this exists in those genera that belong to the aberrant family of *Stenopidæ*, which possess the branchia of the *Astacidea*, the pereiopoda of the *Penæidea*, and the development of the *Caridea*.

In the *Penæidea* the three anterior pairs of pereiopoda only are chelate, and this feature increases in importance posteriorly, and in the depauperised species the first and second pairs depart from that condition, whereas the third, however feeble, still retains the chelate character; the fourth and fifth pairs are never chelate, generally enfeebled, rudimentary, or obsolete.

In the *Caridea* there are never more than two pairs of legs chelate, and the posterior three pairs are invariably simple and, generally, robust and efficient organs of a pediform character.

With each of these three divisions there is more or less constant condition of development.

In the *Astacidea* the embryo always leaves the ovum in a more or less perfectly developed megalop condition, with the exception of those genera that belong to the *Stenopidæ* which are hatched in the zoæa stage.

In the *Penæidea* the young is supposed to be hatched in a nauplius form, which has been demonstrated in *Leucifer*: in *Sergestes* and *Penæus*, as has approximately been shown in *Sergestes*, it is produced in the form of a blind *Xelaphocaris*. In this division the ova are not connected with the animal by any membranous attachment, and are probably deposited in the open sea, there to be brought to maturity if they do not fall a prey to hungry animals.

Within each division a greater or less departure from the typical character takes place, the variation generally being the greater or less developed condition of the branchiæ and the pereiopoda or walking legs, and this departure is generally connected with an important change in some external feature belonging to the animal, although there are some instances, as may be seen in the European and North American crayfish, where there is an alteration in the branchial condition without any external evidence. Sometimes, as in *Notostomus* and *Miersia* the branchial arrangement continues the same, while the external features vary considerably. Again, in the history of development, as in the genus *Alphæus*, the young of some species are hatched in a distinct form from that of others, while the parents exhibit no sign of variation, while again the common shrimp and the common prawn (that is *Crangon* and *Palæmon*), which evidently differ from each other, hatch their young in the same form.

The variability according to its importance and constancy breaks the several divisions into *Families*, *Genera*, and *Species*, while the character of development demonstrates a continuity in the history that exists in apparently widely separated species; an example of which may be seen in comparing the genus *Ibaccus* with that of *Palinurus*, which appear to possess little or nothing in common, while their offspring in the earliest stages of development appear to be identical.

But in whatever stage the young may quit the ovum, there is one common chapter in their history; that is, they invariably seek the surface of the sea, feeling as it were for light, air, and warmth, which for most of them would appear to be the chief condition for which they struggle in the earlier days of their existence, after which they generally sink to that abyss, whence they have been brought to light through the far-reaching powers of modern investigation.

Animals so delicate and fragile as these are very liable to injury and destruction from many causes.

As far as our experience teaches us, they never in the rougher weather reach the surface, or, at least, remain there, and where they have the power of congregating most they fall a prey as food to many larger animals. Taking their several means of destruction besides those that seem natural to the condition of their young lives, we must suppose that a very much larger number must be hatched as compared with those that permanently arrive at the adult form.

It is difficult to determine the number of young born of any known species, but it must be very great if we consider that a prawn of average size bears about a thousand eggs, and that a large *Palinurus*, such as is sold in our markets as the crawfish or spiny lobster, produces many thousands; the ova being small, or about one-fiftieth of an inch in diameter, while those of *Homarus* are one-tenth, and those of *Astacus* are one-eighth.

The stage at which development of the embryo has advanced at the time when it quits the egg appears to bear some relative proportion to the size of the ovum.

Thus our common edible shrimp has an egg only one-fortieth of an inch in diameter, while that of the Arctic species has one that is the eighth of an inch. The smaller ovum produces an animal in the zoæa condition, while from the larger the young appears in the megalopa stage.

Palinurus, Arctus, Ibaccus, and other allied genera, produce their young in an intermediate condition, more advanced than a zoæa and less mature than a megalopa, in a form long believed to be an animal of distinct individuality known as *Phyllosoma.*

The genus *Palinurus*, perhaps more than any other, will assist in demonstrating the bearing which the character and condition of the young have in the geographical distribution of species.

I cannot here resist pausing to remark that, if an animal that has furnished the tables of Europe with food from the earliest civilisation until now, and has been known to scientific students since the days of Aristotle, has not its life history known to us, it cannot be a matter of surprise that time is yet required to obtain the many links that are necessary to complete our knowledge of the successive stages of life upon the earth?

The spiny lobster, known to fishermen on the coasts of Devon and Cornwall as the crawfish, the *Palinurus vulgaris* of naturalists, is common all around the shores of Europe, and abundant at the entrance of the English Channel, where as many as fifty or sixty may be captured by a single fisherman in one night. With this abundance it is remarkable that two or three specimens only of the young in the phyllosoma form have ever been procured off the coast.

This species is represented in the southern hemisphere by *Palinurus Lallandii*, which ranges from the islands of Tristan d'Acunah in mid-ocean to the Cape of Good Hope, while *P. Edwardsii* exists around the coasts from the Cape of Good Hope to New Zealand. Another species (*P. frontalis*) exists off the western coast of South America. *Palinurus longimanus* belongs to the West Indies. *P. trigonus* has been taken at Japan, and another, which I think will ultimately be classified as being generically separate, *P. hugelii*, has been taken in the Indian Ocean.

Besides these are others only separated by definitions that have been appreciated by the more analytical research of modern investigators.

They consist of many species that are distinguishable from the preceding by the long and slender form of their first pair of antennæ. This the late Dr. Gray identified by the name of *Panulirus*. The latter form embraces a large number of known species; their localities are more distributed, but appear most generally to be confined to the seas of the tropical or warmest latitudes.

Three of these inhabit the Chinese and Japanese waters; three inhabit the Indian Seas; four belong to the West Indies; one has been found off the coast of California, and two have been procured from the Islands in the Pacific.

In point of geological time, the family to which these genera belong ranges from the Lias and lithographic limestones of England and Germany, in both of which it is represented by the solitary species *Palinurina longipes* of Minster.

The genus *Ibaccus* and its near allies *Scyllarus, Thenus, Arctus*, &c., differ from the *Palinurinæ* in having a generally flattened or depressed appearance, and in the second pair of antennæ, which, instead of being long, robust, and rigid, capable of being used as weapons of offence, are short, flat, and leaf-like.

Most of these genera inhabit the warmer zones. *Ibaccus Peronii* has been taken as far south as Australia, but the other species appear to be located within the tropics.

One species of the genus Scyllarus has been taken as far north as Japan, or latitude 40° north.

A species of the closely allied genus *Arctus*, though a tropical form, has been found as far north as the 50° of latitude, being common off the French coast, along the English Channel and occasionally off the shores of Devon and Cornwall, while species more or less distinct have been found on the eastern shores of Asia and in the eastern Archipelago, as well as near the Canary and Cape Verde Islands in the Atlantic.

Not very distant in structural features are the deep-sea genera that belong to the family of *Polychelidæ*, which bear a common general appearance and close anatomical relation to that of the fossil form of *Eryon*, from the lithographic limestones of Bavaria and the Lias of England.

Polycheles, Willemœsia, and their congeners, are inhabitants of the deepest parts of the ocean that have been explored with the dredge, and there is little doubt but that they have been brought up from the bottom of the sea.

The largest specimens have been taken from the greatest depth.

Willemœsia leptodactyla has been taken at 1,900 fathoms, or rather more than two miles in depth in the Pacific and Atlantic Oceans.

The closely allied genus *Penticheles*, which is represented by six species that differ from each other in no very remarkable degree in their external features, ranges from 120 to 1,070 fathoms in depth, and is scattered over a large area.

On the western shores of South America, around the broken coast of Patagonia, it has been taken in the channels between the rocky islands that lie along the shore; others have been taken among the Philippine Islands; also from the deeper water around New Guinea; two species off the Fiji Islands from near the New Hebrides; whilst their near ally and congener *Polycheles*, which is represented by four species, has been taken in the Mediterranean and off the coast of Spain, in mid-Atlantic and off the Fiji Islands, as well as near Kermadec and New Guinea, and the beautiful *Polycheles crucifera*, that bears so near a resemblance to the extinct *Eryon* of geological record, was captured in the West Indian Seas.

These genera wonderfully show that where conditions remain unaltered how little a thing is time, even when measured by geological æons, in the history of the progressive growth of species.

However different *Eryon* may be from *Polycheles*, the difference in structural evidence is not greater than that which exists among species of the same genera in recent epochs.

These animals are inhabitants of the deep sea. Their seeing powers are reduced in construction and extent, and the organs are so hidden that they were long supposed not to exist; in the fossil representative they have not yet been determined.

It has generally been supposed that this depreciation in the power of vision in animals that live in deep waters is largely due to their being so far beyond the reach of light; but this can scarcely be the cause, inasmuch as that the genus *Glyphocrangon*, in which the eyes are remarkable for their large and well-developed condition, is found at equally great depths and frequently associated with them, and, taking the several ranges at which species have been found, the average depth of the Willemœsian group is less than that of other deep-sea forms in which the eyes are large and conspicuous organs.

An examination of the animal while yet in an embryonic condition—and I have only had the opportunity of observing it before it has quitted the egg—shows that in its earliest stages of development the young has organs of vision similar to the ordinary crustacean type.

Thus it is like the genus *Alphæus*, in which the eyes are reduced in size and hidden beneath the carapace in the adult, while in the younger stages of existence it possesses organs of vision of considerable size. The animals as they grow appear to retrograde in the condition of their organs of sight, a circumstance that induces one to believe that the adult animals cease to exist under the same conditions as the young, and depart from roaming in the open water to the hidden recesses where exposed organs of vision would be useless and liable to injury.

The consideration of these deep-sea forms gradually leads us to that of another genus of no very distant structural character, but with very distinct surrounding conditions.

Instead of inhabiting the deeper recesses of the sea, the genus *Astacus* and its allies dwell in the shallow fresh-water streams and lakes of the continents and larger islands.

Species exist in the Northern and Southern Hemispheres.

Those of the northern genera differ in the number of the branchia from those of the southern. The crayfish of Europe and Asia possess fewer branchial plumes than those of North America, and those of North America fewer than those of the Southern Hemisphere.

The species of Eastern Europe and Western Asia differ in general form from those of Western Europe, although they correspond in their branchial arrangement, while those of Western Europe closely resemble those of Eastern America, although they differ from them in their branchial condition.

The species of South America differ in general external form from those of the Northern Continent, but correspond with those of Australia, which again differ from the species of New Zealand; while the solitary species in Madagascar differs from all others structurally, but corresponds externally with that of Australia. And the recently discovered Astacus from the Eocene strata of North America possesses the same congenital features peculiar to the recent form of the Northern Hemisphere.

Thus it would seem that each province has its own peculiar form, or what we call genus. All these bear a general resemblance to one another, as if they all came—the northern form from its common parent, the southern from its common parent, and both from one still older in the remote history in the life of these species.

The genus of long-legged prawns, to which Professor A. Milne-Edwards has given the name of *Nematocarcinus*, is essentially pelagic. The several species pass their lives floating in mid-water, with perhaps an occasional contact with the sea bottom.

Their geographical range is very extended, and their average floating area is about half a mile below the surface of the ocean.

The deepest point at which specimens have been taken is off the north-western coast of the Celebes Islands, at 2,150 fathoms, a depth of about $2\frac{1}{4}$ miles, but on the western coast near the shore they have been taken at 255 fathoms.

The next deepest range is south of Japan at 1,875 fathoms, and also at 560 and 350 fathoms respectively of the southern and western coast of Japan; the 100 fathom line is very near the shore at a point where the sea bottom dips suddenly to 2,000 or 3,000 fathoms. Again, near the Island of Juan Fernandez, at 1,375 and 1,450 fathoms. It has also been taken far south, in latitude 61° south, in the Indian Ocean, beyond the reach of any known land, at a depth of 1,260 fathoms. Off Kermadec Island it has been taken at 600 fathoms, or about three-quarters of a mile, also near the Fiji group.

The very varied recorded depths, differing as they do from $\frac{1}{4}$ to $3\frac{1}{2}$ miles, is suggestive that the animals do not reside at the extremest recorded, but that they were here entangled in colonies, swimming in mid-water, and brought to the surface.

Two of the deepest recorded stations are not distant from two or three of the shallowest. We must suppose that in the same region the species have either the power of living under distinctly separate conditions of temperature and bathymetrical influences, or that they live suspended in the ocean over these greater depths.

According to the observations brought home, the several species vary in form in points of little importance from each other, such as a longer and shorter rostrum, a short or a long foot. They extend over an area that reaches from the Antarctic snow line to the latitude of Japan, from the western coast of South America to the eastern shores of China.

The lowest temperature recorded is that of 1·5°, and the highest 5·0°. They consist of nine or ten species from seventeen localities, besides those recorded from the West Indies and the Cape Verde Islands by A. Milne-Edwards.

The fresh-water genus, *Atyoïdea*, is remarkable for the peculiarity of its form, as well as for having been found in localities so distant from one another.

The American naturalist, Randall, has described it from specimens taken in the rivers and ponds of the Hawaiian Islands, where they were also found by Dana. Another, but very closely allied, species was taken by the late Dr. Stimpson in the island of Tahiti, whence specimens have been brought home in the 'Challenger' collection. A third has been taken in the Mexican rivers by Saussure, and a fourth has been recently added to our knowledge from the rivers of Brazil by Dr. Fritz-Müller.

These animals have a peculiar character in the articulation of the heavy chelate joint of the first two pairs of pereiopoda with the carpus, being connected at the lower extreme angle only. The impinging fingers of the hand are hollowed out in the fashion of a spoon, the margins of which are fringed with a thick mass of long hairs; this, when the hand is open, spread as a kind of fan, gathers and detains fine mud, around which the hairs close when the hand is shut, compressing it into pellets, which are passed into the mouth.

The animal thus lives on the small organisms that exist in the mud, which it collects with great rapidity.

The male of this singular little animal is not provided with any offensive weapon, and is smaller than the female.

The question naturally arises as to how far asunder can animals, that are believed to derive their origin from a common parent, have attained their habitats without any connecting influence as far as we can determine.

Mons. A. Certes says that he took some carefully collected sediment, from which he evaporated the water, and kept for three years; he then heated the material with boiled and filtered rain water.

On the following day, notwithstanding all care had been taken to keep out germs from the air, specimens of *Flagellata* and *Ciliata* exhibited themselves, and two months later, nauplius-like forms appeared, which rapidly increased, and later assumed the form of *Artemia salina.*

Life being so long persistent in animals so high in organic structure is suggestive that, under more favourable conditions, others still higher might retain their vitality for a longer time than is generally believed, and that wading birds may be the means of carrying mud in which small crustacea, such as *Atoydea*, may have been encased with their ova, and so have transferred to a considerable distance the specimens of a distant locality.

One of the most abundant of specific forms is that of the genus *Alphæus*, in which I include those congeners that have been separated from it, more for the convenience of classification than on account of any structural value.

It contains twenty recognised species, and, with the exception of one single instance, they have all been taken within a depth of fifty fathoms of water. They are mostly recovered from muddy bottoms, but they are frequently found sheltered among masses of sponge or coral. From their peculiar habitat, and the protected condition of their eyes, I am induced, to believe that they burrow beneath the surface of the mud.

They are mostly inhabitants of the warm seas, abounding in tropical and subtropical regions, becoming more scarce in the temperate, and gradually disappearing towards the cold temperate and Antarctic regions. One species, that of *Betæus truncatus*, is recorded from Cape Horn, where it was dredged in about ten fathoms of water. With this exception none has been observed farther south than New Zealand, or 50° of S. latitude, or farther north than the English Channel, or 52° of N. latitude.

They are essentially a sub-littoral form, for the instances of their having been taken beyond twenty fathoms of water are few, and those are suggestive of a doubtful record.

Alphæus avarus is twice recorded in the 'Challenger' collection as having been taken off the coast of New Holland—once at a depth of eight fathoms, and once at 2,675 fathoms.

I cannot conclude this short sketch of the habits and range of some of the more common and abundant species of prawns without noting that of a minute swimming specimen that is called, in 'Bell's History of the British Crustacea,' *Thasanopoda Couchii.*

In the spring of the year this little creature, scarcely three-quarters of an inch in length, appears in great abundance in the English Channel a short distance beneath the surface of the sea; myriads come pouring in from the Atlantic.

These, which are mostly laden with ova, are of a slightly yellowish colour, and semitransparent; following these the herring comes ravenously on, and devours all it meets with; after the herring swim larger fish, which, in their turn, are chased by others. The geographical distribution of the more minute crustacea guides and limits that of the more important animal, and the study of the former will undoubtedly add much to our knowledge of the latter, and teach us that much of our own position in the world is dependent upon the existence and the condition of life of other animals, which, from our want of knowledge of them and their habits, we are accustomed to regard as unimportant and insignificant.

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2. *On the Geographical and Bathymetrical Distribution of the Crinoidea.* *By* P. HERBERT CARPENTER, *D.Sc.*

The geographical distribution of the Crinoids is fully as extensive as that of the other echinoderms. Comatulæ range between the two parallels of 81° N. and

52° S., while the corresponding limits for the Stalked Crinoids are 68° N. and 46° S. Some genera, such as *Actinometra* and *Pentacrinus*, occur in shallow water everywhere, or almost everywhere within the tropics; though *Pentacrinus* has not yet been obtained in the Pacific east of long. 170° W., nor between the meridians of 5° W. and 120° E., its nearest approach to the Indian ocean being the Moluccas. *Metacrinus*, on the other hand, has been found in the neighbourhood of Singapore, but it is otherwise almost entirely limited to the tropical regions of the West Pacific, ranging, however, as far north as Japan; while *Pentacrinus Wyville-Thomsoni* occurs in the Atlantic as far north as lat. 45°. Holopus, however, has never been obtained out of the Caribbean Sea.

Of the stalked crinoids *Rhizocrinus* has the greatest northern range (68° N.), but it has not been met with more than once, or possibly twice, south of the equator, and is limited to the Atlantic and Caribbean Sea. *Bathycrinus*, while ranging through 100° of latitude in the Atlantic and Southern Sea, does not occur in the Pacific at all. *Antedon*, on the other hand, is cosmopolitan, five species inhabiting the Arctic Ocean, while the genus is also well represented in the Southern Sea.

As a general rule the individual species of Crinoids are much limited in their range, though there are a few well-marked exceptional cases. Both species of Rhizocrinus occur in the east as well as in the west Atlantic, *Rhizocrinus Lofotensis* ranging from the Lofoten islands to 9° S., or perhaps to 35° S. While three species of Pentacrinidæ occur in the South Pacific near the Kermadecs, and also among the Philippines. The four Caribbean species of *Pentacrinus* are widely distributed among the West India islands, and it is very probable that systematic dredgings in Oceania, like those of the Blake in the Caribbean Sea, would largely increase the specific range, both of *Pentacrinus* and of *Metacrinus*.

Among the Comatulæ, the well-known *Antedon Eschrichti* is universally distributed in the Arctic Ocean and on both sides of the Atlantic as far south as lat. 43° N., while *Antedon dentata* of the Barents Sea, the north-east Atlantic, and the Scandinavian coasts is abundant on the banks off New England. *Antedon carinata* is another widely distributed species, occurring both on the Atlantic and on the Pacific coasts of South America, at Java, Mauritius, the Seychelles, and elsewhere; while *Actinometra pulchella* of the Caribbean Sea has also been dredged in moderately deep water off the coast of Morocco. The greater number of the Comatulæ, however, like the four species of *Bathycrinus* and most of the Pentacrinidæ have as yet been obtained at one or two localities only, and those not very widely separated.

The genus *Pentacrinus* has been found at all depths between 40 and 1,350 fathoms, though it has not been dredged more than sixteen times at a greater depth than 200 fathoms, and only three times below 700 fathoms. It is abundant in the Caribbean Sea, and has also been found in the east Atlantic, west Pacific, and among the Philippines. The allied genus *Metacrinus*, on the other hand, has a much more limited range, both bathymetrical and geographical, while it is unknown in the fossil state, for it has only been dredged twice below 200 fathoms, and never below 700; while, though extraordinarily abundant in shallow water at certain localities in the Malay Archipelago, it appears to be confined to the warmer parts of the western basin of the Pacific.

Rhizocrinus, on the other hand, is almost entirely limited to the north Atlantic and the Caribbean Sea, and has been obtained at all depths from 80 to 1,900 fathoms; it is fairly abundant down to 1,000 fathoms, though it is extremely rare below that depth. Here, however, it is replaced by *Bathycrinus*, which has been dredged eight times between one and two thousand fathoms, and once at 2,400 fathoms. This genus ranges from the Atlantic into the Southern Sea, but is not known elsewhere, nor does it occur in the fossil state as *Rhizocrinus* does.

Two genera of recent Crinoids, *Hyocrinus* and *Thaumatocrinus*, have large oral plates covering the peristome, and are thus to be regarded as in a permanently larval condition. Both were dredged in the Southern Sea at depths of 1,600 fathoms and upwards, and both have certain affinities with the Palæocrinoids. *Hyocrinus* has a tripartite base, which occurs in no other Neocrinoid, while the arms are very narrow relatively to the radials, and bear long pinnules on every second or third joint, very much as in the Carboniferous *Barycrinus herculeus*.

Thaumatocrinus, on the other hand, although a true Comatula, has calyx-interradials resting directly on persistent basals, and so separating the first radials laterally, this being a peculiarity which is especially characteristic of certain Rhodocrinidæ. A still more extraordinary feature in the calyx of *Thaumatocrinus* is the presence of an anal appendage of the same nature as the so-called small lateral proboscis in *Taxocrinus* and *Onychocrinus*; while three Lower Silurian genera, *Heterocrinus, Reteocrinus,* and *Xenocrinus* seem to have possessed a similar structure. Its function appears to have been that of supporting the anal inter-radius of the disc, though it was in no way pierced for the reception of the hind gut. There is no trace of such a structure in any other Neocrinoid but *Thaumatocrinus,* and its appearance in such a specialised type as a recent Comatula is therefore not a little remarkable.

As regards the other Comatulæ, *Antedon* is found in all climates and at all depths, ranging from the littoral zone down to 2,900 fathoms. It has, however, only been obtained four times below 1,200 fathoms, and at these great depths is only represented by extremely minute individuals. The same is the case with the ten-rayed *Promachocrinus,* which seems to be fairly abundant in shallow water at certain localities in Kerguelen's Land; while dwarfed and almost colourless individuals were obtained at 1,600 and at 1,800 fathoms at other localities in the Southern Sea. *Actinometra,* on the other hand, is principally limited to the tropical and subtropical seas, and has not been obtained more than seven times below 200 fathoms, its lowest range yet known being 533 fathoms. *Eudiocrinus,* a curious five-armed Comatula, not otherwise distinguishable from *Antedon,* has been dredged at various depths in the Atlantic and Pacific between the littoral zone and 1,050 fathoms; while the singular type *Atelecrinus*, which represents a permanently premature stage of other Comatulæ, is confined to depths between 300 and 600 fathoms, roughly speaking.

Thus, then, while *Bathycrinus, Hyocrinus,* and *Thaumatocrinus* are the crinoids which are more especially characteristic of the abyssal zone below 1,200 fathoms, *Rhizocrinus, Pentacrinus,* and three Comatulid genera extend down into it from quite shallow water. All five, however, are much reduced in size at these great depths, and it is further noticeable that the only species of *Pentacrinus* which occur below 1,000 fathoms are those with comparatively few arms, the type which has the greatest range being the simple ten-armed *Pentacrinus Naresianus.*

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3. *On the Origin of Fresh-Water Faunas.* *By* Professor W. J. Sollas, *F.G.S.*

The poverty of fresh-water faunas is not to be explained by the difference in composition or climate of fresh-water areas as compared with marine; but more probably by the exclusion of free-swimming larvæ as a means of distribution, since these feeble and fragile forms are unable to make headway against the current of a river which is always directed seawards. An attached form, introduced by any means into a river, could not establish itself so long as it propagated exclusively by free-swimming larvæ. Hence, this method of propagation should never, or only very exceptionally, occur in the case of fresh-water forms. Nor, as a matter of fact, does it. In Hydra, fresh-water sponges, and Polyzoa, the young emerge in a complete state from a horny cyst. In Unionidæ the characteristic glochidium stage occurs. In most gastropods the eggs are attached by imbedment in jelly, and *Paludina* is viviparous. The suppression of a free-swimming larval stage not only occurs in fresh-water, but in some marine invertebrates. This is connected with the fact that the larval stage is one of immense disadvantage as compared with the adult, and to escape from it development comes to take place in seclusion. From this a series of other modifications results, such as accelerated and abbreviated development.

Of the various causes which have led to the transformation of marine into fresh-water forms, the commonest can be traced to the conversion of marine into fresh-water areas. The earliest known lacustrine areas, those of the Old Red Sandstone, have yielded a species of pond-mussel, which has been described as *Anodonta Jukesi* by Forbes. The Permo-Triassic lakes contributed additional fresh-water forms, such as the Neritina and Melaniidæ; other genera probably arose at this time, the occurrence of Uniò, Physa, Valvata, and Lymnea, in the Nearctic, Palæarctic, and Oriental regions during Cretaceous times suggests for them a high antiquity, possibly reaching into Palæozoic times.

The lakes of the Tertiary period furnished probably the fresh-water genera *Lithoglyphus* and *Dreissena.*

Thus existing fresh-water genera are probably descended from marine forms which became metamorphosed in the waters of the Devonian, Triassic, and Tertiary lakes.

4. *On a Fish supposed to be of Deep-sea Origin.* *By* the Rev. D. Honeyman, *D.C.L.*, *F.R.S.C.*

5. *On the Trapping of Young Fish by the Water Weed,* Ultricularia Vulgaris. *By* Professor Moseley, *LL.D.*, *F.R.S.*

The fact that the plant thus preys upon vertebrata was discovered by Mr. G. E. Simms, son of a tradesman in Oxford, and communicated to 'Nature' in a letter by Professor Moseley, printed in 'Nature' of May 22, 1884. There appears to be room for much interesting further research as to the action of the plant in the process. Professor Moseley found of one batch of young fish placed in a vessel with a quantity of weed a certain residual number remained untrapped for several weeks. Possibly the plant soon loses its power of trapping when left in confinement, or is affected by change of temperature in the weather. The old traps seem possibly less active than the young. Possibly young fish of certain species are from their habits less liable to be trapped than others. The bodies of the dead entrapped fish are rapidly reduced to a glairy mass by swarms of infusoria, which possibly thus prepare the prey for the nourishment of the plant, taking the place of actual digestive organs, which Mr. Darwin showed to be absent in Utriculariæ.

6. *On the Concordance of the Mollusca inhabiting both sides of the North Atlantic and the intermediate Seas.* *By* J. Gwyn Jeffreys, *LL.D.*, *F.R.S.*—See Reports, p. 531.

FRIDAY, AUGUST 29

The following Reports and Papers were read:—

1. *Fourth Report of the Committee for the Investigation of the Natural History of Timor-Laut.*—See Reports, p. 263.

2. *Report of the Committee for the Exploration of Kilima-njaro and the adjoining Mountains of Eastern Equatorial Africa.*—See Reports, p. 271.

3. *Report of the Committee for arranging for the occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 252.

4. *Report on the Record of Zoological Literature.*

5. *Report of the Committee for preparing a Bibliography of certain Groups of Invertebrata.*—See Reports, p. 270.

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6. *Report on the Migration of Birds.*—See Reports, p. 266.

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7. *On the Characteristic Features of North American Vegetation. By* Professor ASA GRAY.—See Reports, p. 555.

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8. *On the Identity of the Animals and Plants of India which are mentioned by early Greek Authors. By* V. BALL, *M.A., F.R.S.*

When engaged in inquiries with reference to the identification of the mineral productions of India which are mentioned by early Greek writers, I noticed that many of the animals and plants alluded to by Herodotus, Megasthenes, Ktesias, Arrian, Ælian, and Strabo are susceptible of exact identification when discussed from the point of view of our present knowledge of the natural productions of India, and the peculiar views held by the natives regarding some of them.

The result has been to remove from the category of myths many stories which have been hitherto regarded as unworthy of credence, and to remove from some of the writers the charges of mendacity which have freely been cast upon them by commentators who were unacquainted with the local circumstances from which the peculiarities of the stories took their rise.

In the very latest editions of some of the Greek authors are to be found comments derived proximately from Lassen, but ultimately from Ritter, and others before him. These comments, some of them upwards of half a century old, have been repeated without the slightest reference being made to the more exact information regarding India which is now available.

In a paper shortly to be published in the 'Proceedings of the Royal Irish Academy' I have given a list of about thirty animals and twenty plants, the majority of the identifications having never before been suggested. The following are among the more important of these.

ANIMALS.

The *Martikhora* . . .	= Tiger.
„ *Krokottas*[1] . . .	= Spotted Hyena (*H. Crocuta*).
„ *Kartazonon* . . .	= Rhinoceros.
„ *Skolex*	= Crocodile or Gharial.
„ Oil of the *Skolex* . .	= Petroleum.
„ *Elektron*	= Shell lac.
„ *Kelas*	= Adjutant (*Leptoptilos*).
„ *Kerkion*	= Maina (*Eulabes*).
„ *Dikairon*	= Dung Beetle (*Scarabæus*).

PLANTS.

The *Calamus Indicus* . .	= Fan Palm (*Borassus flabelliformis*).
„ *Parebon*	= *Ficus religiosa*.
„ *Siptakhora* . . .	= *Bassia latifolia*. = *Schleichera trijuga*.
„ Purple flowers yielding dye	= *Grislea tomentosa*.

The paper referred to will contain a full discussion of all these identifications.

[1] As is mentioned by our authors, this is an Ethiopian animal. Hitherto it has been mistaken for the jackal.

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9. *On the Classification and Affinities of Dinosaurian Reptiles.* *By* Professor O. C. MARSH.

The author presented briefly the results of a study of Dinosaurian reptiles on which he had been engaged for several years. The complete results will be published in a series of monographs now in preparation. The material on which the investigation is mainly based consists of the remains of several hundred individuals of this group collected in the Rocky Mountains by the author, and now preserved in the Museum of Yale College.

Other important American specimens have been examined by the author, who has also studied with care the more important remains of this group in the museums of Europe. The investigation is not yet completed, but the results already attained seem to be of sufficient interest to present to the Association at this time.

In previous publications on this subject, the author had expressed the opinion that the *Dinosauria* should be regarded, not as an order, but as a sub-class, and his later researches confirm this view.

The great number of subordinate divisions in the group, and the remarkable diversity among those already discovered, indicate that many new forms will yet be found. Among those already known there is a much greater difference in size and structure than in any other sub-class of vertebrates, with the exception of the placental mammals. Compared with the Marsupials, living and extinct, the Dinosauria show an equal diversity of structure and size.

According to present evidence, the Dinosaurs were confined entirely to the Mesozoic age. They were abundant in the Jurassic, and continued in diminishing numbers to the end of the Cretaceous period, when they became extinct. The great variety of forms that flourished in the Triassic renders it more than probable that some members of the group existed in the Permian period, and their remains may be brought to light at any time.

The Triassic Dinosaurs, although very numerous, are known to-day mainly from footprints and fragmentary osseous remains; hence, many of the forms described cannot at present be referred to their appropriate divisions in the group.

From the Jurassic, however, during which period Dinosaurian reptiles reached their zenith in size and numbers, representatives of no less than four well-marked orders are now so well known that different families and genera can be very accurately determined, and almost the entire osseous structure of typical examples, at least, can be made out with certainty.

Comparatively little is yet known of Cretaceous Dinosaurs, although many have been described from incomplete specimens. All these appear to have been of large size, but much inferior in this respect to the gigantic forms of the previous period. The remains best preserved show that, before extinction, some members of the group became quite highly specialised.

Regarding the Dinosaurs as a sub-class of the *Reptilia*, the forms best known at present may be classified as follows:—

Sub-Class DINOSAURIA.

Premaxillary bones separate; upper and lower temporal arches; rami of lower jaw united in front by cartilage only; no teeth on palate. Neural arches of vertebræ united to centra by suture; sacral vertebræ coössified. Cervical and thoracic ribs double-headed. Ilium prolonged in front of acetabulum; acetabulum formed in part by pubes; ischia meet distally on median line. Fore and hind limbs present, the latter ambulatory and larger than those in front; head of femur at right angles to condyles; tibia with procnemial crest; fibula complete. First row of tarsals composed of astragalus and calcaneum only, which together form the upper portion of ankle joint.

I. Order SAUROPODA (Lizard-foot). Herbivorous. Premaxillary bones with teeth. Large antorbital opening. Anterior nares at apex of skull. Post-occipital bones. Anterior vertebræ opisthocœlian; cervical ribs coössified with vertebræ;

pre-sacral vertebræ hollow; each sacral vertebra supports its own transverse process. Fore and hind limbs nearly equal; limb bones solid. Feet plantigrade, ungulate; five digits in manus and in pes; second row of carpal and tarsal bones unossified. Sternal bones parial. Pubes projecting in front, and united distally by cartilage; no post-pubis.

1. Family *Atlantosauridæ*. A pituitary canal. Ischia directed downward, with expanded extremities meeting on median line. Sacrum hollow. Anterior caudals with lateral cavities.

Genera: *Atlantosaurus, Apatosaurus, Brontosaurus.*

2. Family *Diplodocidæ*. Dentition weak. Brain inclined backward. Large pituitary fossa. Two antorbital openings. Ischia with straight shaft, not expanded distally, directed downward and backward, with ends meeting on median line. Caudals deeply excavated below. Chevrons with both anterior and posterior branches.

Genus: *Diplodocus.*

3. Family *Morosauridæ*. Small pituitary fossa. Ischia slender, with twisted shaft, directed backward, and sides meeting on median line. Sacral vertebræ solid. Anterior caudals solid.

Genus: *Morosaurus.*

European forms of this order: *Bothriospondylus, Cetiosaurus, Chondrosteosaurus, Eucamerotus, Ornithopsis, Pelorosaurus.*

II. Order STEGOSAURIA (Plated Lizard). Herbivorous. Feet plantigrade, ungulate; five digits in manus and in pes; second row of carpals unossified. Pubes projecting free in front; post-pubis present. Fore limbs small; locomotion mainly on hind limbs. Cervical ribs free. Vertebræ and limb bones solid. Osseous dermal armour.

1. Family *Stegosauridæ*. Vertebræ bi-concave. Neural canal in sacrum expanded into large chamber; ischia directed backward, with sides meeting on median line. Astragalus coössified with tibia; metapodials very short.

Genera: *Stegosaurus* (*Hypsirhophus*), *Diracodon*, and in Europe *Omosaurus.*

2. Family *Scelidosauridæ*. Astragalus not coössified with tibia; metatarsals elongated; four functional digits in pes. Known forms all European.

Genera: *Scelidosaurus, Acanthopholis, Cratæomus, Hylæosaurus, Polacanthus.*

III. Order ORNITHOPODA (Bird-foot). Premaxillaries edentulous in front. A premandibular bone. Herbivorous. Feet digitigrade, five functional digits in manus and three in pes. Pubes projecting free in front; post-pubis present. Vertebræ solid. Cervical ribs free. Fore limbs small; limb bones hollow.

1. Family *Camptosauridæ*. Clavicles wanting; post-pubis complete.

Genera: *Camptosaurus, Laosaurus, Nanosaurus*; and in Europe *Hypsilophodon.*

2. Family *Iguanodontidæ*. Premaxillaries edentulous. Post-pubis incomplete. Known forms all European.

Genera: *Iguanodon, Vectisaurus.*

3. Family *Hadrosauridæ*. Teeth in several rows, forming with use a tesselated grinding surface. Anterior vertebræ opisthocœlian.

Genera: *Hadrosaurus* (*Diclonius*), *? Agathaumas, Cionodon.*

IV. Order THEROPODA (Beast-foot). Carnivorous. Premaxillary bones with teeth. Anterior nares at end of skull. Large antorbital opening. Vertebræ more or less hollow. Limb bones hollow. Feet digitigrade; digits with prehensile claws. Pubes projecting downward, with distal ends coössified.

1. Family *Megalosauridæ*. Anterior vertebræ convexo-concave; remaining vertebræ bi-concave. Pubes slender. Astragalus with ascending process.

Genera: *Megalosaurus* (*Poikilopleuron*), *Allosaurus, Cœlosaurus, Creosaurus, Dryptosaurus* (*Lælaps*).

2. Family *Labrosauridæ*. Lower jaws edentulous in front. Cervical and dorsal vertebræ convexo-concave. Pubes slender, with anterior margins united. Astragalus with ascending process.

Genus: *Labrosaurus.*

3. Family *Zanclodontidæ*. Vertebræ bi-concave. Pubes broad elongate plates,

with anterior margins united. Astragalus without ascending process. Five digits in manus and in pes.

Genera: *Zanclodon, ? Teratosaurus.*

4. Family *Anchisauridæ.* Vertebræ bi-concave. Pubes rod-like. Five digits in manus, and three in pes.

Genera: *Anchisaurus* (*Megadactylus*), *? Bathygnathus, ? Clepsysaurus, Palæosaurus, Thecodontosaurus.*

Sub-Order Cœluria.

5. Family *Cœluridæ.* Vertebræ and bones of skeleton pneumatic. Anterior cervicals convexo-concave; remaining vertebræ bi-concave. Cervical ribs coössified with vertebræ. Metatarsals very long and slender.

Genus: *Cœlurus.*

Sub-Order Compsognatha.

6. Family *Compsognathidæ.* Cervical vertebræ convexo-concave; remaining vertebræ bi-concave. Three functional digits in manus and in pes. Ischia with long symphysis on median line.

Genus: *Compsognathus.*

Sub-Order Ceratosauria.

7. Family *Ceratosauridæ.* Horn on skull. Cervical vertebræ plano-concave; remaining vertebræ bi-concave. Pubes slender. Pelvic bones coössified. Osseous dermal plates. Astragalus with ascending process. Metatarsals coössified.

Genus: *Ceratosaurus.*

The four orders defined above, which the author first established for the reception of the American Jurassic Dinosaurs, appear to be all natural groups, well marked in general from each other. The European Dinosaurs from deposits of corresponding age fall readily into the same divisions, and, in some cases, admirably supplement the series indicated by the American forms. The more important remains from other formations in this country and in Europe, so far as their characters have been made out, may likewise be referred with certainty to the same orders.

The three orders of Herbivorous Dinosaurs, although widely different in their typical forms, show indications of approximation in some of their aberrant genera. The *Sauropoda,* for example, with *Atlantosaurus* and *Brontosaurus,* of gigantic size, for their most characteristic members, have in *Morosaurus* a branch leading towards the *Stegosauria.* The latter order, likewise, although its type genus represents in many respects the most strongly marked division of the Dinosaurs, has in *Scelidosaurus* a form with some features pointing strongly towards the *Ornithopoda.*

The Carnivorous *Dinosauria* now best known may all be placed at present in a single order, and this is widely separated from those that include the herbivorous forms. The three sub-orders here defined include very aberrant forms, which show many points of resemblance to Mesozoic birds. Among the more fragmentary remains belonging to this order, this resemblance appears to be carried much further.

The *Amphisauridæ* and the *Zanclodontidæ,* the most generalised families of the *Dinosauria,* are known only from the Trias. The typical genera, however, of all the orders and sub-orders are Jurassic forms, and on these especially the present classification is based. The *Hadrosauridæ* are the only family confined to the Cretaceous. Above this formation there appears to be at present no satisfactory evidence of any *Dinosauria.*

The peculiar orders *Hallopoda* and *Aëtosauria* include carnivorous reptiles which are allied to the *Dinosauria,* but they differ from that group in some of its most characteristic features. In the former genus, the entire limbs are crocodilian, and this is also true of the dermal covering. In both of these genera there are but two sacral vertebræ, but this may be the case in true Dinosaurs, especially from the Trias. Future discoveries will probably bring to light intermediate forms between these orders and the typical Dinosaurs.

The *Crocodilia* have some strong affinities with the *Dinosauria*, especially with those of the order *Sauropoda*. The extinct genus *Belodon* of the Triassic, for example, resembles *Diplodocus*, particularly in the large antorbital vacuities of the skull, the posterior position of the external nasal aperture, as well as in other features.

The *Rhynchocephala*, represented by the genus *Hatteria*, have several important characters in common with the *Dinosauria*, and, as the former is evidently an ancient type, it is probable that a real affinity may exist between these two groups.

That birds are closely related to Dinosaurs, there is no longer any question. In addition to the various characters which these groups have been known to share with each other, two more may be added in consequence of discoveries made during the past year. The genus *Ceratosaurus*, a carnivorous Dinosaur from the Jurassic of the Rocky Mountains, recently described by the author, has the pelvic bones coössified, as in all known birds, living and extinct, except *Archæopteryx*. The same reptile, moreover, has the metatarsal bones firmly united, as in all adult birds, with possibly the single exception of *Archæopteryx*; while all the known *Dinosauria*, except *Ceratosaurus*, have both the pelvic and the metatarsal bones separate. The exception in each case brings birds and reptiles near together at this point, and their close affinity is now a matter of demonstration.

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10. *On the Rudimentary Hind-Limb of the Tay Whale*, Megaptera longimana. *By* Professor J. STRUTHERS, *M.D.*

The author said the humpbacked whale was extremely rare on the British coast. One had been seen often spouting for some weeks in December in the Firth of Tay; it was mortally wounded, and finally towed ashore dead, near Aberdeen. It was a male, forty feet in length. After it had been exhibited for a couple of weeks at Dundee he had partially dissected it. Having been preserved, it was further exhibited, and he had only completed his dissection immediately previous to coming out. The presence of a rudimentary thigh-bone had been discovered in this species many years ago by the late Professor Reinhardt of Copenhagen. The thigh-bone was composed entirely of a cartilage of conical shape, in length five and a half inches on the right side, four inches on the left; it was incased in fibrous tissue, and rested loosely on the pelvic bone without artificial surface. Looking at the anatomical facts, and comparing them with those in the other species he had referred to, the conclusion which must be arrived at was that the thigh-bone in the humpbacked whale was a rudimentary structure: a vestige of a more complete limb possessed by ancestors from which it was descended. The skeleton of this whale would, he hoped, be placed in the Dundee Museum, before the Association met in Aberdeen next year.

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11. *Note on the occurrence of Bacteria on the Surface of Coins. By* Professor LOUIS ELSBERG, *A.M.*, *M.D.*

In the early part of this year Professor Paul F. Reinsch, of Erlangen, well known as a student of algæ, published in the German periodical 'Flora' (No. 9, 1884) a description of two new species of algæ found in the incrustations on the surface of old coins, and named by him respectively *Chroococcus monetarum* and *Pleurococcus monetarum*. He also announced that he had discovered on pieces of money that had long been in circulation innumerable bacteria. These he described as 'rod-shaped bacteria (oscillaroid forms), with oscillating motion (vibrio), and spiral motion (spirillum), and spherical bacteria (micrococcoid forms), with their peculiar oscillatory dancing motions.' He said, 'Sometimes all these forms occur on one coin; but in most cases either spherical or rod bacteria predominate, the first constituting most frequently the main mass. Spirillum is found more rarely, but on careful investigation certainly also on very many coins. Of the typical bacterium there occur 4–12 linked rods of 0·0055—0·0077 mm. length upon all silver, copper, and bronze coins examined. The links at each end of the rod are usually thickened into a little head.'

I was requested to translate Professor Reinsch's paper, and it has been widely published in various parts of the United States; but only recently I have repeated Professor Reinsch's investigations. As to the occurrence of palmella-like and chroococcoid algæ I can express no doubt; but most of the coins that I have examined, it is true the majority having been American, showed rod bacteria either to be present in very much smaller number than Professor Reinsch describes, or to be entirely absent, as I shall presently state, and the movement of the largest number of particles seen I believe to be molecular only.

It is of interest that on the surface of a silver Spanish coin of the time of Charles II., 1777 (which I have good reason to believe had been put away and kept entirely out of circulation for at least fifty years), I found a few bacilli and bacteria in fields containing numerous micrococci exactly like those observed on coins now in circulation. The oldest coins examined were a Spanish silver piece of the reign of Philip V., 1721, another of Ferdinand VI., 1754, the one mentioned above, and a United States copper cent of 1803, in the sediment from all of which the micro-organisms were as active and of the same appearances as in more recent current money.

I must also note that the American coins examined were the cleanest of all, and the most difficult to obtain matter containing bacteria from. Whether this is on account of any peculiarity of coinage or mixture of metals, which may interfere with retention of sediment that acts as nidus, I do not know; but it held good of gold, silver, nickel, and copper coins. No American piece showed much micro-vegetation unless at least from six to ten years old, while European pieces usually showed the same when of dates only three or four years back. Many speculative reasons might be suggested to explain this, but I simply note the fact as I found it. Perhaps it was merely accidental, but I have examined a great many more American coins than European.

I always found in the incrustation some fat and starch granules, and about half the number of rods were motionless.

Professor Reinsch has pointed out the probability that the micro-organisms play a *rôle* in the process of erosion of the surface of circulating coins, and also the hygienic importance which may have to be ascribed to the presence, upon an object so diffused as money, of bodies in many cases recognised as the zymotic agents, the carriers and diffusers of disease. I am far from wishing, however, to promote the occurrence of what neurologists nowadays describe as mysophobia, a malady from which those who suffer have a morbid fear of contamination from handling money.

On examining the dust that had been undisturbed for a long time in a crease of a writing-desk cover, and on tops of doors in some rooms, I found similar but not identical micro-vegetation, while the matter that I could obtain from between the projections on the fine adjustment screw-head of a microscope, long in use, contained to all appearances the very same as the coins; although positively to decide the question whether or not the organisms are *peculiar* to money incrustations I must admit my incompetency so far as the algæ are concerned, and my inability to find grounds for a differential diagnosis between the bacteria found.

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12. *On the Comparative Variableness of Bones and Muscles, with Remarks on Unity of Type in Variation of the Origin and Insertion of certain Muscles in Species unconnected by Unity of Descent.*[1] *By* G. E. Dobson, *M.A.*, *F.R.S.*

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[1] Published in the *Journal of Anatomy and Physiology*, October 1884.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Papers were read :—

1. *On the Value of Nerve-Supply in the Determination of Muscular Anomalies. By* Professor D. J. CUNNINGHAM, *M.D.*

The author spoke of the muscula sternalis as a new muscle in man, which had no counterpart among animals. It was, according to his experience, found more frequently among females than males, while Professor Sheppard, of McGill College, had, he learned, had three cases, all among males.

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2. *On the Mutual Relation of the Recent Groups of Echinoderms. By* Professor A. MILNES MARSHALL, *M.D.*

The author said that of these there were four groups, the common starfish, brittle starfish, sea-urchins, and holothurians. The nerve-system was originally derived from the skin. In some animals the nerve-system sank below, in others it remained near the skin, the latter being in a more primitive condition than those in which the nerve-system had sunk down.

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3. *On the Fœtal Membranes of the Marsupials. By* W. H. CALDWELL.

This paper gave an account of the development of the marsupial embryo, which has been hitherto a riddle in biology.

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4. *On the Progress of his Investigations in Australia. By* W. H. CALDWELL.

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5. *An Attempt to exhibit Diagrammatically the several Stages of Evolution of the Mammalia. By* G. E. DOBSON, *M.A., F.R.S.*

PLATE IX.

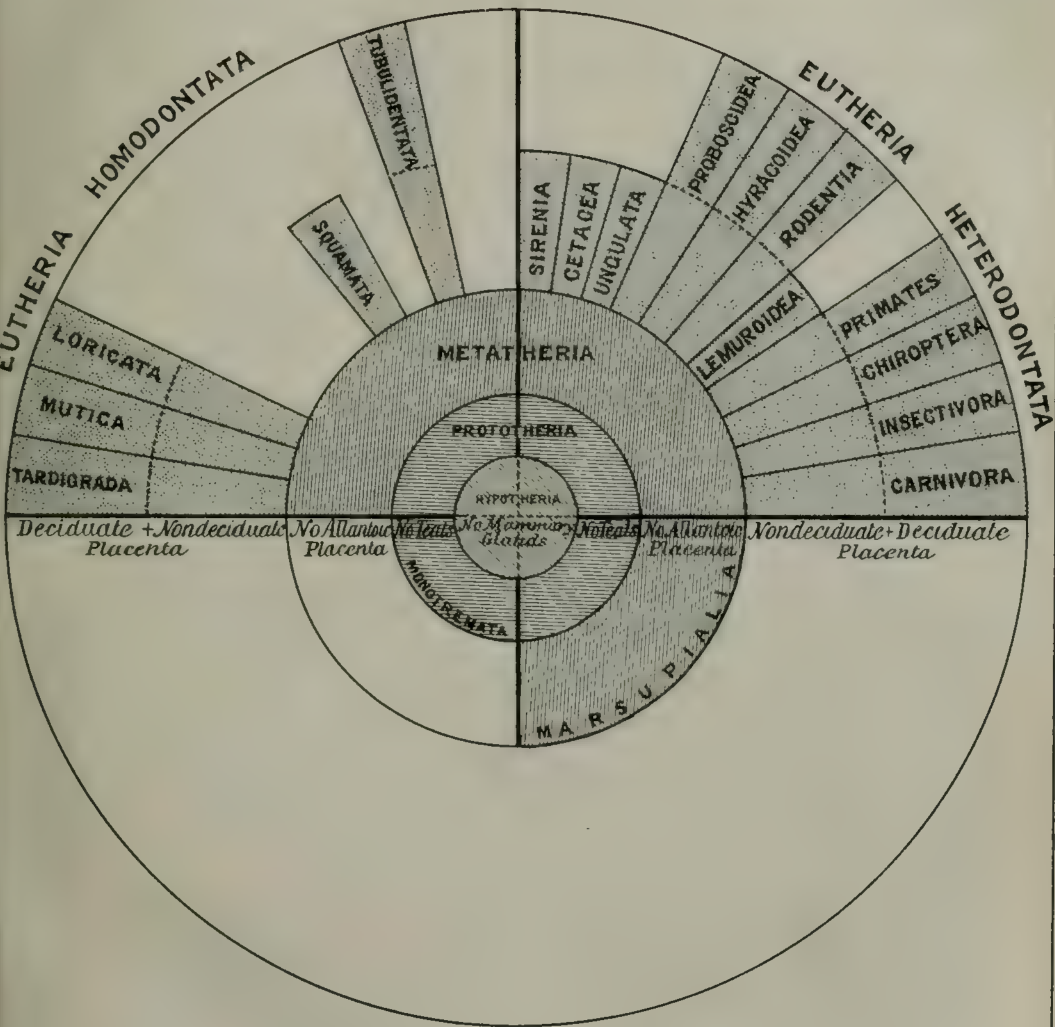
Since I had the privilege of hearing Professor Huxley read his paper on the Application of the Laws of Evolution to the Arrangement of the Mammalia, I have endeavoured to discover some mode of presenting his views, more particularly those with respect to the Mammalia, in diagrammatic form, which might serve to convey at a glance to the mind of the student the relative position of the various existing groups of this class, not only to one another but also to the pre-existing classes from which they have been derived.

In the diagram which I now present I hope that not only has this object been in a great measure attained, but that also some minor points, untouched in the paper referred to, have been at the same time illustrated.

To everyone who has read Professor Huxley's paper this diagram is, I trust, self-explanatory; to those who have not, the following notes may be acceptable.

In this diagram the stage of evolution of the existing mammalian groups is indicated by a series of concentric circles, so that at a glance the position of any group with regard either to the hypothetical ancestors of the class, or to any other group, is at once seen.

These hypothetical ancestors, termed by Huxley Hypotheria, are included within



Illustrating Mr. G. E. Dobson's Paper, "An Attempt to Exhibit Diagrammatically the several Stages of Evolution of the Mammalia".

Spottiswoode & Co. Lith. London

the small innermost circle. Such ancestors would, properly, not be classed as Mammals, for although they possessed two occipital condyles, yet the absence of mammary glands and the articulation of the mandible with a quadrate bone would necessarily prevent their recognition as such.

From these ancestral forms, which would probably differ from their nearest vertebrate allies by the presence of two occipital condyles, the retention of the left as the principal aortic arch, the existence of an amnion and the non-existence of branchiæ, we may conceive the evolution of the primary Mammalian forms, termed by Huxley Prototheria (indicated in the diagram by the second ring), and of which the evidently highly differentiated species included within the genera Ornithorhynchus and Echidna are the sole existing representatives.

While such forms by the possession of mammary glands would rank as Mammals, yet the absence of teats, the presence of a deep cloaca, the hypocystic position of the openings of the ureters, and the characters of the generative organs generally, indicate the early stage of their Mammalian organisation.

It is possible, however, that at this early stage separation into two groups took place (indicated in the diagram by horizontal lines), from one of which proceeded the ancestors of the Placental, and from the other those of the Implacental Mammals. That such was the case appears to be indicated by the presence of epipubic bones in both Monotremata and Marsupialia, while their existence, whether in a reduced or rudimentary state, is, to say the least of it, doubtful in all other mammals.

Again, a binary division evidently also took place in each of those groups (indicated in the diagram by vertical lines), giving origin on one side to the ancestors of the existing Monotremata (shown in the diagram to be a terminal group) and to the Marsupialia, and on the other to those of the Homodont and Heterodont subclasses of the higher Mammalia.

The next stage of evolution termed by Huxley Metatherial (indicated in the diagram by the third ring), is represented among existing Mammals by the Marsupialia, themselves, like the Monotremata, a terminal group, though there can be no doubt that they are greatly modified representatives of this sub-class. It is more than probable that the now extinct Metatherial ancestors of existing Placental Mammals differed altogether from those of the existing Marsupials, though belonging to the same evolutionary stage, in that they possessed neither marsupial bones nor pouches, nor were their young brought forth at a much earlier period than in existing Carnivores and Rodents, but exhibited in common with them a marked advance in development, as evidenced by the presence of mammary teats, in the reduced condition of the cloaca, in the ento-cystic mode of opening of the ureters, and in the general characters of the generative organs. Nevertheless these mammals still presented little advance in the intra-uterine mode of nutrition of the fœtus, the placenta being still non-allantoic; indeed, as I am informed by Mr. Sedgwick, the recent discoveries of Mr. Caldwell in Australia, show that in their highly differentiated descendants, the Marsupialia, there is scarcely what deserves the name of a placenta.

In the next stage, that of the Eutheria or Higher Mammalia (indicated in the upper semicircle of the diagram by the outer broad ring), we find a great advance in development in the presence of an allantoic placenta which may be non-deciduous, as in the orders Ungulata, Cetacea, Sirenia, and Lemuroidea, and in the Homodont order Squamata, or deciduate as in the remaining orders; and this is shown at a glance in the diagram by the position of the words indicating the orders, those with deciduate placenta occupying the outer and higher position in the evolutionary scale.

It is highly probable that the separation of the Homodont Mammals, represented by the existing and extinct Edentata (which for many reasons should be considered a separate sub-class), took place at an early period of Mammalian evolution, perhaps in the Prototherian stage, as I have indicated by the vertical line dividing the upper semicircle into two equal parts.

The natural affinities of the orders of Heterodont and Homodont Eutherians to one another are indicated, as far as a linear series will allow, by their position in the section to which each belongs.

6. *On some Peculiarities in the Geographical Distribution of certain Mammals inhabiting Continental and Oceanic Islands.*[1] *By* G. E. DOBSON, *M.A., F.R.S.*

The author points out the interesting fact, not hitherto noticed, that many of the most characteristic species of the Chiropterous fauna of Australia have their nearest allies not in the Oriental but in the Ethiopian region, thus contrasting remarkably with the avi-fauna, and instances the presence of species of the genera *Chalinolobus* and *Mormopterus* as occurring in the Ethiopian and Australian regions, while they are unrepresented in the Oriental; and also the strong natural affinities existing between certain species of other genera inhabiting the former regions. He also draws attention to the fact that not less than 80 per cent. of the species of *Pteropus*[2] are restricted to Australia and Madagascar with its islands, while a single species only, evidently derivative, inhabits the immense continent of India and the island of Ceylon. The necessity, in the first place, of postulating some connection between Africa, Madagascar, and the Australian Continent, to account for their distributional peculiarities, appears evident from consideration of the above noted facts, but the writer remarks that such connection was not by way of India, as shown by the absence of connecting species in that country, and points out that we are therefore obliged to suppose that at a comparatively recent period a chain of islands connected these continents, the islands being sufficiently far apart to prevent the entrance of terrestrial mammals, yet near enough to permit of the occasional passage of some of the flying species. As it might with reason be urged that such propinquity of islands would also permit of interchange of the avi-fauna, the writer remarks that the existence of a complete chain of islands separated by sufficiently narrow straits may have existed for a short period only, the completeness of the chain being, perhaps, dependent on some volcanic group, which may have disappeared as suddenly as it came into existence; under such circumstances bats would be much more likely to establish themselves successfully in the new continental lands open to their migrations for the following reasons:—(1) that the food of both the frugivorous and insectivorous species is of a more general character than that of birds, few of the species of which are so omnivorous, within these limits, as the bats; (2) that the nocturnal habits of the bats would enable them to escape observation from enemies always sure to recognise the presence of solitary individuals.

With respect to the peculiar distribution of the species of the genus *Pteropus*, including the great frugivorous bats, it is a noticeable fact that, although the small islands of Mauritius, Bourbon, and the Comoro group have each two very distinct species, the great continent of India and Burma and the island of Ceylon have but one. It appears, therefore, probable that India owes its single flying-fox to some other region, and in seeking for the country from which it is derived we must consider its nearest allies among the species of the genus.

Now this species differs from *P. Edwardsii* of Madagascar and the Seychelle Islands in few and unimportant characters, presenting such differences only as might have resulted in a few generations, though they now appear to be permanent. It is, therefore, evident that these two species have been derived within a comparatively recent period from a common ancestor, and probable that the enormous number of individuals of *P. medius*, now representing the genus in India, are the descendants of a few individuals originally escaped from their island homes in the Indian Ocean, and now cut off by subsidence of some of these islands from their nearest relations. On no other hypothesis can we account for the discontinuous distribution of the species of this genus, for the incapability of these large bats to traverse wide oceanic spaces is shown by the fact that the narrow channel of Mozambique between the Comoro Islands and the African coast has sufficed to prevent their entrance into Africa, where tree fruit is abundant, and where immense

[1] This paper will be published *in extenso* in the *Annals and Magazine of Natural History*, series 5, vol. xiv.

[2] Flying-foxes.

numbers of other fruit-eating bats abound. Indeed it is difficult to imagine one of these great bats, whose flight appears so slow and laboured compared with that of all other species of Chiroptera, traversing 50, much less 500, miles of unbroken sea—for, even if carried out to sea by a storm, their wings would evidently collapse long before they had travelled half the distance; on the other hand it is quite out of one's power to understand their present distribution, except on the old grounds of independent creation, without postulating a much closer connection than Mr. Wallace appears disposed to admit between the island groups in the Indian Ocean at a comparatively recent period.

The above-noted facts lead to the following deductions, namely, that in the first place a chain of islands sufficiently close to allow of the passage, not only of the representatives of the genera of insectivorous bats referred to, but also of the large slow-flying frugivorous bats, must have existed between Madagascar and Australia; and, secondly, that at a later period a temporary connection of a similar kind lay between Madagascar and India.

It may be said that such connection with India would also permit of the introduction of insectivorous bats; but it must be again remembered that volant insects, on which such bats feed, are very scarce in oceanic islands, while tree fruit, which forms the food of the frugivorous species, is usually abundant. Bearing these facts in mind, it is necessary to suppose that the islands, assumed to have formed the high-road for the insectivorous bats between Africa and Australia, must have been sufficiently large to support volant insects; while, on the other hand, a chain of small coral islands, placed not too far apart, and provided only with a few fruit-bearing trees, would have sufficed for the passage of the frugivorous species; and it appears more than probable that it was by such a chain that the ancestors of the flying-foxes of India were introduced into that continent.

A review of the above-noted statements lends strong support to the theory of a continent, or series of large, closely connected islands, extending across the Indian Ocean at a comparatively recent period from Madagascar to Australia, which, originally advanced by Mr. P. L. Sclater, F.R.S., is still maintained by many most important distributional facts.

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7. *On the Geographical Distribution of the Laridæ (Gulls and Terns), with special reference to Canadian Species. By* Howard Saunders, *F.L.S.*

The author pointed out that, excepting in the case of the circumpolar and subarctic species of *Laridæ*, the Atlantic forms a barrier between the Gulls of the Palæarctic and Nearctic regions; and almost so with the Terns. This he instanced by reference to some European species and their Canadian representatives. Owing to the belt of warm water between the tropics in the Atlantic, hardly any Gulls, and but few Terns belonging to the northern hemisphere, cross the equator; but in the Pacific, where the expanse of warm water is narrowed by the approximation of the cold Humboldt's current, which runs from the Antarctic regions to the equator, on the one side, and by the Japanese cold current, reaching nearly to the equator, on the other, several species of Gulls which breed in the far north, winter in the southern hemisphere. The Pacific coast of North and South America is inhabited by various species of Gulls differing widely in coloration from those of the Old World, with the exception of a single species found in Japanese and Chinese waters, and which presented intermediate characteristics. The North Pacific was, moreover, the home of *Sterna aleutica*, which partakes of the coloration of the typical Terns and of those of the inter-tropical Sooty-Tern group. It was only in the Pacific that the winter range of the circumpolar forked-tailed gull, *Xema sabinii*, extended to the south of the equator; overlapping the area between the Galápagos Islands and the coast of Peru, the home, so far as is known, of the very rare *X. furcata*, only three specimens of which are in collections. Nearly all the large Gulls without hoods are found in the North Pacific and Bering Sea; and there also that peculiar marine genus, *Rissa* (the Atlantic representative of which, *R. tridactyla*, has no developed hind toe), shows an approach to the typical four-toed Gulls by having a distinct hind nail. Many other points indicate that it is in the Pacific that the majority of the existing groups, and even species of Gulls and Terns, have originated.

8. *Result of the Investigations of Insular Floras.* By W. B. Helmsley.

9. *Some Observations on the direct descendants of Bos Primigenius in Great Britain.* By G. P. Hughes.

The author gave a brief sketch of the grounds we have, through numerous remains of Bos Urus or Primigenius, and from the account in Roman history of the domestic and wild ox of 2,000 years ago, for supposing that the three typical breeds we have remaining in the parks of Chartley, Cadzow, and Chillingham are well nigh direct descendants of that aboriginal race.

He described the difference between the Bos Primigenius and the Bos Longifrons, the ancestors of our British cattle.

He pointed out some mistakes in the report sent to the late Mr. Storer of the Cadzow herd of cattle, stating that they were a polled herd of cows. The author found the entire herd possessed of well-set on horns of 18 inches long; he also found their colour to be white, with a few black ticks, and not cream-coloured. He visited the Chillingham herd, and gave particulars as to an attempt at crossing being tried with a Durham bull. He considers the Chillingham herd the finest type of the Primigenius at this day extant.

10. *On Natural Co-ordination, as evinced in Organic Evolution.* By Dr. W. Fraser.

Nature affords us no decisive evidence of either creative or annihilative interference, all its manifestations seeming to result solely from the spontaneous operation of pre-inherent energies. But while the universe as a whole appears thus like an independent and uninterrupted system, with sequences limited and determined only by intrinsic capacities and tendencies, all its subordinate individual parts, consisting of mere potentialities, dependent for the actual evolution of their energies on supplementary aids, and also liable to adventitious disturbances, have their activities limited and determined by extrinsic as well as intrinsic conditions.

Inorganic units, comprising both atoms and molecules, are universally intransmutable and agenetic in constitution and endowments, being utterly devoid of either progressive or productive individual capacities, for, though compound chemical substances may be resolvable into more elementary ones, this constitutes neither production nor progress, as the physical processes of alternate composition and decomposition are indefinitely reversible without the slightest appreciable modification of intimate constitution in any of the factors engaged.

In contrast to the intransmutable and agenetic character of inorganic units, all organic forms, embracing germs, organisms, and structural elements, are distinguished by the possession of transmutable dispositions and genetic potentialities; no organisation ever remaining absolutely alike during any consecutive periods of developmental activity, and every integral portion, when properly supplemented and protected, seeming competent to directly or indirectly engender and perpetuate interminable successions of more or less similarly endowed products.

As organic units, in common with all other subordinate material systems, include but mere potentialities, the absence or incongruity of auxiliaries often as effectually restrains their evolutional tendencies as would the direct operation of positively injurious agencies.

All development is practically subjected to extraneous restraints, no organisation ever realising the greatest results which its inherent potentialities would admit. The restraints to collective development are clearly seen in the limited expansion of the organic world compared with the elasticity potentially inherent in the reproductive capacities of its members. The more restricted range of particular groups is due to their more special needs, as well as to the necessarily more numerous obstacles encountered; the total aggregate having to strive only against the resistances and encroachments of inorganic nature, whereas each component part has also to contend with the competition and assaults of distinct congeners. Not only the extent but also the configuration of organic distribution is determined by the manner in which the inward expansive and outward repressive forces counteract or overcome each other at their several places of collision. At some points, from diminution of sustenance, increase of enemies or competitors, or from other adverse circumstances, expansion may be checked or contracted, while at other points, from opposite causes, it may be permitted to an unusual extent, thus leading to frequent or perpetual oscillations of outline, varying on different occasions, but always being a resultant of conflicts between centrifugally expanding and centripetally compressing forces.

Though not so obvious, it is no less conclusive that individual morphology, in like manner, invariably results from the efforts of intrinsic or developmental energies against extrinsic or envelopmental restraints and encroachments. A homogeneous unit expanding centrifugally from a single point, with equal intensity in every direction, amidst an unresisting or uniformly resisting medium would retain an absolutely spherical figure, its magnitude being a resultant of the equilibrium between internal tension and external resistances; any deviation from its original symmetry indicating a corresponding degree of inequality between mutually opposing inward and outward forces at their several points of contact. Such a unicentral expanding system would have no internal conflicts, all the obstacles to its evolutional tendencies being purely of external origin; but a multicentral or composite body, such as every complex organism represents, including many distinct simultaneously evolving parts, must necessarily be the subject of interior as well as exterior conditions of restraint, not only its total bulk and shape, but also the confirmation and relative position of different organs, as well as the localisation and composition of every tissue element, being consequences of equilibria between innumerable developmental tensions and envelopmental restraints, any modification in such an economy (wherever occurring and however induced) possibly reverberating so as to effect its entire constitution. Every complete germ at its inception contains a certain specific potentiality or developmental capacity, which, under an optimism of conditions would evolve a maximum of normal results.

The different cells in this incipient economy constitute a number of distinct centres of latent or potential elasticity, which, by nutrition, become separate foci of mutually conflicting expansive energies. In such an interdependent arrangement some parts may be unduly favoured and developed at the expense of incorporated elements, yet in no possible way can any structure be made to evolve more than was potentially included in its primitive organisation, for, while accessory provisions are indispensable to development, these possess only a stimulative or permissive value, never a creative power; their share in the process consisting in the liberation and determination of previously occluded inherent potentialities.

Hence, when some new character is evolved or an old one modified (whether abruptly in a single individual or gradually through a succession of generations does not alter the case, genealogical attainments being never more than the sum or resultant of individual acquirements), this does not imply that such has been directly annexed, or introduced *ab extra*, but rather indicates that some unusual facility has been afforded, or some previously imposed restraint relaxed; the communication of new facilities and the withdrawal of former restraints being equivalent expressions.

The mere association, however, of developmental impulses and envelopmental restraints could never issue in any definite progressive results unless subjected to the determination of some controlling mechanism of order, so that the regularity, definiteness, and consistency observable in organic reactions and relations, testify to the additional existence and jurisdiction of a supplementary principle of co-ordinative supervision. As man by factitiously arranging the means at his disposal, in accordance with his needs and tastes, institutes systems of artificial co-ordination, so the spontaneous adjustment of organic activities in subjection to and conformity with prevailing correlated tendencies and requirements constitutes a system of natural co-ordination.

In the elaborate establishment of specific organic products natural co-ordination performs the two distinct though complemental offices of a directive and a selective function, the former determining each temporary step in the process, the latter deciding which, out of many possible courses, will be permanently or successively adopted. In a dependent evolving system, with abundant accommodations, provisions, and protection, it might remain a matter of indifference what number and kind of forms were produced, as all would be alike preserved; each succeeding phase being simply a direct product of antecedent stages, without the intervention of any subsequent eliminating process.

Here the principles of co-ordination could only have directive scope; but in a circumscribed station, with limited supplies and liability to invasion, as soon as the rate of production would exceed the means of support, co-ordination would assume a selective *rôle*, submitting the various competitors for the different available positions to prescribed tests, accepting such as would conform with required standards, and rejecting all relatively unsuitable or incompetent ones. Organisation seems to have been planned and conducted according to some such method and design; its potentialities constituting an incalculable fund of transmutable and genetic material, affording the principle of co-ordination enormous resources whereon to operate, so as to render possible the realisation of results practically inconceivable. Such being, apparently, the simple natural means and methods employed in elaborating all the wonderfully complex and diversified products of organic evolution, the primordial germ or germs having virtually involved not only all past, present, and future developmental achievements, but also a practically infinite store of unrealised possibilities; the principle of co-ordination submitting originally indefinite potentialities to definite arrangements of facilities and restraints; thus directing the course of development into innumerable special channels, and from the multifarious types evolved selecting such as provisionally conform with their various conventional requirements; while the marvellous progress revealed in the past history of these operations affords most encouraging assurance of inconceivably higher realisations in the future course towards the relatively approximable, though perhaps never absolutely attainable, state of ultimate universal perfection.

SUBSECTION OF PHYSIOLOGY.

1. *On the Coagulation of Blood.* *By* Professor H. N. MARTIN *and* W. H. HOWELL.

The blood of the Slider Terrapin, a turtle easily obtainable in Baltimore, had been used for a number of experiments, the object of which was to determine whether the views entertained by Hammersten or by Schmidt were most reliable. The general conclusions went to show that the views of Hammersten were more in accordance with the results of these observers.

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2. *On the Blood of* Limulus Polyphemus. *By* FRANCIS GOTCH, *B.Sc.*, *and* JOSEPH P. LAWS, *F.C.S.*

Comparatively few observations have previously been made on the blood of the king crab (*Limulus polyphemus*), the most important being those of Genth.[1] The fact which his researches brought out—namely, that the blood contained a com-

[1] Genth, *Annalen der Chemie und Pharmacie*, 1852, p. 68.

paratively large amount of copper—is one of sufficient interest to warrant further investigation.

In June last Professor Moseley kindly placed at our disposal the blood of a large number of these animals which he had obtained alive from America; we were thus enabled to procure sufficient material for analysis.

Over two litres of blood were obtained from twenty animals, by making a small transverse incision at the joint between the cephalothorax and abdominal carapace; no distinction was made with regard to sex. The freshly drawn blood was an opaque-white liquid, which in a few seconds gelatinised, and soon assumed a more or less blue colour; the jelly subsequently contracted into a firm yellowish-white clot, and squeezed out a large amount of a blue liquid.

The blue liquid had a specific gravity of 1·040, was slightly alkaline, coagulated on boiling and on addition of alcohol, but was not coagulated with ether; treated with strong acids or alkalies it coagulated *en masse,* the blue colour completely disappearing. After dilution, the addition of weak (1 per cent.) mineral acid to the blue liquid blanched without coagulating it. In some cases the blue colour returned on addition of ammonia. When the blue liquid was kept in a stoppered vessel for twenty-four hours it blanched; the blue colour immediately reappearing when it was shaken with air, to disappear on standing.

In connection with this fact, it was of interest to observe the manner in which the blood assumed its blue colour when freshly drawn. In order to observe this under the best possible conditions, blood was drawn from an animal with precautions which, as far as possible, prevented access of air. A pipette containing oil was introduced into the incision and a small amount of blood carefully drawn into it, both ends of the pipette were then sealed; under these conditions the blood did not become blue.

From a free incision a sudden rush of blood was allowed to fill two small beakers, one of which contained oil; in both cases a yellowish coagulum separated, floating in a tolerably clear liquid. The one with a surface layer of oil remained untinged, whereas the other assumed the blue colour which appeared first on the surface.

Experiments were made with blood received under oil into closely stoppered bottles with similar results; in these cases the blue colour has never appeared. No satisfactory blanching of the blue liquid was observed when a stream of CO_2 gas was passed through it. The colour, however, disappeared on addition of ammonium sulphide, and returned for a short time again on shaking up the mixture with air. The passage of oxygen markedly intensified the blue colour; this was the case also with the blue blood of the Octopus as shown by Fredericq.[1]

The following table shows the percentage composition of the ash of the blue liquid which may be advantageously compared with those of Genth. It may be observed with reference to these results that the determination of copper and iron was made in 13·57 grammes of ash, as compared with the 3·6 grammes employed by Genth:—

Genth.	A	B	*Present Analysis.*	
Sodium chloride	79·207	83·507	Sodium chloride	85·184
Potassium chloride	4·607	2·395	Potassium chloride	2·707
Magnesium chloride	3·848	1·840	Magnesium chloride	—
Potassium sulphate	3·264	1·686	Potassium sulphate	0·594
Calcium sulphate	2·159	3·470	Calcium sulphate	3·986
Calcium carbonate	2·950	1·448	Calcium carbonate	·275
Phosphate of magnesia	1·709	0·444	Phosphate of magnesia	·236
Magnesia	1·959	5·128	Magnesia	6·457
Oxide of iron	traces	0·081	Oxide of iron	0·029
Oxide of copper	0·297	0·085	Oxide of copper	0·508
	100·000	100·084		99·976

[1] *Bulletin de l'Académie Royale de Belgique,* 1878, p. 717.

The result of the analysis was to show that the ash of the 'serum'(?) contained ·508 oxide of copper. This is considerably in excess of the maximum found by Genth—viz., ·338 per cent. in a duplicate determination of the copper in sample A. The method of estimating the copper, shortly stated, was as follows: 500 c.c. serum were evaporated to dryness over the water-bath, the residue then incinerated and weighed, the resulting ash dissolved in hydrochloric acid with a slight addition of nitric; the copper then precipitated as sulphide by passing a stream of SH_2 gas through the liquid; the precipitate collected and washed with SH_2 water (due precaution being taken to prevent oxidation); the filter-paper and sulphide were then transferred to a platinum capsule and burned; this ash redissolved in nitric acid and precipitated (this time as black oxide) by boiling with a slight excess of caustic potash, the precipitate collected, and washed, and burned as before, after moistening with nitric acid.

As far as the salts are concerned the composition of Limulus serum appears to be more like sea water than Mammalian serum; the latter contains about 28·5 per cent. chlorine, with only a little more than $\frac{1}{2}$ per cent. of magnesia, whereas the former contains about 55·25 per cent. c.c. and 6·25 per cent. magnesia.

Some interesting points remain to be noted with reference to the organic constituents of the blood; the coagulum obtained from the freshly drawn blood appears more albuminous than fibrinous; the microscopic appearances presented during its formation were not characteristic of fibrine, and the fresh clot itself gave none of the recognised fibrine reactions; the expressed blue liquid gave no precipitate with 10 per cent. chloride of sodium or saturated magnesium sulphate. A partial coagulum of pure white colour was obtained on boiling, the liquid still remaining blue. Genth states that along with this coagulum the copper is precipitated; we have not, however, verified this statement.

In the case of the Octopus Fredericq concluded that the serum of the blood contained a body allied to the proteids which he called Hæmocyanin, and which, when acted on by acids, &c., splits up into an albuminoid substance containing no metal, and a substance containing copper. The blood serum of Limulus probably contains a complex proteid body, closely allied to Hæmocyanin. In order to preserve the serum for further investigation, thin films were dried on porcelain slabs at the temperature of the room, the dried films scraped off, powdered, and perfectly dried in a water-oven. A per-centage determination of the nitrogen in this dried substance gave 11·322 per cent. N., for the ash-free substance this would be equal to 15·459 per cent.

We fully realise the incompleteness of our communication, but in consequence of the limited time at our disposal and the want of a supply of 'fresh' material, we were unable to carry our investigation further; should an opportunity of continuing it at any time present itself, we should endeavour, first, to separate the copper-containing pigment to which the blood of Limulus probably owes its peculiar properties; secondly, to determine more precisely its relations to oxygen; and thirdly, to analyse the liver and blood clot.

3. *On Vaso-motor Nerves. By* Professor H. P. Bowditch.

The author gave an account of some experiments he had been making to determine the need of vaso-motor nerves. He had employed an entirely new method, namely, the use of the plethysmograph.

4. *Demonstration of the Co-ordinating Centres of Kronecker. By* T. Wesley Mills, *M.A., M.D.*

5. *On the Cardiac Nerves of the Turtle. By* Professor Hugo Kronecker *and* T. Wesley Mills, *M.A., M.D.*

(1.) The authors have experimented upon sea turtles, and found: (*a*) A *vagus* trunk with the usual functional relations to the heart; (*b*) *Accelerantes* nerves;

branches connecting the sympathetic and vagus, but with anatomical relations varying not only in different species, but in different specimens of the same species. The influence of these nerves over the heart has been described.

(2.) Certain other nerves with peculiar functions in relation to the heart that cannot be readily summarised.

(3.) They have also noted in the case of two species of land turtle that the *venæ cavæ superiores* when isolated from the heart are pulsatile, and under the control of the *vagus.*

6. *On the Functions of the Marginal Convolution.* *By* V. Horsley, *M.B., B.Sc., and* Professor E. A. Schäfer, *F.R.S.*[1]

The object of experiments made by the authors was to ascertain the effect of stimulation of localised areas of the marginal convolution in the monkey, and their results filled up a gap in the well-known work of Ferrier in that they were able to show that removal of certain areas, the excitation of which had previously caused movements of muscles of the trunk, &c., on both sides led to paralysis of muscles of the trunk of such a degree that the animal was unable to stand. By removal of the frontal lobes no paralysis of voluntary movements was obtained. These results were in opposition to those obtained by Munk, of Berlin.

TUESDAY, SEPTEMBER 2.

The following Papers and Report were read:—

1. *On the Ova of Monotremes.* *By* Professor H. N. Moseley, *LL.D., F.R.S.*

The President stated that he had a most important announcement to make. He had just received a cablegram from Sydney, from Professor Liversidge, announcing that Mr. Caldwell, the Balfour student, who was sent out to Australia to investigate the mysteries in connection with the mammals of that country, had discovered that the Monotremes were oviparous. He did not consider that a more important telegram in a scientific sense had ever passed through the submarine cables before. The Monotremes formed two families characterised by the duck-billed Platypus and an animal which was known to the Australians as the ant-eater. These were the lowest forms of mammals, and it had never been known how they produced their young. The extraordinary discovery was now made that these mammals laid eggs, and that the development of these eggs bore a close resemblance to the development of the eggs of the Reptilia; proving that these animals were more closely connected with the Sauropsida than with the Amphibia.

2. *Report on the Influence of Bodily Exercise on the Elimination of Nitrogen.*—See Reports, p. 265.

3. *Remarks on the Caldwell Automatic Microtome.*

4. *On Sensory Nerve-sacs in the Skin of Amiurus (Siluridæ).* *By* Professor R. Ramsay Wright, *M.A., B.Sc.*

In his recent work, 'Ueber die Hautdecke und Hautsinnesorgane der Fische,' Leydig refers to certain pores in the skin of *Lota* which, although not situated in the course of the lateral line or in that of the 'mucous' canals of the head,

[1] See 'Proceedings of the Royal Society,' No. 231, 1884.

apparently belong to sense-organs referable to the same category, and are distributed widely over the surface of the body. The histology of the portions of skin containing these is not described. Again, in *Esox*, similarly scattered sense-organs are met with which, however, Leydig considers to be identical in structure with the beaker-shaped sense-organs or end-buds.

In one of the commonest North American silurids, *Amiurus catus*, the skin is possessed of numerous small independent sense-organs, which unquestionably belong to the type of 'Nervenhügel' (nerve-hillock), only they are neither so superficial as the 'free' nerve-hillocks of other Teleosts, nor included in a groove or canal like the larger nerve-hillocks met with in the course of the lateral line, or in the canals of the head. These structures are small flask-shaped sacs, occupying the whole thickness of the epidermis, but not affecting the corium. The superficial epithelium is continued into the mouth of the sac, which is lined by a cuticular border derived from it, except in the fundus, where a few conical sensory hair-cells are found. These are surrounded by imbricated supporting cells, 'Stützzellen,' which gradually pass into the above-mentioned superficial epithelial cells. In the mode of their distribution on the head, as well as in their histological structure, these sense-organs recall the 'nerve-sacs' of the ganoids, but, instead of being confined to the head, they extend over the whole trunk on the dorsal and ventral, as well as on the lateral aspects. Whether they have any segmental grouping like the large nerve-hillocks in the lateral canals must be a matter for future investigation.

5. *On the Function of the Air-bladder and its relationship to the Auditory Organ in Amiurus.* *By* Professor R. Ramsay Wright, *M.A., B.Sc.*

The anatomical features of the parts concerned have been already described in a preliminary communication to the 'Zoologischer Anzeiger,' No. 162. The functions of the air-bladder in the light of Moreau's researches were alluded to, and it was suggested that the alterations of pressure incident to change of level in water are communicated to the brain through the auditory nerve. Professor Wright supposes that the air-bladder is also sensitive to sound-waves, and that the same channel of communication with the auditory apparatus serves for the transmission of vibrations to the endolymph. In confirmation of the latter view Professor Haddon referred to the more specialised conditions in some tropical siluroids, and to the stridulating apparatus described by him in some of these.

6. *On the Jessop Collection, to illustrate the Forestry of the United States, in the New York Natural History Museum.* *By* Albert S. Bickmore.

The great importance of the forest industries and lumber trade of the United States led General Walker, the Superintendent of the Tenth Census, to provide for a corps of competent experts, under the direction of Professor Charles S. Sargent, who have made new explorations of our forest lands, and gathered original data regarding their present extent. The results of these elaborate researches have been partially published from time to time in the form of bulletins, and the completed work will soon appear in two large quarto volumes of the census series. To place this great fund of valuable information before the artisan and labouring classes in an accessible form, a great collection of our forestry and its products was needed, and this Mr. Morris K. Jessop offered to provide at his own expense. After the field work planned by the census had been finished, Professor Sargent directed his assistants to return to the forests, and to carefully select the individually largest and soundest tree of each species. Professor Sargent is preparing a manual which will be a guide to the collection, and which contains all the most important information in the large census volume that will be useful to the visitors and to the artisan classes. The museum is most fortunate in its location in Central Park, where more native and domesticated species are flourishing than can be seen together at any other place on the continent. This is the first effort yet made in this country to gather the native woods together into one collection on a scale commensurate with the extent of the new continent and the importance of its forests.

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7. *On the Structure and Development of Loxosoma.* *By* Sidney F. Harmer, *B.A.*, *B.Sc.*

The nervous and excretory systems of the adult were investigated specially in *L. crassicauda*, in the living condition or by means of glycerine preparations.

1. The *ganglion*, situated between mouth and anus, has been frequently figured in previous papers on *Loxosoma*, but has hitherto invariably been wrongly identified as some part of the generative system. It is a dumb-bell shaped organ, developed in the bud from ectoderm, and giving off at its two ends nerves to the tentacles and other parts of the body. The ectoderm contains numerous sense-cells, bearing one or more long stiff tactile hairs projecting into the water. Each sense-cell is directly connected with the nervous system by means of a single fine nerve fibril, swelling into a bipolar ganglion cell at some part of its course.

2. The excretory system consists of a pair of fine tubes, ciliated internally, and composed of a small number of large perforated cells, the proximal cell being in all probability a flame-cell. There is no ciliated funnel, the excretory organ ending blindly near the ventral wall of the stomach. Each tube opens independently into the vestibule, between mouth and anus. The nephridia of *Loxosoma* thus differ markedly in structure from those of Brachiopoda or Phoronis, but resemble in a striking manner the head kidney of Annelid larvæ, as well as the permanent nephridia of Rotifers and Platyhelminths.

3. The development of *Loxosoma* has been studied by means of sections in a species, probably hitherto undescribed, occurring on *Leptoclinum* in the Gulf of Naples.

The 'dorsal organ' is not developed from hypoblast cells, as stated by Hatschek in *Pedicellina* ('Zeitschr. f. wiss. Zool.,' Bd. xxix. 1877, S. 502), but, on the contrary, entirely from the epiblast. An epiblastic invagination is formed, but soon loses its lumen, then appearing as a solid crescent-shaped mass of cells, applied to whose deeper surface is a conspicuous mass of fibrous tissue. The 'dorsal organ' bears two large eyes, and is in all probability the *brain* or *supra-œsophageal ganglion* of the larva. The permanent ganglion of the adult is hence infra-œsophageal, and the line between mouth and anus is ventral.

The 'dorsal organ' takes no part in the budding of the larva, which after a free life of some hours may be seen to have developed a pair of lateral buds, one on each side of the 'dorsal organ,' but at a level intermediate between this structure and the ciliated ring. The alimentary canal appears to atrophy during the budding, and it is hence probable that the larva dies after the production of two or more buds. It is doubtful whether the larva ever permanently fixes itself, or whether the budding takes place normally during the free life of the larva.

4. The Entoproctous Polyzoa conform perfectly in structure to the *Trochosphære* type. This view is much strengthened by the study of their excretory organs. The results of the present investigation seem to show that the Polyzoa have their nearest adult allies in the *Rotifera*, whilst they have but little in common with *Brachiopoda* or *Phoronis.*

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8. *On Anatomical Variations:* (1.) *Par-occipital Process occurring in Man.* (2.) *Secondary Astragalus.* (3.) *Persistence of the Left Duct of Cuvier in Man.* *By* Professor Shepherd, *M.D.*

1. *Par-occipital Process in Man.*—The skull of an Irish navvy, aged about thirty years, was exhibited, in which there was a well-marked par-occipital process. Left jugular process of occipital bone, prolonged downwards to articulate with the transverse process of atlas, length, 2 c.m.; diameter, 1 c.m. In the same skull, on same side, the styloid hyoid ligament was ossified and articulated with the hyoid bone—length, 6·2 c.m.; diameter, 3 c.m.

2. *Secondary Astragalus.*—Three cases were shown in which the small process overhanging the os calcis and external to the groove for the flexor longus pollicis tendon was separate from the astragalus. In all three cases these ossicles were connected with the posterior fasciculus of the external lateral ligament of the ankle-joint.

3. *Double Superior Vena Cava.*—Three examples of this anomaly were exhibited. Two occurred in females, one in a male. The transverse innominate vein in all the cases was of small size, and the left cava (persistent left duct of Cuvier) was continuous with the coronary sinus.

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9. *On the Presence of Eyes and other Sense Organs in the Shells of the Chitonidæ. By* Professor H. N. Moseley, *LL.D., F.R.S.*

The Chitonidæ have hitherto been regarded as characterised by an entire absence of organs of vision, the presence of eyes in the shells of numerous genera having been entirely overlooked by naturalists. The author first discovered the eyes in a specimen of *Schizochiton incisus* dredged by Captain Chimmo, R.N., in the Sulu Sea, in which species they are larger and more conspicuous than elsewhere, and on examining carefully the shells of certain other forms found eyes present there also. The eyes are entirely confined to the shells, and to the exposed parts of these the 'tegmenta,' not occurring at all on the 'articulamenta.' They never occur on the girdle or zone or any other part of the mantle. They appear as bright, highly refracting convex beads on the shell surfaces, encircled by zones of dark pigment formed by the pigment layers. The eyes are usually circular in outline and very minute, measuring in *Schizochiton incisus* about $\frac{1}{175}$ of an inch in diameter, in *Acanthopleura spiniger* $\frac{1}{350}$ of an inch, and in *Corephium aculeatum*, in which they are oval in outline, $\frac{1}{600}$ of an inch by about $\frac{1}{400}$.

In the case of all the intermediate shells, the eyes are confined to the areæ laterales, or to the lines of demarcation between the areæ laterales and the area centralis, which latter is usually entirely devoid of them.

In some genera of Chitonidæ, such as Acanthopleura and Corephium, the eyes appear to be often destroyed and obliterated in the older regions of the shells by decay and delamination of the tegmental surface, or its destruction by boring algæ or animals. They are, however, constantly re-formed by the mantle in the process of growth of the shell at the growing margin of the tegmentum, and may be observed in this situation in all stages of construction.

In other genera, such as Tonicia, the eyes lie in shallow pits of the shell surfaces and thus escape destruction by wear, nearly the entire number which have been formed being thus found present in fully grown shells. The tubercles and prominences by which the tegmenta are covered in some forms serve perhaps as protection to the eyes from attrition.

The entire substance of the tegmentum in the Chitonidæ is traversed by a series of branching canals, which are occupied in the living animal by corresponding ramifications of soft tissues and nerves. The strands of soft tissue are continuous with the tissues of the mantle along the line of junction of the margin of the tegmentum with the upper surface of the articulamentum, by means of a series of tubular perforations in the shell substance. Further, in the intermediate shells of most genera, there are a pair of lateral slits (*incisuræ laterales*), one on either side, in each shell in the lateral laminæ of insertion; these slits lead each to a narrow tract in the deep substance of the shell which follows the line of separation between the area centralis and area lateralis. This tract is permeated by longitudinal canals, into which open a series of fine apertures on the under surface of the shell. By these apertures numerous nerves enter the tract from the bed of the shell, and traversing the longitudinal canals give off a series of lateral branches on either side from it to the network within the tegmentum. In the cases of the anterior and posterior shells there are usually a considerable number of slits present in the laminæ of insertion, each connected with a similar nerve-supply to the tegmentum.

The network terminates at the surface of the tegmentum all over in a series of elongate cylindrical organs of touch ('megalæsthetes'), the plug-like ends of which are somewhat dice-box shaped, and can be protruded beyond the level of the tegmental surface from a series of pores ('megalopores') by which this surface is covered. These larger organs of touch give off from their sides fine branches of soft tissue, which pass vertically to the surface of the tegmentum and terminate there in minute plug-like organs, like the larger ones but much smaller ('micræsthetes'), and which are protrusible from a series of smaller pores ('micropores') in the shell substance. These megalæsthetes and micræsthetes and their corresponding pores are disposed on the surface of the tegmentum with more or less exact regularity in different genera of Chitonidæ, in many cases in very definite lines and patterns.

The eyes are connected with the same network of soft tissue as the touch-organs, and are apparently to be regarded as having arisen in development as special modifications of them. The soft structures of each eye lie in a more or less pear-shaped chamber excavated in the substance of the tegmentum. The stalk of the pear, which forms the canal for the passage of the optic nerve, is directed always towards the full margin of the tegmentum, and here its wall is pierced by a circular aperture which is covered by the cornea. The cornea is calcareous, resisting the action of strong boiling caustic alkalis, but collapsing at once when treated with acids. In sections it is seen to be composed of a series of concentric lamellæ. Its substance is continuous with the general calcareous substance of the tegmentum at its margins.

The pear-shaped cavity of the eye formed by the shell substance is lined by a dark-brown pigmented membrane, of a stiff and apparently somewhat chitinous texture. This membrane exactly follows the shape of the cavity, but by projecting inwards beyond the margin at the cornea all round, forms an iris of a less diameter than the latter. A perfectly hyaline, strongly biconvex lens is placed behind the iris aperture. It is composed of soft tissue, and dissolves in strong acetic acid. The optic nerve at some distance from the retina is a compact strand, but before reaching the latter has its numerous fine fibres separated and loose. The retina is composed of a single layer of rather short but extremely distinct nucleated rods of roughly hexagonal section, with their free ends presented to the light. Immediately behind them is a dense mass of nerve fibres with numerous nuclei and nerve cells interspersed. The retina is on the type of that of Helix, and not, as might have been supposed, on that of the dorsal eyes of Onchidium.

A large part of the peripheral fibres of the optic nerve do not pass to the retina, but pass outside the eye chamber by a series of apertures in the choroid round the iris margin, and end at the shell surface in a zone of micræsthetes encircling the eye. The micræsthetes are identical in structure with the smaller touch organs already described as appended to offsets of the megalæsthetes all over the shell. In giving off nerves to a series of such small organs, the eye thus corresponds exactly in structure to the megalæsthetes, and its homogeny with them is thereby clearly indicated. The arrangement of the eyes varies much in the different genera.

In *Schizochiton incisus* the eyes are restricted to single rows traversing the lines separating the lateral areæ from the areæ centrales, and corresponding in position with the incisuræ laterales and courses of the principal nerves. There are six rows of eyes, with six marginal slits on the anterior shell and six on the posterior, and a single pair on each of the intermediate shells, twenty-four rows in all, with an average of about fifteen eyes in each, or in all 360 eyes.

In *Acanthopleura spiniger* the eyes are irregularly scattered around the bases of the tubercles with which the surface of the tegmentum is covered, and are confined in the specimens examined to the region of the margins of the shells adjoining the mantle. The surface of the older regions of the tegmentum seems in this species especially liable to flake off, carrying the eyes with it, and it will probably be found when series of examples of various eyes are examined that the eyes are originally more widely extended over the shell surfaces. In *Corephium aculeatum* the eyes are very small, with corneas oval in outline, the long axis of the oval being directed vertically to the shell margin. They are never placed on the tubercles, with rows of which the shell surface is covered, but between the bases of these. The megalopores and micropores lodging the organs of touch are arranged in vertical parallel lines with great regularity, the large pores occurring at intervals in the lines of smaller pores. The eyes are present in enormous numbers, the anterior shell alone bearing more than 3,000, and the entire eight shells more than 11,500.

In *Tonicia marmorata* the eyes are arranged in single straight radiating rows, on the anterior and posterior shell. On each lateral area of the intermediate shells there are from two to four similar rows of eyes. In Onithochiton the eyes are disposed somewhat similarly.

In the genus Chiton, eyes appear to be entirely absent, though the touch organ of two sizes and corresponding pores are present. In Molpalia, Maugina, Lorica, and Ischnochiton, I have as yet detected no eyes. In Chitonellus there are no eyes, and the supply of touch organs is scanty and confined to the margins of the tegmenta.

The arrangement and structure of the eyes and organs of touch will probably be of great value in the classification of the Chitonidæ, which has hitherto proved so difficult a problem.

No traces of any structures resembling the eyes and touch organs of the Chitonidæ can be detected in the shells of Patella or allied genera. The tegmentary part of the shells of this group appears to be something *sui generis,* entirely unrepresented in other Mollusca. Its principal function seems to be to act as a secure protection to a most extensive and complicated sensory apparatus which in the Chitonidæ takes the place of the ordinary organs of vision and touch present in other odontophora, and fully accounts physiologically for the absence of these latter in them.

Dr. W. B. Carpenter observed the perforate structure of the tegmentum in Chiton, though he did not examine the nature of the contained soft network. The late Dr. Gray, in his well-known paper on the structure of Chitons, recognised the fact that the tegmentum in the Chitonidæ is something *peculiar* to the shells of this family.

Since the above was written, the author had his attention drawn to a memoir by Dr. W. Marshall, in which the tubulate structure of the tegmentum of the shells of Chitonidæ is described, and to papers by J. F. Van Bemmelen, in which the papilliform bodies which occupy these in *Chiton marginatus* are described and figured. These memoirs are referred to fully in an extended and illustrated memoir on the present subject, published in the 'Quarterly Journal of Microscopical Science,' for January 1885. The eyes appear to have entirely escaped the observation of naturalists hitherto.

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10. *On the Structure and Arrangement of the Feathers in the Dodo.* *By* Professor H. N. MOSELEY, *LL.D., F.R.S.*

Professor Moseley's observations were made on the only existing specimen of the skin of the bird, namely, that covering the head belonging to the Oxford University Museum. The feathers differ from those in all other birds in being arranged in groups of three. This peculiarity is shown in the well-known old oil paintings of the Dodo. The homologues of the lateral feathers in each group of three are to be sought in the two minute filo-plumes which spring from the sheath of each feather at its base, one on either side in modern pigeons. An illustrated paper on this subject will be communicated to the Zoological Society in the spring of 1885.

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11. *On the Presence in the* Enteropneusta *of a structure comparable with the Notochord of the* Chordata. *By* WILLIAM BATESON.

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12. *A Contribution to our Knowledge of the* Phytopti. *By* Professor P. MCMURRICK.

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13. *On the Diatomaceous remains in the Lake Deposits of Nova Scotia.* *By* A. H. Mackay.

Subsection of Physiology.

1. *On the Demonstration of an Apparatus for Recording Changes of Volume.* *By* Professor E. A. Schafer, *F.R.S.*

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2. *Remarks on the Problem of Aquatic Breathing.* *By* Professor McKendrick, *M.D., F.R.S.*

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3. *On the Biliary Concretions; demonstrating a Uniformity in the Construction of Concretions in the Animal, Vegetable, and Mineral Kingdoms.* *By* Dr. G. Harley, *F.R.S.*

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4. *On the Secretion of Oxalic Acid in the Dog.* *By* T. Wesley Mills, *M.A., M.D.*

This paper describes the results of a diet of (1) Flesh, (2) Flesh and fat, and (3) of Flesh and carbohydrates, on the secretion of oxalic acid in the dog. It consists of (1) A comparative examination of the different methods in vogue for the quantitative determination of oxalic acid in the urine of man, and shows that Schultzen's method is the best; (2) The perfecting of a method for the determination of oxalic acid in dog's urine; (3) An application of this method to the problem proposed in the heading of this paper.

A dog was kept under constant observation, punctually fed daily, the urine removed, its quantity, reaction, specific gravity, &c., determined, diluted to a definite volume, filtered, and its nitrogen and oxalic acid determined. A complete tabular statement of the results was given. The principal conclusions are as follows:—

(1.) Under all three diets given oxalic acid was daily found in the urine in determinable quantity.

(2.) The average for seven days' flesh diet was ·0113 gramme. It will be seen that this was larger than by either of the other diets, and the strong acid reaction of the urine throughout points to the flesh diet as a cause of the same.

(3.) The average under diet (2) for five days, ·0055 gramme, denotes a decided falling off under the substitution of fat for flesh.

(4.) The average under diet (3) for seven days is ·0033 gramme, and shows that carbohydrates do not increase the secretion of oxalic acid, but the contrary.

The animal was throughout kept in nitrogenous equilibrium.

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5. *On the Mechanism of Absorption.* *By* Professor E. A. Schäfer, *F.R.S.*

It has hitherto been almost universally held that the mechanism of absorption of alimentary substances from the intestinal tract is strictly analogous to the passage of fluids through moist animal membranes, and it has been considered a sufficient explanation of the process to assert this belief, and thus to account for the passage of the comparatively diffusible peptones, sugars, salts, and water, into the albuminous fluids which occupy the blood-vessels and lymphatics.

But there are many objections to regarding absorption as a mere example of physical osmosis. For the difference in the osmotic equivalents of the digested food materials and of the blood or lymph is comparatively small, and quite insufficient to account for the rapidity with which absorption may occur. Moreover, when the mucous membrane has become thinner owing to loss of the lining epithelium in disease (as in cholera), although the conditions are thereby rendered more favourable for the osmotic process, absorption from the interior of the intestine is either much diminished, or the flow is entirely in the opposite direction, and this in spite of the fact that the blood and lymph are of more than normal density. And, further, the osmotic theory has always failed to account for the absorption of substances such as fat, which, although finely subdivided, are not brought into solution by the action of the digestive juices. In consequence of this the absorption of fat has always been treated of as a subject quite distinct from that of absorption of other nutritive matters, and has been explained by entirely different theories. Finally, no attempt has been made to explain how and where the peptones which are formed in the alimentary canal are transformed into the proteids of the blood and lymph, although it is well known that these fluids contain no peptones, so that the transformation must have occurred in the passage from the intestine into them.

I shall endeavour to show that the process of absorption from the intestine is in all cases the same, and is not in all probability a mere process of osmosis, but that it is effected by and through the activity of protoplasm. If this is really the case, the phenomena of intestinal absorption in the higher animals will be brought into close equivalence with the processes of absorption and assimilation which occur in the simple Protozoa, with those of intercellular digestion which have been observed in many of the lower Metazoa, and with processes of physiological and pathological absorption of tissues which occur in higher animals.

In studying the phases of absorption it is convenient to employ fats as a part at least of the diet, because of their property of becoming stained darkly by osmic acid. In most of my experiments therefore the animal has been fed, a certain time before being killed, with food containing fat, and immediately after death minute portions of the mucous membrane of the small intestine have been placed in osmic acid or in a mixture of chromic and osmic acid. These fluids instantly fix the tissues, and stain the fat globules in them.

I have always found at a certain period after ingestion of food, the period varying in different animals and in different portions of the small intestine, fat in great abundance in the columnar epithelium cells. The fact of its occurrence in them is so well known and so easy to circumstantiate that one is surprised to find it ignored by some eminent histologists. The fat globules occur first of all in the part of the protoplasm nearest the cuticular surface of the cell; later they are found also on the other side of the nucleus, and here most generally in a more finely divided condition. Examined still later, fat globules, generally very fine, are seen in large numbers in the leucocytes which are so abundant in the retiform tissue of the villi and mucous membrane generally, and which extend also between the epithelium cells. And, finally, the lacteal in the centre of each villus is found to contain similar fine fatty globules in large amount. I have not been able to find any evidence, either in teased preparations or in sections, of the presence of fat in the network of the retiform tissue, but only in the epithelium cells, the leucocytes, and the central lacteal.

So far the facts which I have here mentioned are not new, for they were announced already in the 8th edition of Quain's 'Anatomy,' and in my 'Course of Practical Histology,' published in 1876. And the conclusion which I was led to draw from them, and which seems to me to be inevitable, is that in the absorption of fat, the finely divided fat particles are taken up from the intestinal contents by the columnar epithelium cells, are by them passed on to the leucocytes which have wandered between those cells, and are by the leucocytes carried, by virtue of their amœboid movements, to the central lacteal, where the cargo of absorbed fat is discharged. I was unable at the time to determine how this discharge of the fat particles is effected, nor whether the same leucocytes may pass back again to the epithelium, and serve to carry a fresh cargo.

More recently, however, in continuing these and other researches bearing upon the functions and properties of the white blood corpuscles and similar cells, I have come across another fact which fully elucidates this problem, and which shows, moreover, that this carrying of fat by the leucocytes of the intestinal mucous membrane is incidental merely to a much more general function which they subserve in the process of assimilation and absorption. For it appears, from an examination of osmic preparations like those above mentioned, that *the leucocytes find their way in large numbers into the commencements of the lacteals, and there become dissolved and completely disintegrated*, so that the proteids which constitute their protoplasm come into solution in the lymph or chyle, and the fatty and other particles which they may contain are also set free. This immigration of the leucocytes into the lacteals during absorption of food, and their subsequent disintegration in the lymph, is quite independent of the nature of the food, for it is seen just as abundantly with a bread diet as with a fatty diet. It is reasonable, therefore, to infer that the process of absorption is in all cases the same whatever the nature of the food, and consists essentially in a selection by the columnar epithelium cells of the materials to be absorbed from the intestine, the passage of these to the leucocytes, the carrying of them by the leucocytes into the lacteals, and the disintegration and solution of the greater number of the thus immigrated leucocytes in the chyle or lymph. It is also very probable that during the sojourn of the absorbed products of digestion in the columnar epithelium and in the leucocytes changes of a chemical nature may occur in them, *e.g.*, that the peptones which are absorbed may become changed again before reaching the lacteals into ordinary proteids. In this way the cells in question may be regarded as fulfilling important functions not only of absorption but also of assimilation.

It is obvious that the facts above mentioned do not by any means exclude the possibility of a direct passage of the more diffusible fluid substances into the blood-vessels and lacteals.

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6. *On a Method of studying the behaviour of the Germs of Septic Organisms under Changes of Temperature. By the* Rev. Dr. DALLINGER, *F.R.S.*

The author described a new apparatus invented for this purpose.

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7. *On a Vegetable Organism which separates Sulphur. By* A. W. BENNETT.

The author gave a description of *Beggiatoa alba*, an organism found in the effluent water from sewage-works, known as the 'sewage-fungus,' which has the property of separating sulphur out of the organic matter in the water, or in the salt used in precipitating the sewage, in the form of minute sharply refringent globules.

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8. *On the Physiology of Therapeutics of the Chloral Hydrate and Anæsthetics generally. By* Dr. W. ALEXANDER.

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9. *On the Growth of Children. By* Dr. C. S. MINOT.

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10. *On the Proteids of Serum. By* W. B. HALLIBURTON *and* Professor E. A. SCHAFER, *F.R.S.*

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11. *On the Climate of Canada and its relations to Life and Health. By* Dr. W. H. HINGSTON.

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12. *On the Production and Propagation of the American Trotter and Classification of the Spermatozoa and Ova. By* Dr. W. MCMONAGH.

There has been originated by the breeders of America a new type of horse, capable of a high rate of speed, 'The American Trotter-Pacer,' with instincts, heredity, and habits of locomotion peculiar to itself, being so self-persistent as to be conveyed from parents to their progeny with such certainty that the trotter in the near future will become thoroughbred, with the capability of propagating its own kind continuously and uniformly.

The result of the author's investigations leads to the conclusion that the consummation of this type and new production results from the utilisation and union of the sperm and germ cells of the pure-bred English runner with the germ and sperm potency of the native American horse, and that within the last fifty years this high rate of trotting and pacing speed has been produced progressively and gradually from a locomotion capable of covering a mile in three minutes, to an increase of speed to the mile of two minutes and nine and three-quarter seconds.

Section E.—GEOGRAPHY.

President of the Section—General Sir J. H. Lefroy, C.B., K.C.M.G., L.L.D., F.R.S., F.S.A., Vice-Pres. R.G.S.

THURSDAY, AUGUST 28.

The President delivered the following Address:—

Connected as I was in early life with this country, and for several years associated with one of its scientific institutions and one of its scientific societies, I cannot but feel proud and gratified to be honoured at this late day, and on so memorable an occasion, with the Presidency of this Section. I will not ask your indulgence for any weakness you may observe in my discharge of its obligations, nor will I plead what, however, I feel very strongly, that the lapse of thirty years since I last had the honour to address an audience in Canada, has not been wholly advantageous to my position. I may, however, make one observation. It is that, whereas the short interval elapsed since the delivery of an exhaustive summary of Geographical Progress by the President of the Royal Geographical Society makes it at all times difficult for the President of this Section to find fresh topics, I have been made more than usually conscious of that disadvantage by having to close the present address some weeks earlier than would be necessary at a meeting held in Great Britain.

2. Man's acquaintance with the planet he inhabits, with the earth which he is to replenish and to subdue, has been a thing of growth so slow, and is yet so imperfect, that we may look to a far distant day for an approach to a full knowledge of the marvels it offers, and the provision it contains for his well-being. He has seen, as we now generally believe, in silent operation, the balanced forces which have replaced the glacier by the forest and the field; which have carved out our present delights of hill and dale in many lands, and clothed them with beauty; and it may be that changes as great will pass over the face of the earth before the last page of its history is written in the books of eternity. But it is no longer before unobservant eyes that the procession of ages passes. Geography records the onward march of human families, often by names which survive them; it rears enduring monuments to great discoverers, leaders, and sufferers; it is an indispensable minister to our every-day wants and inquiries; but beyond this it satisfies one of the most widely diffused and instinctive cravings of the human intelligence, one which from childhood to maturity, from maturity to old age, invests books of travels with an interest belonging to no other class of literature. If 'the proper study of mankind is man,' where else can we learn so much about him, or be presented with such perplexing problems, such diversity in unity, such almost incredible contrasts in the uses of that noble reason, that Godlike apprehension, which our great poet attributes to him; or see the 'beauty of the world, the paragon of animals,'[1] in conditions so unlike his birthright. Geography, then, is far from being justly regarded as a dry record of details which we scarcely care to know, and of statistics which are often out of date.

3. It is scarcely necessary to do more than allude here to the intimate relations between geography and geology. The changes on the earth's surface effected within historical times by the operation of geological causes, and enumerated in geological books, are far more numerous and generally distributed than most persons are aware of; and they are by no means confined to sea coasts, although the presence of a natural datum in the level of the sea makes them more observed

[1] *Hamlet*, Act ii. sc. 2.

there. A recent German writer, Dr. Hahn, has enumerated ninety-six more or less extensive tracts known to be rising or sinking. We owe to Mr. R. A. Peacock the accumulation of abundant evidence that the island of Jersey had no existence in Ptolemy's time, and probably was not wholly cut off from the continent before the fourth or fifth century. Mr. A. Howarth has collected similar proofs as to the Arctic regions; and every fresh discovery adds to the number. Thus the gallant, ill-fated De Long, a name not to be mentioned without homage to heroic courage and almost superhuman endurance, found evidence that Bennett Island has risen a hundred feet in quite recent times. Nordenskiöld found the remains of whales, evidently killed by the early Dutch fishers, on elevated terraces of Martin's Island. The recent conclusion of Professor Hull, that the land between Suez and the Bitter Lakes has risen since the Exodus, throws fresh light on the Mosaic account of that great event; and to go still further south, we learn from the Indian survey that it is 'almost certain' that the mean sea level at Madras is a foot lower, *i.e.*, the land a foot higher, than it was sixty years ago. If I do not refer to the changes on the west side of Hudson's Bay, for a distance of at least six hundred miles, it is only because I presume that the researches of Dr. Robert Bell are too well known here to require it. Any of my hearers who may have visited Bermuda are aware that so gently has that island subsided, that great hangings of stalactite, unbroken, may be found dipping many feet into the sea, or at all events, into salt-water pools standing at the same level, and we have no reason to suppose the sinking to have come to an end. We learn from the Chinese annals that the so-called Hot Lake Issyk-kul, of Turkistan, was formed by some convulsion of nature about 160 years ago,[1] and there seems no good reason to reject the Japanese legend that Fusiyama itself was suddenly thrown up in the third century before our era (B.C. 286). These are but illustrations of the assertion I began with, that geography and geology are very nearly connected, and it would be equally easy to show on how many points we touch the domain of botany and natural history. The flight of birds has often guided navigators to undiscovered lands. Nordenskiöld went so far as to infer the existence of 'vast tracts, with high mountains, with valleys filled with glaciers, and with precipitous peaks' between Wrangel Land and the American shores of the Polar Sea, from no other sign than the multitudes of birds winging their way northward in the spring of 1879, from the 'Vega's' winter quarters. The walrus hunters of Spitzbergen drew the same conclusion in a previous voyage from the flight of birds towards the Pole from the European side. Certainly no traveller in the more northern latitudes of this continent in the autumn can fail to reflect on the ceaseless circulation of the tide of life in the beautiful harmony of nature, when he finds that he can scarcely raise his eyes from his book at any moment, or direct them to any quarter of the heavens, without seeing countless numbers of wild fowl, guided by unerring instinct, directing their timely flight towards the milder climates of the South.

4. To address you on the subject of geography, and omit mention of the progress made within these very few years in our knowledge of the geography of this Dominion, might indeed appear an unaccountable, if not an unpardonable oversight; nevertheless, I propose to touch upon it but briefly, for two reasons: first, I said nearly all I have to say upon a similar occasion four years ago; secondly and chiefly, because I hope that some of those adventurous and scientific travellers who have been engaged in pushing the explorations of the Geological Survey and of the Canada Pacific Railway into unknown regions, will have reserved some communications for this Section. I cannot, however, refrain from alluding to that remarkable discovery recently communicated to the Geographical Society of Quebec by M. N. A. Comeau, of which we shall, I hope, hear fuller particulars from Professor Laflamme. I mean the extent and importance of Lake Mistassini. That it should be left to this day to discover in no very remote part of the north-east a lake rivalling Lake Ontario, if not Lake Superior, in magnitude, is a pleasant example of the surprises geography has in store for its votaries. Canada comprises within its limits two spots of a physical interest not surpassed by any others on the globe. I mean the pole of vertical magnetic attraction, commonly called the mag-

[1] *Proc. R. G. S.* vol. xviii. p. 250.

netic pole, and the focus of greatest magnetic force; also often, but incorrectly, called a pole. The first of these, discovered by Ross in 1835, was revisited in May 1847 by officers of the Franklin Expedition, whose observations have perished, and was again reached, or very nearly so, by McClintock in 1859, and by Schwatka in 1879; the latter of these explorers, however, was not equipped for observation. The utmost interest attaches to the question whether the magnetic pole has shifted its position in fifty years, and although I am far from rating the difficulty lightly, it is probably approachable overland, without the great cost of an Arctic expedition. The second has never been visited at all, although Dr. R. Bell, in his exploration of Lake Nipigon, was within 200 miles of it, and the distance is about the same from the Rat Portage. It is in the neighbourhood of Cat Lake. Here then we have objects worthy of a scientific ambition and of the energies of this young country, but requiring liberal expenditure and well-planned efforts, continued steadily, at least in the case of the first, for, perhaps, three or four years. Of objects more exclusively geographical, to which it may be hoped that this meeting may give a stimulus, I am inclined to give a prominent place to the exploration of that immense tract of seventy or eighty thousand square miles, lying east of the Athabasca River, which is still nearly a blank on our maps, and in connection with such future exploration, I cannot omit to mention that monument of philological research, the Dictionary of the Languages of the native Chipewyans, Hare Indians, and Loucheux, lately published by the Rev. E. Petitot. The lexicon is preceded by an introduction giving the result of many years' study among these people of the legends or traditions by which they account for their own origin. M. Petitot, who formerly was unconvinced of their remote Asiatic parentage, now finds abundant proof of it. But perhaps his most interesting conclusion is that in these living languages of the extreme north, we have not only the language of the *Nabajos,* one of the Apache tribes of Mexico, which has been remarked as linguistically distinct from the others, but also the primitive Aztec tongue, closely resembling the language of the Incas, the Quichua, still spoken in South America. I need not say how greatly these relations, if sustained by the conclusions of other students, are calculated to throw light upon the profoundly interesting question of the peopling of America.

5. This is perhaps a proper occasion to allude to a novel theory proposed about two years ago, with high official countenance, upon a subject which will never cease to have interest, and perhaps never be placed quite beyond dispute. I mean the landfall, as it is technically called, of Columbus, in 1492. The late Captain G. V. Fox, of the Admiralty, Washington, argued in a carefully prepared work, that Atwood's Key, erroneously called Samana on many charts, is the original Guanahani of Columbus, renamed by him S. Salvador, also that Crooked Island and Acklin Island are the Maria de la Concepcion of Columbus and the true Samana of succeeding navigators in the sixteenth century. The last supposition is unquestionably correct. Crooked, Acklin, and Fortune Islands, which from the narrowness of the channels dividing them may have been, and very probably were, united four centuries ago, are plainly the Samana of the Dutch charts of the seventeenth century, and are so named on the excellent chart engraved in 1775 for Bryan Edwards' 'History of the West Indies,' but the view that Atwood's Key is identical with Guanahani is original, and is neither borne out by any old chart, nor by Columbus' description. This small island is conspicuously wanting in the one physical feature by which Guanahani is to be identified '*una laguna en medio muy grande.*' There is no lake or lagoon in it, nor does its distance from Samana tally at all with such slender particulars as have been left us by Columbus respecting his proceedings. The name S. Salvador has attached, not to Atwood's Key, but to Cat Island, one of the Bahamas; it is true that modern research has shifted it, but only to the next island, and on very good grounds. Cat Island is not *muy llana,* very level; on the contrary, it is the most hilly of all the Bahamas, and it has no lake or lagoon. Watling Island, a little to the SE. of Cat Island, and now generally recognised as the true Guanahari or S. Salvador, is very level; it has a large lagoon, it satisfies history as to the proceedings of Columbus for the two days following his discovery, by being very near the numerous islands of Exuma Sound, and I think few impar-

tial persons can doubt the justice of the conclusion of the late Admiral Becher and of Mr. Major as to its identity; there are difficulties in the interpretation of Columbus' log on any hypothesis, but there is one little 'undesigned coincidence' which to my mind goes far to carry conviction. Columbus, when he sighted land, was greatly in want of water, and he continued cruising about among the small islands in search of it for some days. Clearly, therefore, the *laguna* on Guanahani was not a fresh-water lake; nor is the lagoon on Watling Island fresh water, and so it exactly meets the case.

6. The report of Lieutenant Raymond P. Rodgers, of the United States Navy, on the state of the canal works at Panama so lately as January 25 last, which has doubtless been eagerly read by many present, leaves me little to say on that great enterprise. Perhaps the following official returns of the amount of excavation effected in cubic metres (a cubic metre is 1·308 cubic yards) will enable the audience to realise its progress:—

		Total excavated	In each month			Total excavated	In each month
1883	October . .	2,042,034		1884	January . .	3,340,534	580,000
	November .	2,375,534	333,300		February .	3,974,191	633,657
	December .	2,760,534	385,000		March . . .	4,590,022	615,831

The total quantity of excavation to be done in a length of 46·6 miles is estimated at 100 millions of cubic metres, but the rapid augmentation of quantity shows that the limit has not been attained. This is no place to speak of the stimulus given by this great work to mechanical invention or the gigantic power of the machines employed, which will probably receive attention in another section, but I may mention the two great problems which still await solution. The first is how to deal with the waters of the river Chagres; the second is how to manage a cutting nearly 400 ft. deep (110 m. to 120 m.). The Chagres is a river as large as the Seine, but subject to great fluctuations of volume; it cuts the line of the canal nearly at right angles, and for obvious reasons it is impossible to let it flow into it. It is proposed to arrest the stream by an enormous dyke at Gamboa, near the divide. It will cross a valley between two hills, and be 1,050 yards long at the bottom, 2,110 yards at the top, 110 yards thick at the base, and 147 ft. in greatest height. Out of the reservoir so constructed it is proposed to lead the overflow by two artificial channels, partly utilising the old bed. The cutting will be nearly 500 ft. wide at the top (150 m.), with sides at a slope of $\frac{1}{1}$. It is proposed to attack it by gangs or parties working on twelve different levels at the same time, one each side of the summit, dividing the width at each level into five parallel sections. Thus there will be 120 gangs at work together, and it is confidently hoped that the whole will be really finished in 1888, the date long since assigned for its completion by M. de Lesseps. There is practically no other project now competing with it: for the proposed routes by the Isthmus of Tehuantepec, the Atrato, and San Blay may be regarded as almost universally given up; both the latter would involve the construction of ship tunnels on a scale to daunt the boldest engineer. The so-called Caledonia route has not stood the test of examination. There remains but the Nicaragua route, and this, while practicable enough, has failed to attract capitalists, and is environed by political and other difficulties, which would leave it, if completed, under many disadvantages as compared with its rival. Among the latter must be named the necessity for rising by locks to the level of the Lake of Nicaragua (108 feet).

It is very tempting to speculate on the probable consequences of bringing the Hispano-Indian republics bordering on the Pacific into such early contact with the energies of the Old World, but these speculations belong to politics rather than geography; moral transformations, we know, are not effected so easily as the conquest over physical difficulties.

7. Let us now turn to another quarter. This meeting cannot fail to share the pride and satisfaction with which the Royal Geographical Society regards the execution by Mr. Joseph Thomson of the important missions intrusted to him last year, in East Africa, and to share my regret also, that he is not here to receive

our plaudits and our congratulations. Mr. Thomson was commissioned to explore the unknown country about Mount Kilima-njaro and Mount Kenia, and if possible to continue his route to Lake Nyanza. He has done all this and much more. After an unsuccessful start from Zanzibar in March of last year, in which, however, he reached Kilima-njaro and ascended it about 9,000 ft., he returned to the coast from Taveta, and started again in July, this time from Mombasa. We are not yet fully acquainted with his route, but we know that he again reached the great mountain, reputed to have an elevation of more than 20,000 ft., that thence he reached the east side of Lake Nyanza, that he is the first who has stood on the shores of L. Baringo. That thence, always among natives who had never before seen a white man, he reached Mount Kenia, reputed to be 18,000 ft. high, and found his way back to the coast without any conflict or loss of life by violence, and this after a journey of about 500 miles, nearly the whole of it through a country previously unknown to geography. I have been favoured by him with a short communication, which will be read presently. The courage and the temper, the decision and the tact required for successful progress among the warlike and rapacious tribes whose territories he passed through, are qualities which demand our genuine admiration. Take a single trait: 'As an illustration of their readiness to draw their swords, I may mention,' he says, 'my own case, in which a Masai actually drew his *cimé* to settle matters with me, because, getting tired of his extreme curiosity to see the whiteness of my leg, I pushed him away. On his drawing his *cimé* I laughed and pretended I wanted to see it, and so the matter ended.'

Before Mr. Thomson had actually returned to Zanzibar, another explorer, under the direction of a Committee of this Association, had started in the same direction. Mr. H. H. Johnston, whose plans, however, are devoted primarily to the investigation of the fauna and flora of Kilima-njaro, left the British Residency, Zanzibar, in May last for Mombasa, having by the advice of Sir John Kirk selected that route for Kilima-njaro. Mr. Johnston had succeeded with Sir John Kirk's kind assistance in getting together a well-organised party both of collectors and porters, and started in good health, with every hope of ultimate success. Further details on this subject will perhaps be given in the report of the Kilima-njaro Committee to be read in Section D, and we have a communication from Sir John Kirk, dated July 10, to be read presently, which shows that he has reached his ground.

8. To the great desire of the French to unite their possessions in Northern and Central Africa, and to command the commerce of the native states south of the Sahara, we owe many important expeditions, one of which terminated unfortunately in the destruction of Colonel Flatters, together with several other officers and men, by the Tuaregs in February 1881. Nevertheless continued progress has been made in the completion of our maps of that region. Colonel Flatters found everywhere evidences that at some remote period the great Wadi Igharghar was the bed of a river flowing into one of the most westerly of the Tunisian depressions, that large tracts were once fertilised by it, of which small and scattered oases alone have survived to our epoch, and that subterranean water probably exists along its course. The hand of man, which is about to admit the waters of the Mediterranean into those depressions, may yet work surprising changes in these arid regions. We have evidence of the improvements possible, in the description given by Mr. Oscar Lenz, of the young Arab city of Tenduf on the skirts of the desert (cir. 27° N.). Founded only thirty years ago, in the heart of Islam, he describes it as now consisting of large well-built houses surrounded with well-watered gardens of vegetables, and groves of date palms, a centre for caravan routes in four directions. This traveller, who visited Timbuktu in 1880, describes it as a decayed city of very little commercial importance, as may be imagined from their currency of cowries at the rate of 900 for a franc; and greatly in want of a little more intercourse with the world. The people, indeed, imagine their river, the Niger, to be identical with the Nile. The project of a railway thither from Algeria, actually marked on some maps, he dismisses as a chimera; the idea, however, has not been abandoned. The line now proposed is from Wargla by Insalah and Inzize to Timbuktu.

I am tempted here to remark that French travellers have made one observation which is far from being a matter of concern to them alone. They dwell with emphasis on the probable consequences of the rapid progress of the religion of Mahommed among the African races of the northern equatorial zone. Native tribes, hitherto without moral or political cohesion, are being knit together on the Western Sudan, the Upper Niger, and the Gambia, with a rapidity which endangers the peaceful advance of European commerce. It is, of course, to be expected that this movement will in time reach the populous basin of the Congo, and we have had too recent evidence of the fanaticism it is capable of inspiring, not to perceive here a moral element which may greatly affect white settlements and missionary enterprise in Central Africa hereafter. Any political changes which would substitute larger units of territory, and definite boundaries, and permanent names, for the present fleeting landmarks and multiplied tribal designations which confuse our maps, would in one sense be welcome. In the meantime Central African exploration is daily revealing to us the unsuspected wealth of that Dark Continent in all that can fit it for destinies more noble than it has yet been called to fulfil.

9. Although the Upper Congo from Stanley Falls to Stanley Pool has now been so often travelled that it may be regarded as pretty well known, this by no means excludes the possibility of many geographical corrections. For instance, a map issued as lately as July 1883 by the International Congo Association, lays down its lower course between the Equator and 4° South latitude, nearly 100 miles more to the west than is shown in the best modern atlas. As regards its tributaries much remains to be learned. Mr. Stanley has discovered two new lakes. The labours of that energetic traveller, M. de Brazza, have, to a great extent, cleared up the geography of the region included between the Congo and the Ogowé from the Equator southwards, and there are now said to be twenty-two trading stations in this part of the country; we are not informed what commerce exists. Higher up, but still to the north, Mr. Stanley has ascended the Aruwimi about 100 miles, without having solved a question of no little interest, namely, whether it is identical with the Wellé, and takes its rise in the same watershed which feeds the White Nile, or whether we have not, beyond its sources, a drainage system as yet untraced, but which may connect together a number of rivers whose relations to one another and whose final outlet are alike unknown. Lupton Bey reported nearly two years ago that a very large lake had been visited by one of his native subordinates west of the Aruwimi, and it is, in his opinion, probable that the Wellé flows into it.

The southern basin of the Congo has been crossed from Loanda to Nyangwé through a new country by the late Dr. Pogge and Lieutenant Wissmann, the latter of whom has inscribed his name on the roll of great African travellers by continuing his journey across the continent by way of Tabora, or Unyanyembe, to Zanzibar. It is worthy of note that he brings confirmation of the often reported existence of a dwarfish race, the Watwa, on the upper waters of the Sankuru, not a new fact in African ethnography, because we have long been familiar with the diminutive Bushmen of the Cape of Good Hope; but interesting, like the fair-complexioned natives seen by Stanley and Johnston, as evidence of the diversities of origin, character, and capabilities, which better acquaintance with the African people is likely to disclose, and which has at all times been a potent factor in human progress. It is scarcely necessary to refer here to the laborious work of Mr. Cust on the Modern Languages of Africa as a treasury of information. It may be said in military phrase that the east and west of Africa are in touch. Stanley was able to despatch letters in December last, *viâ* Nyangwé, to Karema from his most easterly station on the island of *Wana-Rusani*, Stanley Falls. We can better appreciate the teeming life of these Equatorial regions, when we read that his little expedition of three steam launches encountered, on November 24 last, a flotilla of over a thousand canoes (*plus de mille canots*), which had just before devastated the village of Mawembé, murdering all the men, and carrying off the women and children into slavery. They did not molest him, and all up this great river the natives, with few exceptions, were found on this last occasion eager to contract alliances (ratified by the exchange of blood), desirous of his protection, and craving a white resident to instruct them.

Proceeding southward to the region claimed especially as their own by Portuguese travellers, Messrs. Britto Capello and Ivens, who successfully reached the Upper Quango in 1878, returned last January to Loanda with the intention, it is said, of endeavouring to descend one of the great tributaries, of which there are four whose sources have been crossed at a great elevation by Cameron and others, but whose course for about 1,000 miles has never been followed: they are now on the Kunene. An English sportsman, Mr. Hemmings, starting from Walfisch Bay, has quite recently, in company with a Dutch hunter, found his way partly through the Portuguese territories, partly through native states beyond their boundaries, to the Congo, which he struck at Vivi. Cameron, it will be remembered, was astonished by a cold of 38° F. on the watershed between the Zambesi and the Kassabé in about 12° South latitude. Dr. Pogge compares the climate of Mussumba on the 8th parallel, in the month of December, to that of North Germany, and the fact illustrates what we learn from so many other quarters, that much of the interior of Africa belongs, by reason of its elevation above the sea, to a far more temperate zone, and is better suited to the European constitution than its geographical position promises. The terrible prevalence of fever which has cost so many lives will probably be mitigated in time and by improved accommodation. The hills are comparatively free from it. Having alluded to Dr. Paul Pogge, whose death at Loanda in March last deprives geography of an adventurous explorer, I may add that the account of his journey in 1875 to Mussumba, the capital of the powerful negro kingdom of the Muata Yanvo, or Matianvo of Livingstone, published in 1880, remains to be translated. That great traveller failed to reach it. Cameron crossed the territory, but a long way to the south of it, and no previous scientific traveller, that I am aware of, has described it. Dr. Pogge resided there four or five months, and we learn many interesting particulars from him, and from Dr. Max Büchner, a subsequent traveller. The people, although Fetish worshippers, practise the rite of circumcision: they are a fine, warlike race, unhappily addicted to slave-hunting, but far in advance of their cannibal neighbours of Kauanda. Their institutions are of a feudal character. Muata Yanvo is an hereditary title. Among many peculiar customs is one which invests one of the king's half-sisters, under the designation of the Lukokesha, with the second authority in the kingdom. She is forbidden to marry, but permitted a sort of morganatic alliance with a slave, any offspring being ruthlessly destroyed, and on the death of the king she has the principal voice in determining his successor, who, however, must be selected from among the sons of the late king. Since Dr. Pogge's visit the Muata Yanvo has been deposed and poisoned by his Lukokesha. The extraordinary custom prevails here that a man's children do not belong to him, but to the eldest brother of their mother, and should a child die the father must make compensation. Surely I have now justified the remark I made above on human perversities.

10. As many of my hearers may not be fully aware of the rapid extension of white occupation, hardly as yet to be called settlement, in Central Africa, and of the early fruit borne by the heroic life and death of Livingstone, and other scarcely less devoted travellers and philanthropists, and as many of the places are not to be found in any ordinary atlas, I give at the end a table as complete as I have been able to make it, of actual centres of communication or trade, or missionary instruction now established there. Lake Nyassa, we are told, is becoming a busy inland sea. There are two steamers upon it, and one on the River Shiré. Upon Tanganyika three. Many years cannot elapse before the primitive and costly practice of carrying goods by an army of porters will be a thing of the past, when pack animals, perhaps wheeled vehicles, will have replaced them. Donkeys have been already introduced, with good promise, by the Universities' missionaries and the African Lakes Company, although they have not been a success on the Congo. That first necessity of civilisation, a road of some sort, will connect the petty capitals, and link in friendly communication tribes which know one another now chiefly by hostilities and reprisals. The African Lakes Company, of Glasgow, has ten small depôts between Quillimane and Malawanda on Lake Nyassa, and from this place a practicable road of 220 miles has been carried to Pambete, on

Lake Tanganyika. Those places are likely to become the first centres of trade, at which the natives have already learned to respect the white man, where there are residents who have mastered their language, and where native interpreters are to be found. Believing, then, that social problems of no common degree of complexity are certain to arise in a few years from the conflict of many creeds and nationalities, in a sort of 'no man's land,' the table I subjoin may assist those who desire to have a definite idea of the progress already made. I am bound to add that 'no man's land' is a phrase which only expresses European views. The natives have very definite territorial ideas.

11. From Central Africa it is not an unnatural transition to Central Asia, the region next the most inaccessible, and pregnant, perhaps, with greater events. The Russian project for diverting the Oxus or Amu Darya from the Sea of Aral into the Caspian, remains under investigation. We learn from the lively account of Mr. George Kennan, a recent American traveller, that there is more than one motive for undertaking this great work, if it shall prove practicable. He states that the lowering of the level of the Caspian Sea, in consequence of the great evaporation from its surface, is occasioning the Russian Government great anxiety, that the level is steadily but slowly falling, notwithstanding the enormous quantity of water poured in by the Volga, the Ural, and other rivers. In fact, Colonel Vinukof says that the Caspian is drying up fast, and that the fresh-water seals, which form so curious a feature of its fauna, are fast diminishing in number. At first view there would not appear great difficulty in restoring water communication, the point where the river would be diverted being about 216 ft. above the Caspian; but accurate levelling has shown considerable depressions in the intervening tract. As the question is one of great geographical interest we may devote a few minutes to it. It is not to be doubted that the Oxus, or a branch of it, once flowed into the Caspian Sea. Professor R. Lenz, of the Russian Académie Impériale des Sciences, sums up his investigation of ancient authorities by affirming that there is no satisfactory evidence of its ever having done so before the year 1320; passages which have been quoted from Arab writers of the ninth century only prove in his opinion that they did not discriminate between the Caspian Sea and the Sea of Aral. There is evidence that in the thirteenth and fourteenth centuries the river bifurcated, and one branch found its way to the Caspian, but probably ceased to do so in the sixteenth century. This agrees with Turkoman traditions. Even so late as 1869 the waters of the Oxus reached Lake Sara Kamysh, 80 or 90 miles from their channel, in a great flood, as happened also in 1850, but Sara Kamysh is now some 49 feet lower than the Caspian, and before they could proceed further an immense basin must be filled. The difficulties then of the restoration by artificial means of a communication which natural causes have cut off, are (*a*) The disappearance of the old bed, which cannot be traced at all over part of the way; (*b*) The possibility that further natural changes, such as have taken place on the Syr-Daria, may defeat the object; (*c*) The immense expenditure under any circumstances necessary, the distance being about 350 miles, which would be out of all proportion to any immediate commercial benefit to be expected. We may very safely conclude that the thing will not be done, nor is it at all probable that Russian finances will permit the alternative proposal of cutting a purely artificial canal by the shortest line, at an estimated expense of 15 to 20 million roubles.

We have had, I think, no news of the intrepid Russian traveller, Colonel Prejevalsky, who started from Kiakhta on November 20, of later date than January 20, when he had reached Alashan, north of the Great Wall. He had for the third time crossed the great Desert of Gobi, where he experienced a temperature below the freezing point of mercury, and was to start for Lake Kuku-nor (+10,500 ft.) the following day, thence to proceed to Tsaidam, where he proposed to form a depôt of stores and provisions, and leaving some of his party here, to endeavour to reach the sources of the Yang-tse-kiang, or Yellow River. It was his intention to devote the early part of the present summer to exploration of the Sefani country, situated between Kuku-nor to the north and Batan to the south—a country likely to yield an abundant harvest of novelty in natural history—afterwards to transfer his party to Hast, in Western Tsaidam, which may be reached next spring. From this point the expedition will endeavour first to explore Northern Tibet, which is his main object, in the direction of Lhasa and Lake Tengri-nor, and then returning northward, cross the Tibet plateau by new routes to Lake Lob-nor. After the re-assembly of the expedition at this point, it will probably regain Russian territory at Issyk-kul. Colonel Prejevalsky is accompanied by two officers, an interpreter, and an escort of twenty Cossacks.

12. As you are aware, we have been chiefly indebted to natives of India for several years past for our knowledge of the regions beyond the British boundary. Mr. McNair, of the Indian Survey Department, who received the Murchison premium of this year, is the first European who has ever penetrated so far as Chitral, which is only 200 miles from Peshawur. In various disguises, however, natives, carefully instructed, have penetrated the neighbouring but unneighbourly regions of Afghanistan, Kashmir, Turkistan, Nepaul, Tibet—in almost every direction—and these achievements were crowned by one of them, known as A.K., reaching Saitu or Sachu, in Mongolia, in 1882, and thence returning in safety to India, after an absence of four years. His route took him to Darchendo or Tachialo (lat. 31°), the most westerly point reached by the late Captain J. Gill, R.E., in 1877, and thus connects the explorations of that accomplished and lamented traveller with Central Asia. A-k has brought fresh evidence that the Sanpoo and the Brahmapootra are one; the quite modern opinion that the former flows into the Irrawaddy being shown to be groundless. After draining the northern slopes of the Himalayas, the Brahmapootra makes a loop round their eastern flanks, where it has been called the Dehang, and thence, as everybody knows, flows westerly to join the Ganges: the maps have been shown in this instance to be right. The travels of these native explorers, their stratagems and their disguises, their hazards and sufferings, their frequent hair-breadth escapes, are teeming with excitement. One of them describes a portion of his track at the back of Mount Everest, as carried for the third of a mile along the face of a precipice at the height of 1,500 ft. above the Bhotia-kosi river, upon iron pegs let into the face of the rock, the path being formed by bars of iron and slabs of stone stretching from peg to peg, in no place more than 18 inches, and often not more than 9 inches wide. Nevertheless this path is constantly used by men carrying burdens.

One of the finest feats of mountaineering on record was performed last year by Mr. W. W. Graham, who reached an elevation of 23,500 ft. in the Himalayas, about 2,900 ft. above the summit of Chimborazo, whose ascent by Mr. Whymper in 1880 marked an epoch in these exploits. Mr. Graham was accompanied by an officer of the Swiss army, an experienced mountaineer, and by a professional Swiss guide. They ascended Kabru, a mountain visible from Darjeeling, lying to the west of Kanchinjunga, whose summit still defies the strength of man.

13. And here I may refer to that great work, the Trigonometrical Survey of India. The primary triangulation, commenced in the year 1800, is practically completed, although a little work remains to extend it to Ceylon on one side and to Siam on the other. Much secondary triangulation remains to be executed, but chiefly outside the limits of India proper. The Pisgah views, by which some of the loftiest mountains in the world have been fixed in position, sometimes from points in the nearest Himalayas, 120 miles distant, only serve to arouse a warmer desire for unrestrained access. The belief long entertained that a summit loftier than Mount Everest exists in Tibet is by no means extinct, but it is possible that the snowy peak intended may prove eventually to be the Mount Everest itself of the original survey. Still, however, science, in spite of fanatical obstruction, makes sure advances. The extraordinary learning and research by which Sir H. Rawlinson was enabled a few years since to expose a series of mystifications or falsifications relating to the Upper Oxus, which had been received on high geographical authority, can never be forgotten. That river has now been traced from its sources in the Panjah, chiefly by native explorers, and to them we may be said to be indebted for all we know of Nepaul, from which Europeans are as jealously excluded as they are from the wildest Central Asian Khanate, although Nepaul is not so far from Calcutta as Kingston is from Quebec.

Carrying their instruments to the most remote and inaccessible places, and among the most primitive hill tribes, the narrative reports of the officers of the Indian Survey are full of ethnographic and other curious information. Take for example the account given by Mr. G. A. McGill, in 1882, of the Bishnoies of Rajpútana, a class of people, he says, who live by themselves, and are seldom to be found in the same village with the other castes. 'These people hold sacred everything animate and inanimate, carrying this belief so far that they never even cut down a green tree; they also do all in their power to prevent others from doing the same, and this is why they live apart from other people, so as not to witness the taking of life. The Bishnoies, unlike the rest of the inhabitants, strictly avoid drink, smoking and eating opium; this being prohibited to them by their religion. They are also stringently enjoined to monogamy and to the performance of regular ablutions daily. Under all these circumstances, and as may be expected, the Bishnoies are a well-to-do community, but are abhorred by the other people, especially as by their domestic and frugal habits they soon get rich, and are the owners of the best lands in the country.'

In one particular, the experience of the Indian Survey carries a lesson to this country. 'A constantly growing demand,' says General Walker, 'has risen of late years for new surveys on a large scale, in supersession of the small scale surveys which were executed a generation or more ago. . . . The so-called topographical surveys of those days were in reality geographical reconnaissances sufficient for all the requirements of the Indian atlas, and for general reproduction on small scales, but not for purposes which demand accurate delineation of minute detail.' We have in the Canadian North-West, a region which has not yet passed beyond the preliminary stage, and it would probably be possible to save much future expenditure by timely adoption of the more rigorous system. There is perhaps no region on the globe which offers conditions more favourable for geodesy than the long stretch of the western plains, or where the highest problems are more likely to present themselves in relation to the form and density of the earth. The American surveyors have already measured a trigonometrical base of about 10·86 miles in the Sacramento Valley, the longest I believe as yet measured in any country (the Yolo Base) and reported to be one of the most accurate.

14. The Australian continent has been crossed again from east to west, on the parallel of 28° South or thereabouts, by Mr. W. Whitfield Mills. Starting from Beltana, near Lake Torrens, S.A., on June 6, 1883, and travelling almost due west, he finally reached the coast at Northampton, W.A., in January last, after great suffering from want of water. But for the introduction of camels, the expedition must have broken down. On one occasion they were eleven or twelve days without water. He reports a great extent of available pasturage between the Warburton range and the Blyth watershed; but he found only three perennial sources of water supply in 1,600 miles; such conditions give more than usual interest to the recent discovery that subterranean supplies may be expected all over a cretaceous area estimated at 126,000 square miles in the central region of the Australian continent. Good water was struck in April last by an artesian boring at a depth of 1,220 feet at Turkannina, lat. 30° S., long. $138\frac{1}{4}$° E. It is difficult to overrate the importance of this discovery, the supply being very abundant, and not likely to fail, since its sources are believed by Mr. Brown, the Government geologist, to be derived from the rainfall of the southern watershed of the Queensland and Northern ranges.

Mr. Mills started with thirty camels, attended by five Afghan drivers; six of them died from the effects, as was supposed, of eating poisonous herbage. Mr. Mills did not deviate much from the tracks of the late Mr. W. C. Gosse, and of Mr. J. Forrest, his journey has therefore added little to previous geographical knowledge, but it has helped to make the route better known, and afforded fresh evidence that the value of the camel in those terrible Australian Saharas is in no degree less than it is where he has long been known as the 'ship of the desert.'

Another traveller, Mr. C. Winnecke, starting from the Cowarie station on the Warburton River, in 28° S. has traversed about 400 miles of new country in a northerly direction, and made a sketch map of 40,000 square miles, up to Goyders Pillars, a remarkable natural feature in the Tarleton range. He too owed his success to the employment of camels, which he describes as 'behaving nobly.' The recent establishment of a Geographical Society of Australasia promises that many adventurous private explorations, little known and soon forgotten, will hereafter contribute to a better knowledge of that vast interior.

The reported outbreak of a new volcano in the northern part of West Australia, on August 25, 1883, in connection with the great eruption of the Sunda Straits, has not, as far as I know, been verified; but the graphic description of the natives: 'Big mountain burn up. He big one sick. Throw him up red stuff, it run down side and burn down grass and trees,'[1] seems to leave little doubt of the reality of the occurrence.

15. The International Circumpolar expeditions have added, perhaps, to local knowledge, especially as regards the climate and means of supporting life at various stations; but not much, so far as reported, to geography generally. To this remark, however, a brilliant exception must be made, on the intelligence flashed through the telegraph while these lines are passing through the press. The distinction of the nearest approach to the North Pole yet made by man has been won by the late Lieutenant Lockwood and Sergeant Brainerd, of Lieutenant Greely's expedition. They reached, on May 13, 1882, an island not before known, in lat. 83° 24′ N., long. 44° 5′ W., now named after its discoverer. This is four or five miles beyond Captain Markham's furthest point (83° 20′ N.), and it appears to be by no means the only geographical achievement which in some measure rewards the painful sufferings and losses of the party. Lieutenant P. H. Ray, U.S.A., has also rectified many details of the map about Point Barrow, and discovered a range of hills which he has named the Meade Mountains, running east from Cape Lisburne, from which at least two streams, unmarked, flow into the Polar Sea. We may expect similar service from the Italian parties at Patagonia, and from the Germans in South Georgia.

16. There are few particulars in which the best atlases of the present day differ more from those published twenty-five years ago, than in the information they give us respecting the submerged portions of the globe. The British Islands, with the fifty and one hundred-fathom lines of soundings drawn round them, seem to bear a different relation to each other and to the Continent than they did before. The geography of the bed of the ocean is scarcely less interesting than that of the continents, or less important to a knowledge of terrestrial physics. Since the celebrated voyage of H.M.S. 'Challenger,' no marine researches have been more fruitful of results than those of the 'Talisman' and the 'Dacia.' The first was employed last year by the French Government to examine the Atlantic coasts from Rochefort to Senegal, and to investigate the hydrography and natural history of the Cape Verde, Canary, and Azores archipelagos. The other ship, with her companion the 'International,' was a private adventure, with the commercial purpose of ascertaining the best line for a submarine telegraph from Spain to the Canaries. These two last made some 550 soundings, and discovered three shoals, one of them with less than 50 fathoms of water over it, between the continent of Africa and the islands. If we draw a circle passing through Cape Mogador, Teneriffe, and Funchal, its centre will mark very nearly this submarine elevation; the other two lie to the north of it. The 'Talisman' found in mid-ocean but 1,640 fathoms, among soundings previously set down as over 2,000 fathoms. Our knowledge then of the bed of the Atlantic, and of the changes of depth it may be undergoing, is but in its infancy; and we have only to reflect what sort of orographic map of Europe we could hope to draw, by sounding lines dropped a hundred miles apart from the highest clouds, to be conscious of its imperfection. But this knowledge is accumulating, and whether revealing at one moment a profound abyss, or at another an unsuspected summit: marvels of life, form, and colour, or new and pregnant facts of distribution; it promises for a long time to come to furnish inexhaustible interest.

17. If railways are features of a less purely geographical interest than the great interoceanic canals which dissever continents, they are not less important to the traveller; and whether commercial, political, or strategic motives have most influenced their construction, they not less fulfil the beneficent purpose of binding men in closer ties. It is not necessary that I should speak to you of the Canada

[1] *Nature*, February 21, 1884.

Pacific Railway, of which many of my hearers will soon have personal knowledge, or of the proposed railway from Winnipeg to Hudson's Bay; there are numerous other undertakings which serve in an equal degree to mark this nineteenth century as the mother of new forces and new possibilities. The Mexican Central Railway open some time since from El Paso on the River Grande, to Jimenez, has been opened to Mexico itself, and will soon reach Tehuantepec, which will thus be placed in direct railway communication with New Orleans, while the Sonoran branch will connect the United States with Guaymas on the Gulf of California. It requires a moment's recollection of the events we have seen in our own day to appreciate the vastness of these changes.

In South America we have the railway of Dom Pedro II. creeping on towards Paraguay and the Argentine Republic. It has reached Sorocaba, while branches from S. Paolo to the north-west approach great tracts on the Parana and Pazamapanama, which are marked on the latest Brazilian maps as 'unknown Indian territories,' perhaps 100,000 square miles in extent, cut by the tropic, but contributing almost nothing as yet to commerce.

Turning to Africa, the French have a short railway in operation on the Senegal, from Dakar to S. Louis, and a section of a line to Medina opened. French engineers also are engaged on a railway from Enzeti to Teheran, so that before long the capital of Persia will be reached from London in little more than a week.

Looking to the far East, Russia has long since made the shores of the Caspian nearly as accessible as Lake Superior, by her railway from Batoum, by way of Tiflis to Baku, which will also be reached by the lines from Moscow before long. This is but the first section of a line of far more ambitious aims. Starting again from Mikhailovsk, the embouchure of the ancient Oxus, the Trans-Caspian branch has been extended to Bami, and the line has been surveyed to Herat. The political forces in the field may be safely trusted to bring the British Indian lines, at present laid out to Quetta (600 miles from Herat) into a more or less direct communication with the same terminus. These are forces which we cannot ignore, but all we have to do with them here is to recognise, behind their smoke and din, the steady advance of our race in its primeval mission to replenish the earth and subdue it. The next step on the British side is an extension of the railway from Quetta to Candahar, a work which was commenced by a former administration but discontinued. Its completion can bring nothing but benefit to the Ameer and his people.

18. The science of geography reaches perhaps its highest point of public utility when it determines on a sure basis the international disputes ever arising on questions of boundary. Sacred as our neighbour's landmarks are, or ought to be, to us, they are in many cases so ill or incorrectly defined as to give free scope to the passion of aggrandisement. In such a state is the frontier of Afghanistan, between the rivers Tejend and Amu Darya. In such a state, from the Treaty of Ghent to the Treaty of Washington, were the frontiers of this Dominion and are still those of Ontario and Manitoba. In such a state are the frontiers of British Guiana, which have been in dispute for many years with the Republic of Venezuela on the one side, and the Empire of Brazil on the other, both basing their claims on vague rights of the old Spanish crown. To some extent the question as to the original boundaries of the possessions claimed by Portugal in West Africa, including the mouth of the Congo, belongs to the same category. The ambiguity arises more frequently from defective maps and the consequent imperfect geographical knowledge of the statesmen negotiating treaties, than from any other cause, and all that I dwell upon here is the proof so often afforded that liberal, even large expenditure, in the encouragement of scientific exploration, especially of frontier lands, would often prove to be true public economy in the end.

19. I have now touched lightly upon all the points which appear to me to be most noticeable in the recent progress of geographical science; but before I resume my seat I cannot deny myself the pleasure of alluding to that important measure of social reform, so simple in its application, so scientific in its basis, for which you are indebted to the perseverance and enthusiasm of my friend Mr. Sandford Fleming, C.E. I mean, of course, the agreement to refer local time on this continent to a succession of first meridians, one hour apart. There are many red-letter days in the almanac of less importance than that memorable November

18, 1883, which saw this system adopted, whether we consider its educational tendency or its influence on the future intercourse of unborn millions. It is a somewhat memorable evidence also that agreement upon questions of general concern is not that unattainable thing which we are apt to consider it. The next step will not be long delayed; that is, the agreement of the civilised world to use one first meridian, Paris, Ferrol, Washington, Rio de Janeiro, gracefully, as I venture to hope, giving that precedency to Greenwich which is demanded by the fact that an overwhelming proportion of the existing nautical charts of all nations, and of maps and atlases in most of them, already refer their longitudes to that meridian; no other change would be so easy or so little felt.

APPENDIX.

List of Stations occupied by Europeans in Central Africa in 1884.

[This list has been compiled from the latest reports of the Belgian International Association and of the various Missionary Societies, extended by information communicated by that eminent African scholar and linguist, Mr. Robert Needham Cust. The latitudes and longitudes on the Eastern Section are chiefly from Mr. Ravenstein's maps, and in many instances are but an approximation. There are probably a few small out-stations not included, and possibly some of the places named are practically identical with others, as Kiinua-Mgua and Mkunazini, which are mission schools at Zanzibar belonging to Mwembe.]

ABBREVIATIONS EMPLOYED.

A. L. Co.	African Lakes Company of Glasgow.
A. B. M. U.	American Baptist Missionary Union.
A. B. F. M.	American Board of Foreign Missions.
A. P. M.	American Presbyterian Mission.
B. M.	Baptist Missions (British).
C. M. Soc.	Church Missionary Society of London.
B. I. Assoc.	Belgian International Association.
E. C. S.	Established Church of Scotland Mission.
F. C. S.	Free Church of Scotland Mission.
F. E. M.	French Evangelical Mission.
F. P. M.	French Protestant Mission (Arnot's).
G. A. Assoc.	German African Association.
J.	Jesuits, English and French.
L. I. M.	Livingstone Inland Mission.
L. M. Soc.	London Missionary Society.
N. D. d'A.	Notre Dame d'Afrique d'Alger.
S. Esprit.	Pères du Saint Esprit.
S. Cœur de M.	Pères du Sacré Cœur de Marie.
U. M. M.	United Methodist Mission.
U. M.	Universities Mission.

I. EAST OF LONGITUDE 25° E. FROM THE EQUATOR TO THE ZAMBESI.

Stations in italic are understood to be given up.

Place	State	Lat.	Long.	Organisation
		° ′	° ′	
Rubaga	N. of Victoria Nyanza	– 0 18	32 37	C. M. Soc. *Capital of King Mtesa*
Bukumbi . . .	On Victoria N.	*cir.* 2 0	32 0	N. D. d'A.
Kagehy	,,	2 22	33 17	C. M. Soc.
M'Salala . . .	,,	2 40	33 0	C. M. Soc.
Lamu	E. Coast	2 17	41 0	U. M. M.
Teita	Teita Country	3 50	38 35	C. M. Soc.
Kamlikeni . . .	Giriyama . .	3 30	39 39	C. M. Soc.
Kisulutini . . .	Alupanga . .	3 55	39 33	C. M. Soc.
Rabbai	,,	3 57	39 37	U. M. M.
Ruwima (Sawje) .	L. Tanganyika	4 3	29 22	N. D. d'A.
Mombasa Island .	East Coast .	4 4	39 40	C. M. Soc.
Kisaune (Frere-town)	Near Mombasa	4 2	39 43	C. M. Soc.
Jomva or Jomfu .	,,	4 0	39 36	U. M. M.
Shimba	,,	4 15	39 30	C. M. Soc.
Urambo	U'Nyamwize	4 35	32 23	L. M. S.
Ujiji	L. Tanganyika	4 55	30 0	C. M. Soc.
Uyuhi	—	4 57	33 8	C. M. Soc.
Tabora	U'nyanyembe	5 0	33 2	N. D. d'A.

TABLE I. (*continued*).

Place	State	Lat.	Long.	Organisation
		° ′	° ′	
Mkusi	U'Sambara .	5 12	38 49	U. M. 15 miles from Magila
Magila	„	5 9	38 45	U. Medical Mission (80 *miles from Zanzibar*)
Misozwe	„	*cir.*5 0	38 0	U. M., 8 miles from Magila
Umba, or Ambe .	„	5 10	38 53	U. M., 12 miles from Magila
Mtowe or Plymouth Rock	U'Guha, L. Tanganyika	5 45	29 30	L. M. Soc.
Kakoma	U'Ganda . .	5 47	32 28	Belgian International
Mhonda	Nguru . .	6 0	37 30	S. E. and S. Cœur de M.
Saadani	Uzequra . .	6 4	38 50	Belgian International
Kiungani . . .	Zanzibar Island	6 10	39 14	U. M. School
Kiinua Mgua . .	—	—	—	—
Mkunazini . . .	—	—	—	U. M. School
Mbweni	—	6 12	39 12	U. Mission Farm
Mamboia	U'Sagara . .	6 16	36 58	C. M. Soc.
Mpapwa	„	6 22	36 22	C. M. Soc.
Kisokwe	„	6 20	36 16	C. M. Soc.
Mrogoro	„	6 15	36 15	S. E. and S. Cœur de M.
Bagamoyo . . .	Near Zanzibar	6 25	38 55	S. E. and S. Cœur de M.
KAREMA . . .	L. Tanganyika	6 50	32 0	Belgian International
Condoa	U'Sagara . .	6 52	36 55	G. A. Assoc.
Lundwe, or Liendwe	L. Tanganyika	8 45	31 0	L. M. Soc.
Maliwanda . . .	W. of L. Nyassa	9 42	33 30	F. C. of S. and A. L. Co.
Karongas . . .	On L. Nyanza	9 57	33 53	A. L. Co. Store
Mtua	Rovuma . .	10 10	39 30	U. M. *Abdallah Pisa's residence*
Lindi	East Coast .	10 0	39 45	U. M. *Vice-Consul Smith's residence*
Gwangwara . . .	L. Nyassa . .	10 30	35 30	„ „
Gwangwara . . .	„	—	—	Belgian International
Masasi	Inland Station	10 48	38 55	U. M.
Newala	Rovuma . .	10 57	39 13	U. M. *about* 40 *miles S.E. of Masasi*
M. Wambe . . .	L. Nyassa . .	11 35	35 20	U. M.
Mombira	L. Nyassa, A-Ngoni-land	11 30	31 0	F. C. S. above Bandawé
Bandawé (*New Livingstonia*)	L. Nyassa . .	11 54	34 5	F. C. S., Livingstonia Mission, & A. L. Co.
Chitegi's	„	12 10	34 48	U. M.
Blantyre	E. of R. Shiré	13 45	34 57	E. C. of S. *Consul Foote's residence*
Cape Maclear (*Old Livingstonia*)	L. Nyassa . .	14 3	34 44	F. C. of S.
Matope	On the Shiré	15 22	34 55	A. L. Co., *a road hence to below the Murchison rapids on the Shiré*
Mangala	R. Shiré	16 0	35 0	A. L. Co. Stores
Tette (Nyungwe) .	Zambesi . .	16 9	33 28	Jesuit Mission
Lialui	„ *cir.*	15 30	23 15	F. P. M.
Sesheke . . .	„ . .	17 31	24 55	St. J. also F. E. M.
Mosangu (Mwemba's)	„ . .	17 45	27 45	Jesuit
Victoria Falls . .	„ . .	17 55	25 50	French Protestant
Quilimane, or Kilimani	East Coast .	18 0	37 0	Jesuit
Mopea	Zambesi . .	18 0	36 0	„
Panda Ma Tenka .	S. of Zambesi	18 30	25 55	„

II. WEST OF LONGITUDE 25° E. FROM THE EQUATOR TO THE KUIMÉN OR CUNENE.

Place	State	Lat.	Long.	Organisation
		° ′	°	
Island of Wana Rusani	Stanley Falls	+ 0 10	25 0	B. I. Assoc.
Equator Station L	Upper Congo	+ 0 6	18 50	B. I. Assoc. and B.M., 700 *miles from the coast*
Lukolela . . L	"	1 22	17 7	B. I. Assoc. and B.M.
Lecona	"	1 10	17 0	M. de Brazza
Bolobo . . . L	"	2 22	17 45	B. I. Assoc.
Msuata . . L	"	3 28	17 30	B. I. Assoc.
Misongo . . . L	N'Kutu R. .	3 20	17 40	L. I. M.
Qua'mouth . . L	Kwango R. .	3 15	16 42	B. I. Assoc.
Qua'mouth . . .	"	3 24	16 28	B. I. Assoc.
M' Gaucho . . R	"	3 20	16 40	M. De Brazza
Brazzaville (Mfwa) R	Stanley Pool	4 10	15 41	French Establishm.
Leopoldville . . L	"	4 13	15 38	B. I. Assoc. and L. I. M.
Kimbolo (Arthington) L	" SW.	4 9	15 50	B. M.
Kintchassa . . L	"	4 12	15 47	B. I. Assoc.
N'Gombi . . . L	"	4 49	15 22	B. M.
Liverpool	"	—	—	Late B. M.
Lutete	"	4 49	15 10	B. I. Assoc.
Banza Manteka L	"	5 24	14 13	L. I. M.
Manyanga (N. N'Gombi's town) L	"	4 39	14 52	B. I. Assoc. and late L. M.
Lûkungu	"	4 50	14 53	L. I. M.
Isanghila . . . R	"	5 12	14 12	B. I. Assoc.
Mukimbungu . L	"	5 8	14 26	L. I. M.
Bayneston . . L	"	5 13	14 13	B. M.
Vivi . . . . R	"	5 37	13 53	B. I. Assoc.
Palabella. . . L	"	5 34	14 3	L. I. M.
Ikungula	"	5 42	13 45	B. I. Assoc.
Underhill (Wanga-Wanga)	Lower Congo	5 38	13 42	B. M.
Nokki or Noqui L	"	5 42	13 43	B. I. Assoc.
M' Boma, or Boma R	"	5 44	13 3	B. I. Assoc.
Banana Point . R	"	6 0	12 12	L. I. M.
Mukimvika . . L	S. of Congo .	6 11	12 18	L. I. M.
Franceville . . .	R. Passa . .	1 30	13 50	French settlement
Franktown . . .	R. Kwilu . .	3 30	12 45	B. I. Assoc.
Stanley Niadi . .	Kwilu District	3 51	13 3	B. I. Assoc.
Baudouinville . .	"	4 8	12 0	B. I. Assoc.
Stephanieville . .	"	4 10	13 14	B. I. Assoc.
Philipville . . .	"	4 18	13 43	B. I. Assoc.
Nkula	"	4 32	13 4	B. I. Assoc.
Bulangungu . . .	"	4 38	14 30	B. I. Assoc.
M. Boko songho .	"	5 0	13 43	B. I. Assoc.
San Salvador . .	Congo . . .	6 18	14 46	Late B. M.
Rudolfstadt . .	Coast . . .	4 29	11 42	B. I. Assoc.
Grantville . . .	"	4 35	11 46	B. I. Assoc.
Nengeneuge . .	70 miles up Gambia	13 0	16 0 W	A. P. M.

TABLE II. *(continued)*.

Place	State	Lat.	Long.	Organisation
		° ′	° ′	
Benito	Bight of Biafra	2 0	9 45	A. P. M.
Corisco, Island of .	"	1 20	9 45	A. P. M.
Baraka	Near Libreville	1 30	9 30	A. P. M.
Libreville . . .	Gaboon . . .	1 30	9 30	S. Esprit
Kangwe	S. of Ogowe .	1 0	10 0	A. P. M.
Tallaguga . . .	235 miles up Ogowe	0 10	11 50E	A. P. M.
St. Fr. Xavier . .	R. Ogowe . .	0 0	10 45	S. Esprit and Cœur de M.
Lambaré . . .	"	0 45	10 30	S. Esprit and Cœur de M.
Landana	W. Coast . .	5 16	12 7	Ch. of Rome
Malemba	"	5 18	12 10	Ch. of Rome
Hemlas	—	6 0	12 20	Ch. of Rome
S. Antoine . . .	—	6 20	12 10	Ch. of Rome
Bailunda	Angola . . .	12 0	15 25	A. B. F. M.
Bihe	"	12 50	16 26	A. B. F. M.
Huilla	N. of Kunene	15 2	14 0	S. Esprit
Humba	On the Kunene	16 50	15 5	S. Esprit

The stations of the Livingstone (Congo) Inland Mission (originated by the East London Institute for Home and Foreign Missions) have been recently transferred to the American Baptist Missionary Union.

Positions from the mouth of the Congo as far as Stanley Pool are taken from the new map by MM. Capello and Ivens (1883) published by the Portuguese Admiralty.

The letters L., R. signify that the station is on the left or right bank of the Congo

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The following Papers were read :—

1. *A Communication on Mr. Joseph Thomson's recent Exploration in Eastern Africa. By* General Sir J. H. LEFROY, *C.B., K.C.M.G., F.R.S.*

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2. *A Communication from Sir John Kirk on Mr. H. Johnston's Kilima-njaro Expedition. By* General Sir J. H. LEFROY, *C.B., K.C.M.G., F.R.S.*

The President read a letter from Sir J. Kirk, dated July 10, to the effect that Mr. Johnston had arrived safely in Chagga, and had been favourably received by King Mandalla, the absolute ruler of that district, who had not only undertaken to supply Mr. Johnston's party with food free of expense, but also had assigned him a suitable place on the mountain on which to build a house, and so carry on his work of collecting specimens of natural history.

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3. *The latest Researches in the Mœris Basin.*
By F. COPE WHITEHOUSE, *M.A.*

At the York meeting a sketch map was shown on which all the Greek and Latin allusions to Lake Mœris had been placed in their apparent true relations. It was thus made evident that there was no discrepancy between the accounts of the ancient historians, and that the centre of the lake had been near Qasr Qerun. The expectation was expressed that a careful survey of the region lying between the Pyramids and Behnesa, within fifty miles of the Nile, would show the existence of more than one connecting depression, and that two of these, at least, would prove to be about 200 feet below the level of the Mediterranean.

In 1882 and 1883 surveys were made which fully justified this opinion. The Wadi Reian, which runs S.S.E. from Qasr Qerun, is a valley corresponding in shape to the Meridis Lacus of the Ptolemaic maps. It seems, therefore, established that the ancient historians correctly stated that there was a vast reservoir of Nile water to the west of the Nile valley. The Arabic tradition states, with great clearness and probability, that in the early period of Egyptian history the water filled the northern basins now known as the Fayoum, but that this lake received the waters of the inundation like Albert Nyanza, without any artificial regulation of the flow. The great labour expended upon this lake consisted in the formation of the second, or Reian, basin, the canal from Behnesa to the Southern basin, the canal still known as the Bahr Jusuf, and the great wall of the Fayoum which excluded the water from the upper plateau. This region was called by the Jews, Pithom. It was Pi-Tum, or the West. Recent researches by Dr. Schweinfurth fully support the assertions put forth from time to time as the results of repeated (seven) visits to this part of the Libyan Desert, especially the presence of fresh-water shells at the Nile level, and the remains of a town north of Dimeh. Although these conclusions were opposed to the opinion of the entire scientific world—French, English, and German—they have been accepted. They are of peculiar importance, because—

(1.) The integrity and trustworthiness of the ancient historians have been rehabilitated.

(2.) An impulse has been given to seek for other great works, especially the Labyrinth.

(3.) A restoration of the lake is considered feasible.

This restored lake would be about 250 miles in circumference, with over 600 miles of surface, and irrigate an immense area. It would greatly facilitate the redemption of the marshes at the mouths of the Nile, and the construction of a Cairo-Suez canal.

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4. *On Maps of Central Africa down to the commencement of the Seventeenth Century. By* E. G. Ravenstein, *F.R.G.S.*

The author, having gone through the records of discovery and exploration of Central Africa from the most remote period, stated that the maps of the middle ages, which exhibited a well-developed system of lakes and rivers, were the outcome of a very clumsy combination of Ptolemy's map, with the more recent reports of Portuguese explorers. These latter had done important work, and they were fairly well acquainted with the lower Congo, the lower Zambezi, and a considerable tract of territory inland, but no evidence of their ever having crossed Africa had hitherto been brought forward. The expeditions of Fernando Gomez (1508), Gregorio Quadra (1521), and Rebello d'Aragão, of Santarem (1603), which aimed at that object, were cut short at the very outset. At the same time it appeared to be clear that native traders crossed the continent at this early date, for Portuguese manufactures reached Manica overland from Loanda. A casual reference to a journey of a missionary across Africa, in a popular work on oriental drugs, was not supported by other evidence. Had Ludolfus, the learned author of 'Ethiopia,' carried out his intention of compiling a map of the whole of Africa, he would without a doubt have produced a work far superior to the maps of the period, and secured himself a place by the side of such eminent cartographers as de L'Isle and d'Anville.

FRIDAY, AUGUST 29.

The following Papers were read:—

1. *The remarkable Journey of the trained Indian Explorer A. K. on the Frontiers of India and China. By* Trelawney Saunders.

The work of this native scientific explorer, trained by the officers of the great trigonometrical survey of India, has thrown a light over regions on the Eastern frontier of India, partly traversed before by the French Fathers Huc and Gabet, by Manning and Bogle, Turner, Nain Singh and Prejevalski. Besides this the explorer Krishna has penetrated into new regions, of which our only ideas were derived from d'Anville's 'Atlas de la Chine,' containing the maps of Tibet derived from the surveys of Lama priests, made in continuation of the great Jesuit work under the orders of the famous Emperor Kuenlun. It has been all along a most interesting feature of the researches of our native explorers in Tibet that they have in a remarkable degree confirmed these Tibetan surveys, allowing some little differences easily recognised. In the present case the explorer A. K., as he is designated, has struck an entirely new path with the most instructive and valuable results. Leaving Prejevalski's route at a point near the sources of the Hoang-ho, he struck a river which, on placing a reduction of his work upon a reduction of the Lama survey on the same projection and scale, falls exactly, without any exaggeration, upon the course of the Murus Usu, or upper waters of the great river Yang-tse-Kiang. Nevertheless, the conclusions adopted in Calcutta make this river to be the Yalung, one of the great affluents of the Yang-tse-Kiang. But it would be inconsistent with the limits of an abstract to enter upon further details of the greatest interest with which this journey abounds.

2. *The First General Census of India.* *By* TRELAWNEY SAUNDERS.

The first census that has been made for all India was taken on February 17, 1881. It is embodied in about twenty folio volumes, and the general abstract of those volumes extends to three volumes folio. The author commences with a very brief description of the Provinces and States which form the Empire of British India. The entire population enumerated on February 17, 1881, is 253,891,821. The area occupied by this large population is 1,382,624 square miles. The paper then proceeds to draw a comparison, extracted from the general report, between various parts of this large population and other countries of the world—chiefly European. As the occupied Indian house forms, as elsewhere, one of the bases of the return, the nature of the Indian house, especially in so far as it is distinguished from dwellings elsewhere, is described; the ordinary character of the furniture, the family arrangements, not only on European evidence, but on the evidence of a distinguished native as well, is entered upon. It is only doing justice to the nature of this vast work to refer to the headings of the tables comprehended in the returns:—

1. Area of Population.
2. Movement of Population.
3. Religious Classification.
4. Proportions of Sexes and Religious Divisions.
5. Condition of Population.
6. Condition and Age of Population by Religion and Province.
7. Ages by Religion and Province.
8. Languages.
9. Birth-places.
10. Education.
11. Insanity.
12. Blind People.
13. Deaf Mutes.
14. Lepers.
15 and 16. Towns and Villages.
17. Castes.
18. Occupations.

The reports in general are not merely a dry record of figures. They abound with information of the most interesting character concerning this grand division of the world, which stands second only in numbers to its still vaster neighbour the Empire of China.

The author intimated that he had received the instructions of the Secretary of State for India to present to one of the public libraries of the City of Montreal a copy of this 'General Report of the Census of India' in three volumes folio. It may be useful to add that a statistical abstract relating to British India is printed annually, by command of Her Majesty the Queen, by Messrs. Eyre & Spottiswoode in London.

3. *North Borneo.* *By* E. P. Gueritz.

The author gave a general description of the territory under the government of the British North Borneo Company, from personal observations made during a residence of nearly three years, and from the official reports of Messrs. Pryer, Von Donop, Frank Hatton, and Witti. The territory lies between the 116th and 119th degrees of east longitude and the 4th and 7th parallels of north latitude, embracing an area of some 20,000 square miles and a coast line of about 500 miles. A range of mountains, the general direction of which is north-east and south-west, forms a backbone through the heart of the country. Melaio attains an approximate height of 4,000 feet, Mentapok 7,000 feet, Trodan 8,000 feet, and Kina Balu 13,698 feet. From this range, and descending to the coast on either side, are lesser ranges of hills, covered for the most part with virgin forest, and interspersed with fertile plains watered by numerous rivers. The coast, as a rule, is low and flat. It is, to a large extent, lined with the casuarina tree, broken by stretches of mangrove, and diversified by low sandstone cliffs or patches of forest reaching to the water's edge. The country is rich in harbours, the most important being Gaya, Ambong, and Usikan on the west coast, Kudat on the north, and Sandákan on the east. The principal rivers are the Kimanis, Papar, Putatan, Abai, and Tampasuk on the west coast, Paitan and Sugut on the north, and Sibuco and Kinabatangan on the east. Most of these are navigable for steam-launches of light draft, but the entrances are more or less barred.

The products of the country include tobacco, sugar, gambier (the inspissated juice of the *Uncaria gambir*), pepper, tea, coffee, sago, gutta-percha, and camphor. The author describes the Gomanton caves on the east coast, from which are obtained edible birds'-nests to the annual value of 25,000 dols., and which contain an apparently inexhaustible store of guano, deposited both by birds and bats. The coal at present in use is procured from the Muara mines at the mouth of the Brunei river, but boring for workable deposits is being carried on within the territory of the Company. Traces of gold have been found, and samples of silver, cinnabar, antimony, and tin. Mother-of-pearl, bêche-de-mer, and tortoiseshell are also obtainable.

The fauna comprise a small tree-tiger (*Felis macroscelis*) which is found in the interior, deer of various kinds, wild pigs, wild cattle (*Bos gaurus*), and buffalo. On the east coast the elephant and rhinoceros are also found. In the interior are many varieties of the monkey tribe, including an orang-utan. Small black bears are occasionally met with. The tapir and the otter have been seen on the north coast. Squirrels of all shades abound. Amongst the snakes are found the cobra, python, and leaf-snake, but the author has not known a single fatal case of snake-bite during a six years' residence in Borneo. Crocodiles are numerous. The rivers and coast teem with fish. There are pigeons of many kinds, snipe, curlew, plover; the argus and Bulwer pheasant, and several species of partridge.

The climate is said to be fairly healthy. The maximum monthly mean temperature during 1883 was 89·3, and the minimum 75·1. The rainfall at Kudat for the year was 120·56. November, December, and January are the wettest months.

The population is estimated at 150,000. The west coast is peopled by a mixture of Malays, Bajaus, and Ilanuns; on the north and east coasts Bajaus and Sulus are chiefly met with. Chinese, natives of India, and Arabs trade in most of the rivers, and the former are settling in considerable numbers. The aborigines who reside in the interior are called Dusuns, or Ida'an. They grow tobacco, cotton, rice, tapioca, yams, and Indian corn for their own immediate consumption, and use ploughs and harrows which are supposed to have been introduced by the Chinese. Laws have recently been promulgated with a view to the gradual extinction of slavery. The experiment in colonisation now being made in British North Borneo is attentively watched by other nations who have interests in the Eastern seas.

4. *Mount Roraima in Guiana.* *By* Everard F. im Thurn, *M.A.*

The author described a project which he has formed with a view to explore and if possible ascend Mount Roraima, an extraordinary table-mountain, the most remarkable of a very remarkable group, all of somewhat similar character, which stand in the sandstone region of Guiana in latitude 5° 9′ 40″ N. and longitude 60° 48′ W. The various attempts that have been made to acquire definite information concerning Roraima by a few enterprising travellers were enumerated, together with the obstacles they encountered. Although the district contains many streams, it is traversed by no large rivers such as would afford an easy waterway for the boats of travellers who seek to penetrate it; while its many and abrupt mountains, and the scantiness of its population, render it no easy matter to traverse the district on foot. To sum up, it appears that the mountain has been examined at its southern and south-eastern points, and also at its eastern side; its northern end has been viewed from a distance; and along its western side a glimpse has been obtained from a point far to the south-west. The general, but not universal, opinion of those who have seen Roraima is that it is inaccessible, unless perhaps in a balloon. The author, however, doubts whether any traveller has yet had sufficient experience of the mountain to pronounce an authoritative decision, and the chief object of the projected journey is to acquire the necessary data from which to judge whether it is accessible or not. He proposes to examine the mountain as closely as possible on every side, and to make the ascent should circumstances permit. He will further examine and collect the flora and fauna, and investigate the condition of the little-known Arecoona Indians, in whose district Roraima lies. Such are the objects for the attainment of which the author has received the support of the Royal Society and the Royal Geographical Society, and for which he now seeks the support of the British Association. The route by which he will endeavour to reach Roraima is to follow the course of the Potaro, a new and as yet untried river, which rises at a point not very far distant from the mountain, and forms the famous Kaieteur Fall. Judging by the experience gained during two visits to the Fall, the author concludes that the requisite baggage must be carried by boat as far as the Kaieteur, and up to the higher level from which the river there falls. Thence he proposes to reach Chinebowie, a mission-station at a distance of one and a half day's journey, and proceed in boats to a point some two days further on, where, the Indians say, the Potaro forms another fall, as yet unseen by white men, but which he hopes to pass in the same manner as Kaieteur, and proceed to the head of the Potaro. From that point, he is assured, a path leads to the head waters of the Cotinga river, where there are Indian settlements close under the shadow of Roraima.

5. *Object Lessons in Geography.* *By* E. G. Ravenstein, *F.R.G.S.*

The author stated that the times when teachers of geography confined themselves to making their pupils acquainted with barren lists of places were happily behind us, as far as concerned the leading schools. Nevertheless much remained to be done until the teaching of that subject could be said to be carried on in a manner thoroughly satisfactory.

He conceived it to be the object of our elementary schools to make the pupils thoroughly acquainted with the locality in which they lived, and advocated the extensive use of object lessons in order to attain that object.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Report and Papers were read:—

1. *Report of the Committee for promoting the Survey of Eastern Palestine.* See Reports, p. 272.

2. *Comparison of the Climates of the Eastern and Western Hemispheres. By* Dr. J. BEAUFORT HURLBERT.

3. *Some peculiar Storms on the North American Continent. By* Dr. J. BEAUFORT HURLBERT.

4. *On Dominion Surveys. By* TRELAWNEY SAUNDERS.

The advent of the British Association appeared to the author to call for a notice of certain unscientific proceedings in the Dominion Surveys. In particular he alluded to the maintenance of an attempt devised in times of geodetic ignorance in the United States, and adopted in the Dominion from that source, involving the application of a network of squares to the allotment of public lands for the purposes of sale. No doubt the idea of allotting land by the square mile, and divisions of the square mile, would naturally commend itself to surveyors trained in the management of estates and parishes. But such a method cannot be carried out over the surface of the earth to any considerable extent. It is only on the basis of meridians and parallels that rectangular intersections can be applied over a spherical surface of any great extent. The discrepancies and objections to the system of squares in the United States in time attracted the attention of the General Legislature of the United States, and in the opinion of the author it is to be regretted that the conclusion arrived at was a compromise contrary to science, providing a method of correction at certain intervals. So far from this compromise offering facilities for the uniform allotment of land, it is decidedly the reverse. There can be no difficulty in finding the area, in acres or otherwise, of any division, however large or however small, on the true geodetic basis of meridians and parallels; and a given area being once found between any two parallels, it is of course the same all around the sphere in the same belt and over similar limits. It is also to be observed that boundaries defined under the system of squares, or on any other basis natural or even capricious, can be as easily delineated on the true basis as on the false one. There does not, indeed, appear to be any sufficient grounds for retaining the unscientific method now in vogue according to law in the United States, and adopted by law also in the Dominion from the example of the great independent English-speaking Republic.

Notice was also called to the aspect of these allotment-maps. They are rather registers than maps—registers, indeed, of the allotment-squares and compromise-spaces rather than maps of the natural features of the ground. Such true maps are, however, far from being altogether wanting, though the public seldom have access to such maps on a large scale sufficient for the study of geographers.

The triangulation of both the United States and the Dominion of Canada appeared to the author to invite the attention of geodesists, but the subject was perhaps too technical for the present discussion.

5. *An Automatic Sounder. By* JAMES DILLON, *M.Inst.C.E.*

This apparatus, consisting of a bar attached to the side of the boat or steamer, which automatically registers the depth upon a dial to which its upper end is attached, was first explained at the York meeting of the Association.

6. *On the British Commercial Geographical Society about to be founded on the proposal of Commander V. Lovett Cameron, C.B. By* Commander V. LOVETT CAMERON, *C.B.*

In this paper the author, who has taken the initiative in forming the British Commercial Geographical Society, pointed out the growing necessity for strengthening the bonds of union between England and the outlying portions of the British Empire in all parts of the world. He instanced the energy and enterprise of France in seeking at the present time every available opportunity to infuse a love for geographical knowledge in the rising generation destined to take part in the commerce of their country. The knowledge stored in encyclopædias, gazetteers, sailing-directions, consular reports, and other official and non-official documents needs digesting, arranging, and indexing to be rendered available for every-day use in a great commercial centre like London, where business men with little loss of time can inform themselves with the least possible delay on all matters which concern them in their daily avocations. The author set forth the objects of the society, which has already met with the approval of those who have given the subject their consideration, and felt convinced that no time should be lost in repairing an omission in our system of commerce, or rather in meeting a necessity which has sprung up, through the increasing competition of our neighbours, in markets until recently almost exclusively supplied with British products.

TUESDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Arctic Experiences at Point Barrow. By* Lieutenant P. H. RAY, *U.S.A.*

The author made an excursion in 1883 for a distance of 160 miles to the south of his winter quarters, near Point Barrow, in the course of which he struck the Mead river sixty miles above its source, and followed up its course until he came in sight of a range of mountains trending N.W. and S.E. Speaking of the results of his meteorological observations, he stated that he was satisfied that there was no open polar sea, from the fact that the temperature of the sea water is unvarying from the time the sea closes in October until it opens in July, which could not well be the case if there was a large body of warm water lying around the pole.

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2. *Recent Discoveries in Northern Greenland and in Grinnell Land. By* Lieutenant A. W. GREELY, *U.S.A.*

The geographical work of the Lady Franklin Bay Expedition covers nearly three degrees of latitude and over forty degrees of longitude. Starting from latitude 81° 44′, longitude 64° 45′, Lieutenant Lockwood reached, May 18, 1882, on the north coast of Greenland, latitude 83° 24′, longitude 40° 46′. From the same starting-point he reached, to the south-west, in May 1883, in Greely Fiord, an inlet of the western polar ocean, latitude 80° 48′, longitude 78° 26′. The journey to the northward resulted in the addition to our charts of a new coast-line of nearly one hundred miles beyond the farthest point seen by Lieutenant Beaumont, of the Royal Navy. It also carried Greenland over forty miles northward, giving that continent a much greater extension in that direction than it has generally been credited with. The farthest point seen on the Greenland coast was estimated to be about latitude 83° 35′, longitude 38°. There were no indications that the farthest point seen was the northern termination of Greenland. The newly-discovered coast resembled in many respects that of southern Greenland. The mainland was intersected by many deep fiords, with numerous outlying islands. The interior of the country, as seen from an elevation of some 2,000 feet, consisted of confused masses of mountains either eternally snow-clad, or covered with an ice-cap. The fiords presented to the eye nothing but broad, level expanses of snow and ice, being devoid of any marked ice-foot, floe-bergs, pressed-up hummocks, or any other indications tending to prove their direct connection with the Spitzbergen sea. In general the immediate coast was high, rugged, and precipitous. The formation was very like that around Discovery Harbour, schistose slate with a sprinkling of quartz. Vegetation resembled closely that of Grinnell Land; among specimens brought back, the Arctic poppy and several saxifrages were identified. Above the eighty-third parallel traces of the polar bear, the lemming, and the Arctic fox were seen, and a hare and a ptarmigan killed. At the farthest north a snow bunting was heard. A remarkable fact noted was the existence of a tidal crack—so called for lack of better name—which extended from Cape Bryant along the entire coast, running across the various fiords in a direct line, from headland to headland, and varying from one yard to several hundred yards in width. Inside the crack the rough and hummocky ice was but rarely seen, while outside prevailed the paleocrystic ice over which Commander Markham struggled so manfully and successfully in his wonderful journey of 1876. Midway between Capes May and Britannia a sounding was made, but no bottom found at 1,800 feet: apparently no current existed. It may be well to state that the latitude of the farthest north—Lockwood Island—was determined by a set of circum-meridian and sub-polar observations, which were reduced by Gauss's method. The latitude of Cape Britannia and several other points was determined by circum-meridian observations. It affords the author pleasure to testify to the accuracy of Lieutenant Beaumont's maps. The only correction made places Cape Britannia a few miles south and Cape May a few miles west of their assigned positions. These points were located by Lieutenant Beaumont from bearings, and his comparative exactness was remarkable considering the disadvantages under which he laboured.

The author then continues the account of his exploration as follows:—

'The journeys made by Lieutenant Lockwood and myself across Grinnell Land, and into its interior, revealed striking and peculiar physical conditions which have been hitherto unsuspected. Between the heads of Archer and Greely fiords, a distance of some seventy miles, stretches the perpendicular front of an immense ice-cap, which follows closely from east to west the eighty-first parallel. Its average height was not less than 150 feet. The undulations of the surface of the ice conformed closely to the configuration of the country, so that the variations in the thickness of the ice-cap were inconsiderable. In about sixty miles but two places were found where slope and face were so modified as to render an ascent of the ice possible. This ice-cap extending southward, covers Grinnell Land almost entirely from the eighty-first parallel to Hayes Sound, and from Kennedy Channel westward to Greely Fiord and the polar ocean. The glacier discharging into Dobbin Bay is but an offshoot of this ice-cap, and without doubt glaciers are to be found at the head of every considerable valley debouching into Richardson, Scoresby, or other bays. Several valleys which were visited during the retreat southward displayed at their entrances evident signs of such occupancy in the past. In July I was fortunate enough to ascend Mount Arthur, the summit of which is 4,500 feet above the sea. The day was very clear. To the northward of the Garfield Range a similar ice-cap appeared to view, from which extensive glaciers were projected through every mountain gap. One of these, the Henrietta Nasmith glacier, had been visited by me the preceding April, and was found to have a perpendicular face of about 200 feet; it discharged into a small bay. A part of Lake Hazelginman, Abbé, and other glaciers feed streams which empty into that lake. Similarly, glaciers were found at the head of rivers discharging into Saint Patrick, Lincoln, and Basil Norris Bays, and Discovery Harbour. From these indications I estimate the northern ice-cap of Grinnell Land as not far from 6,000 miles in area. Its southern limit closely coincides with the eighty-second parallel. The country between the eighty-first and eighty-second parallels, extending from Kennedy and Robeson Channels to the western polar ocean, was found in July to be entirely free from snow, except on the very backbone. In over 150 miles' travel into the interior my foot never touched snow.

'Vegetation abounded, being exceedingly luxuriant as compared with Cape Hawks, Cape Sabine, or other points farther south visited by me. Dead willow was found in such abundance as to serve for fuel, and in more than one instance willow, saxifrages, grasses, and other plants grew in such profusion as to completely cover large tracts of ground. These valleys afford excellent pasturage for musk cattle, which, feeding towards the seacoast during summer, withdraw to the interior as winter advances. I frequently noted evidences of the recent elevation above the sea of the region now free from ice-cap; such indications consisted of raised beaches, marine shells, and driftwood. At one place the trunks of two large coniferous trees were found in such state of preservation as to allow of their use as fuel. It seems probable that the two ice-caps were originally united. It is certain that both the northern and southern ice-caps have recently retreated, even if such process is not going on now. Along the front of the southern ice were found many small glacial lakes and moraines. To the north, lake Hazen, for some fifty miles, borders the ice-cap. In front of Henrietta Nasmith glacier there were three parallel moraines between the face of the glacier and the main lake.

'At the junction of Lake Hazen and Ruggles River, I discovered the remains of permanent Esquimo huts—many relics were obtained at that place, and at various points along the southern shore of Lake Hazen; but no traces of any kind were found on the northern shore of the lake. It is perhaps worthy of remark that the reindeer, which must have been plentiful in that country, have entirely disappeared, having either migrated or become extinct. In connection with the line of perpetual snow, I may state that on Mount Arthur it was not far from 3,500 feet above the sea. From barometrical measurements, it appeared that the crest of Grinnell Land was of about 2,500 feet elevation in front of the southern ice-cap, and 3,000 feet near Mount Arthur.

'Your indulgence is asked for any imperfections in these notes. Strength has failed for their elaboration, and my memory has necessarily served me in their preparation, as all records and journals are on file in Washington.'

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3. *A Search in British North America for lost Colonies of Northmen and Portuguese.*[1] *By* R. G. Haliburton.

The paper dealt first with Vinland the Good (A.D. 994), which Danish and American writers have placed as far south as Rhode Island. They have treated the Norse poems or Sagas which refer to this subject as truthful narratives. Only one of them can claim any weight, and that is the Saga of Eric the Red, written in Greenland. The significant fact has escaped attention that Eric was a murderer, who fled to Iceland, whence he was soon after banished and outlawed for another murder. He therefore sailed west to a land the existence of which was known to the Northmen; and though covered with snow it was called by him Greenland, because, said he, 'people will be attracted to the country if it has a good name.' Some time after he was induced by rumours of a still more western country to sail to it; but the fact of his horse stumbling and throwing him when on his way to the ship was a bad omen. He therefore let his son Leif go without him; but he probably had a name all ready, one even more taking with emigrants than Greenland, and that was Vinland the Good.

Late Danish authorities fix the latitude of Vinland by the length of the shortest day there, and make it that of Greenland or Newfoundland. The Eskimo were then, as now, the inhabitants of Labrador, and were apparently the only natives known to the Northmen. The geographical notices appended to Rafn's great work all agree together in pointing to a country situated like Newfoundland. Grapes, too, are found on the west coast of that island. Canadian yacht-owners should cruise along it, and try to discover traces of Vinland, which, if found, must be a very different country from what Eric or his bard has pictured it.

Eric and his family have been connected with two puzzling problems, for it was his sons and daughters and his sons-in-law and daughters-in-law that found or

[1] Published *in extenso* in *Proc. R.G.S.* vol. vii. No. 1.

visited Vinland. When we can discover Greenland's verdant mountains, we can also hope to find the vineclad hills of Vinland the Good.

The paper then drew attention to a remarkable fact which is new to historians, that the eastern parts of British North America once formed part of the earliest European Colony in the New World. Documents were quoted that have been within the past year published by the Portuguese, which show that from A.D. 1500 to 1579, commissions were regularly issued to the Corte Reals and their successors. In 1580 Spain annexed Portugal. Last winter was spent by the writer in the Azores, whence two expeditions sailed to colonise Cape Breton, A.D. 1521 and 1567, which probably made settlements at St. Peter's and Ingonishe. When Spain became the owner of Terra Nova, she sent a colony thither, which the writer traced to Spanish Harbour (Sydney) Cape Breton. He also showed that a commission issued in 1521 to Fagundes, as governor of all the country between the Spanish territories and the Land of the Corte Reals. The latter colony was thirteen years earlier than any other in the New World, and the settlement in 1521 was the earliest in North America. It was nearly a century before the French colonised Cape Breton. Cape Race (Cabo Raso 'bare cape'), the Bay of Funday (Fonda 'deep'), and many other names are memorials of a lost colony which existed for almost a century. History has been hitherto silent as to it.

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4. *Note sur quelques bassins hydrographiques du Dominion Oriental. By the* Rev. Abbé J. C. Laflamme, *A.M.*

The author first rendered some account of his own explorations in the basin of Lake St. John, and then spoke of the Mistassini Lake, only quite recently discovered, in the interior of Labrador, and the superior of the Ontario in size.

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5. *On Surveys of the Dominion Lands—North-Western Territories of Canada. By* Lindsay Russell.

The principal topics treated in this paper were:—

1. The relevancy of these surveys to the objects of Section E, in that to them—as they progress—is largely due the attainment of accurate knowledge of the details of topography of an almost continental area.

2. A notice of what the general cartography of these regions owes to individual explorers and scientists who had previously traversed them—Sir Alexander Mackenzie, Dease and Simpson Back, Franklin, Richardson—in general geography; later, in topographical and scientific surveys, to Sir J. H. Lefroy, Sir John Palliser, Dr. Hector, and the Rev. Abbé Pellitot in his mapping of his explorations in the northern basin of the Mackenzie.

3. A short exposition of the system in which Dominion lands are laid out into townships, sections, and quarter-sections—the latter being the unit of individual holdings—preceded by a brief explanation of the circumstances under which these hitherto unsurveyed and almost unmapped regions came under the administration of the Canadian Government, and the consequent necessity that arose for rapid survey of vast areas into these subdivisional units for agricultural occupation.

4. A technical description of processes of survey and of instruments used. The difficulties encountered in securing—within restricting limits of reasonable expenditure—adequate check upon unavoidable accumulation of error, in a system which consists of a continual building or adding on of figures, the contours of which are established by linear measurement under circumstances that unavoidably entail but a very moderate approximation to accuracy. The following are the checks adopted:—

(*a*) Checks by astronomically-determined latitudes: number of latitude stations so determined: instruments used. Comparatively unsatisfactory result of these as checks on account of relatively large local deviations of the vertical met with. Witness those recorded on the Survey of the International Boundary by the joint U.S.A. and Imperial Commission.

(*b*) Checks by telegraphic longitudes. It is but very recently that lines have been constructed admitting of these, the only application, so far, of the method having been that in which the position in longitude of the first initial meridian was fixed by conjoint operation of the Royal Engineers engaged in the boundary survey at Rembina and the 'reader' at Chicago, used as a datum point. It is intended to apply the method where serviceable, now that means of doing so are beginning to be available.

5. *Cartography.*—An account of several maps, of detail maps, and of processes of multiplying copies.

6. A statement of the area surveyed in a season, and of the total area surveyed to present time.

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6. *On the former Connection between North America and the Eastern side of the Atlantic. By* Professor W. Boyd Dawkins, *M.A., F.R.S.*

The former connection of North America with Greenland, Iceland, and North-Western Europe, is most conclusively proved by the distribution of the fossil-plants and animals in the remote geological past—in the eocene and miocene ages.

The magnolia, for example, is a form which was abundant in the eocene forests of Europe and the far north of America. The sequoia, too, now confined to the slopes of the Sierra Nevada, may be quoted as an example of the vegetation common to North America and to Europe; as well as the fox-grape. The common sensitive fern so usually found in this region of Canada occurs, buried under sheets of basalt, in the island of Mull. The *Lepidosteus* of the American rivers was living in the eocene rivers of the south of England. Among the higher mammalia common to both may be quoted the *Coryphodon.* The route by which these animals arrived is shown by the soundings. The tract of comparatively shallow water which ranges from Greenland past Iceland to the Faroes and Northern Scotland, and isolates the deep waters of the Arctic Sea from the depths of the Atlantic, formed the bridge across which the migration took place, the 500-fathom line representing approximately the line of the ancient shores. This barrier became submerged during the stupendous geographical changes which took place at the close of the miocene age. Then, for the first time, were the Arctic waters united with the Atlantic, and Arctic shells gradually found their way southwards into the area of the British Isles.

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7. *On Charles Winnecke's Explorations in Central Australia, with Notes on the Employment of Camels. By* J. S. O'Halloran, *F.R.G.S.*

The author gave a brief account of an adventurous journey through an unknown region lying between the Overland telegraph and Queensland, by collating Mr. Charles Winnecke's diary, which has been laid before the South Australian Legislature. The members of the Association having had the privilege of listening to a stirring description of the perils encountered by the heroes of the Arctic, it seemed appropriate that the meetings of this section should close with a reference to the hardships braved by one of those who followed in the track of men who have laboured to throw light on the unexplored interior of the great island continent of Australia.

Having furnished a broad outline of the physical features of the interior of Australia, the author stated that the introduction of the camel rendered possible the journeys of many explorers, who without such aid could hardly have survived the sufferings involved by traversing the tracts of arid, inhospitable country which too frequently occurred.

Mr. Winnecke's party started on August 16, 1883, from the Cowarie station on the Warburton River, attained its 'furthest' on the Field River, in lat. 22° 50′, and returned to Beltana on December 2. About 400 miles of new country had been traversed, 40,000 square miles of new land had been sketched, and a collection of plants found in Central Australia between lat. 22° 30′ and 28° S., and long. 136° 30′ and 139° 30′ E., had been examined and classified by Baron Ferdinand von Mueller.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Sir R. Temple, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S.

THURSDAY, AUGUST 28.

The President delivered the following Address:—

The General Statistics of the British Empire.

The subject chosen for this address is that of the General Statistics of the British Empire. It will, I hope, be deemed appropriate for the meeting which is held in one of the fairest colonies which this empire contains. Though statistics are fallible, yet the collation and presentation of them must be regarded as essential to political and economic knowledge. Indeed they are, figuratively, the backbone of information, and without them our knowledge would be invertebrate. Owing to the variety of sources from which the facts have to be drawn for an empire that is spread over the world, and owing to the magnitude of the figures which have to be produced, it will frequently be necessary to state the totals approximately and in round numbers. Again, owing to the largeness of the subject and the limitation of space, it will be impossible to do more than state the principal facts in the form of an abstract.

Our statistics then will be grouped under the following headings:—

I. The area consisting of widely extended regions.

II. The inhabitants of these many lands.

III. The works of man as they are displayed in this vast theatre of action.

First, then, the area of the British Empire may be set down at 8,650,000, or more than 8½ millions, of square miles. This area includes the countries which are directly recognised as the component parts of the empire in Europe, in the East and West Indies, in Australia, in North America, in South Africa, and the possessions scattered among nearly all the regions in the world. Out of this total there are only 120,000 square miles in the United Kingdom. Then there are 1½ million of square miles in India, and the remainder, or 7 millions, belong to the Colonies, and to the scattered possessions.

But there are other regions which, though not belonging to the empire, have yet fallen, or are falling under its political control more or less, such as Egypt, some districts in Southern Arabia, a part of Borneo, Zululand, the Transvaal, Afghanistan, Beluchistan, and a part of New Guinea. The area of these additional regions may be set down approximatively at 1,103,000, or about one million of square miles, and this figure is probably somewhat below the reality. Thus the total area, directly or indirectly under the authority of the British Crown, may be taken at nearly 10 millions of square miles, or about one-fifth of the 50 millions of square miles composing the habitable globe.

The dimensions of this imperial area have been ascertained by professional surveys; of which the progress has kept pace with the expansion of the empire. Out of the grand total not less than 2½ millions of square miles have been topographically surveyed, and of this nearly all has been surveyed minutely field by field. This cadastral survey, presenting the details of every field for a vast area, is to be reckoned among the largest operations ever known in the annals of administration. The remainder has been (for the most part) either partially surveyed or partially explored. A small portion, however, remains but imperfectly explored, or else almost unexplored.

As might be expected in an empire whereof the real basis of power is maritime, the coast line is of an extraordinary length, to be measured by about 28,500 miles, with 48 large harbours; for the whole of this length marine surveys have been prepared.

In an empire which lies on both sides of the Equator, and is scattered over both hemispheres, there are varieties of climate touching the extremes of heat and cold. Of the whole about one-sixth is within the tropics, one-third in the antipodes, one-third in North America, and the remaining one-sixth in the temperate zone of Europe and Asia.

But greatness does not depend on area alone, and there is a vast range in the scale of value for lands. For instance, it has been computed that the average letting value of land in the interior of England is several hundred times as great as that in the interior of Siberia. So in the British Empire there are wide tracts, which may be important politically and prospectively, but of which the value cannot be measured by a statistical test. Out of the 10 millions of square miles, hardly one-fifth is cultivated or occupied in the widest use of the term occupation. The area, however, which is capable of being brought under cultivation, and of sustaining the future increase of population, must be regarded as enormous. It is chiefly in Australia and Canada, in which two divisions it may be reckoned at upwards of 2 millions of square miles, enough at the lowest computation to support 200 millions of souls. Even in India, which is popularly, though not quite correctly, supposed to be thickly populated, the cultivable waste is not less than a quarter of a million of square miles. Then there is a residue which is uncultivable waste, and of which the dimensions cannot be precisely measured. It consists of mountains and forests, with some desert, in the heart of Australia. These mountains are among the greatest ranges in the world. The forests are very extensive, and their extent cannot be precisely stated. They are infinitely various both in respect of value and of condition; some being poor or half destroyed, others being rich and well preserved. But there are in the empire about 100,000 square miles of forests which are being formally and professionally preserved to become a mighty source of national wealth.

In the second place, respecting the inhabitants, the total population amounts to 305 millions of souls in those regions which are included directly in the empire. If the countries already mentioned as more or less under political control were to be included, then about 10 millions more would have to be added, bringing up the total to 315 millions.

This mass of humanity is composed of many diverse nationalities, among whom the primary distinction is that of race. There are 45 millions of the fair races; among these about 39 millions are Anglo-Saxons, including German colonists. Three and a half millions are Celtic (mainly Irish), $1\frac{1}{2}$ million are French Canadians, half a million are Dutch in South Africa; and there are a certain number belonging to other nationalities, Scandinavians, Swiss, Greeks; but there are few from the Latin race in the South of Europe, and hardly any Russians.

Again, of the 315 millions, ethnically there are 45 millions of the fair or Caucasian race, 254 of the Aryan, and 5 of the Mongolian, the remainder belonging to aboriginal races.

A cardinal distinction between the several nationalities is that of religion. Christianity, the religion of the dominant race, is professed by somewhat more than the 45 millions of the fair races above mentioned, but the total can hardly exceed 46 millions out of the 315 millions, that is, one-seventh of the whole. The religion which includes the largest number is Hinduism. There are 188 millions of Hindus, and it may indeed be said that the whole Hindu race is subject to the British crown. The Hindus then form more than a half of the total population in the empire. Under the generic name of Hindu, however, there are counted many thousands of Brahmos, who are really Theists, and there are 3 millions of Sikhs and Jains, closely connected with Hinduism.

Then there are 50 millions of Muhammadans under the British crown in India, and there are 10 millions more in the Muhammadan countries connected with the British Empire: in all 60 millions. This number exceeds the number of the Muhammadans belonging to any of the Muhammadan States, such as Turkey, or Persia, and in fact comprise half the Muhammadan world.

The number of Buddhists is not considerable, amounting to about 7,000,000, chiefly in Burmah and Ceylon, with some Chinese in Australia and other divisions of the empire. Then there is a small remainder, about 7,000,000, consisting of Pagans chiefly, the Aborigines of the East Indies, including also the North American Indians, the Australasian natives, and the African tribes of the Cape.

In the United Kingdom the proportion of urban to rural population is large, being more than one-half already, and likely to increase to two-thirds. In England especially, the majority of the people dwell in towns. At present a similar tendency is observable in Australia, where the people are mainly urban. But in the rest of the empire the mass of the population is rural, a certain percentage only being urban. In India, especially, it is to be remarked that nine-tenths of the people are in villages, leaving one-tenth only for the towns.

If the total population were spread over the total area of the empire, the average would amount to only 33 persons to the square mile, which suggests a wonderful sparseness of population in a wealthy and prosperous empire. The sparseness arises from the inclusion in the empire of tracts, either uninhabited or but slightly inhabited, such as the Himalayas, the frigid regions in the north of Canada, a part of the Rocky Mountains, and the arid desert in the heart of Australia. Indeed it were almost idle to reckon the average of the population in the total area in the Dominion of Canada, or in Australia. Even in India the general average amounts to only 184 to the square mile, nevertheless India contains some of the most densely peopled districts in the world. In some Indian provinces a population to be counted by tens of millions, average from 300 to 400 the square mile, and in some Indian districts, with a population to be counted by some millions, the average rises to 800, even to 900 on the square mile. As is well known, England (as separate from Wales, Scotland, and Ireland) is the only part of the empire which is densely peopled throughout, its average per square mile, 485 souls, being almost exactly the same as that of Belgium, the most densely peopled part of the Continent of Europe.

Heretofore under the first two headings we may have wondered at the smallness of the proportion which the United Kingdom bears to the empire in respect of area and population. Under the next or third heading we shall be constrained to admire the largeness of the proportion which the United Kingdom bears to the empire in respect of wealth, commerce, and resources. The third and last heading then relates to the works of man, his riches and power, his industrial and commercial operations.

One among the primary tests of national resources is the public revenue.

The annual revenue and receipts collected in the British empire for the general government or administration amounts to 203,000,000 sterling annually. Of this mighty sum, 89,000,000 pertain to the United Kingdom, 74,000,000 to India, and 40,000,000 to the Colonies, and the Dependencies. This includes British territories only, and not the Native States of India, nor the countries politically connected with the empire. If that could be added, however, the addition would not be very material to so great a total as that above shown.

The revenue which is raised indirectly from the consumer is less felt than that which is levied directly from the tax-payer. It may therefore be well to observe that of the 203,000,000 not more than one-fourth (or 50,000,000) is obtained from direct taxation, land tax, property tax, and the like, the remainder being obtained from customs, excise, and other sources of indirect taxation.

But besides the general government and administration, there is a large revenue received throughout the empire for local purposes. This income (including various receipts but excluding loans) amounts to hardly less than 61,000,000 sterling yearly, of which 49,500,000 belong to the United Kingdom, and 5,000,000 to India; the greater part of this is levied by direct taxation.

Inasmuch as the payer feels the payment whether the money be applied to general or to local purposes, it is but just to add together the two great heads of imperial and local revenue. Thus the total of 203 and 61 millions amounts to 264 millions sterling annually, truly an amazing amount at first sight, the like of which has never yet been imagined. Still the sum is not apparently high for the total population, amounting to 1*l.* 5*s.* 4*d.* per head per annum.[1] But the average incidence varies greatly, being 4*l.* 7*s.* 5*d.* per head in the United Kingdom, 2*l.* 14*s.* 1*d.* per head in the Colonies and Dependencies, and only 7*s.* 11*d.* in India.

Another test of power relates to the provision for external defence and internal protection—in other words, to armies, auxiliary forces, and organised police, to navies and marine.

Now the men trained to arms in the British Empire may be stated at 850,000, including the regular British forces at home and abroad, the militia, and volunteers in the United Kingdom, and in the Colonies, the British Native forces in India, and other countries. This includes 10,000 Egyptian troops under a British general, but excludes the forces of the Native States of India, and of the other countries politically connected with the empire. If, however, the forces of the Native States of India were to be added (and they are generally available for imperial purposes), then the total of 850,000 would be raised to nearly a million.

Thus the men under arms, or effectively trained to arms, are in number more than three-quarters of a million, and under the last-named computation would amount to nearly a million. This number represents those who are really serving, or who are in receipt of allowances, or are actually called out from time to time—and not those who are liable to be summoned in event of emergency. This actual total will bear comparison numerically with the standing armies of the martial empires now in the world, though there may be an important difference in respect to military organisation. But the total is very small in comparison with the size of the British Empire, representing only one soldier to every 10 square miles, and to every 376 of the population. Thus the military forces of the British Empire, taken at the outside figure, are much smaller relatively to the territory and the people than those of any other great State, excepting only the United States of America. There remains, too, the cardinal fact that the British military forces are raised entirely by voluntary enlistment, a circumstance almost unique in the military arrangements of the present age.

Of the total strength 850,000, about 150,000 are soldiers of the dark or coloured races, and the remainder, or 700,000, are of the fair or dominant race. But if the total of a million be taken, then it may be said that 300,000 are of the dark races, and 700,000 of the fair or dominant race. These proportions are satisfactory in respect to the safety of the empire.

The defensive armaments of the empire by sea and land cost 41 millions sterling annually, or 20 per cent. of the total of revenue and receipts, which proportion is less than that shown by any great State in the world, except the United States. If the expenditure be compared with the whole population of the empire, then it amounts to less than four shillings a head, which (always with the exception of the United States) is the cheapest rate to be found in any great State of the world.

Subsidiary to external defence is that internal protection which a police force secures. Now the police force of the British Empire, metropolitan, municipal, and rural together, is in numbers about 210,000. Of this total, 51,000 are in the United Kingdom, and 147,000 in India, the remainder being in the Colonies and Dependencies. It may be a question whether there should be added to this total the number of village police in India, who are paid not by the State, but by village cesses, and who are legally recognised. Their number is not exactly known, but is not less than 350,000, and this addition would bring the grand total of the police for the empire up to 560,000.

[1] This ratio includes the British subjects only, and not the Native States under British control.

Thus we have for the whole empire an average of one policeman to every 571 of the people, and to every 16 square miles.

It is never to be forgotten that one of the main reasons why the British Empire is able to keep its land forces at a comparatively low scale, is its preponderance at sea. Owing to the astonishing difference of power between the different kinds of ships, and in the preparedness of ships to put to sea and fight, the difficulty of exhibiting the strength of a navy by figures is becoming greater and greater.

The predominance which we hope to find in the British navy will hardly be shown by the enumeration of ships. With this caution, however, it may be stated that there are 246 British war vessels afloat, or in commission, of which 72 are sailing ships, and 174 have steam power. There are now 63 ironclads, either complete or nearly complete. The number of officers and men amounts to 57,000. The number of ironclads ready for action at the shortest notice is now 44, of which 25 are at sea. These facts will probably be found to indicate a naval preparedness fit to cope with such foreign combinations as could reasonably be anticipated.

In respect to mercantile shipping a statistical exposition is more applicable. The British merchant navy consists of 30,000 ships, with 8½ millions of tons, manned by 270,000 sailors. The seagoing tonnage under the British flag amounts to 3 millions of tons in steamers, and 5½ millions of tons in sailing vessels. Now under the flags of other nations there are 2½ millions of tons in steamers and 9½ millions in sailing vessels. In other words, the British Empire surpasses all other nations together in respect of steamers, and nearly equals them in respect of sailing vessels. In respect of carrying power in the world by sea, 49 per cent. belongs to the British Empire, and 51 per cent. to other nations. Again, out of 55,000 ships in the world over 100 tons, 21,000 are British. The comparison remains in similar terms in respect to the earnings of shipping. Out of 129 millions of tons carried yearly by the shipping of the world, 63 millions are under the British flag. Out of 133 million pounds sterling earned from freight and passengers by the ships of the world, 73 millions are earned by British ships. A similar proportion is shown by the port entries of the world, represented yearly by 125,000 tons, of which 57,000 (or nearly half) pertain to the British Empire.

In shipbuilding the proportion is still more favourable to the British Empire. Out of 1,800,000 tons built annually, 1,200,000 are built in Great Britain.

The total trade of the British Empire cannot be exhibited statistically because the component parts of the empire are separated by oceans. Consequently, much of the trade is between these parts, and it would be meaningless to sum up the several items into one grand total.

Still it is well to summarise the separate items, each of which is a mighty factor in the prosperity of the empire. As is well known, then, the United Kingdom in 1882 exported 241 millions sterling worth of British produce with 65 millions worth of foreign and colonial produce, and imported 413 millions; the total value of the trade being thus 719 millions sterling. The ocean-borne trade of India is valued at 143 millions sterling annually, that of the Colonies and dependencies amounts to 302 millions; truly an astonishing amount in comparison with their population.

If the aliquot parts of the trade of the principal nations be computed, then about one-fifth, or 21 per cent. of the whole, belongs to the United Kingdom, and 13 per cent. to the Colonies and dependencies. Thus 34 per cent., or one-third of the world's commerce, pertains to the British Empire.

The ratio of seaborne commerce per inhabitant yearly is 20*l.* in the United Kingdom, 31*l.* in Australia, 9*l.* in Canada, and 6*l.* in the United States. In Europe the British ratio is exceeded in Holland and equalled by Belgium, but in other European countries the ratio is far less.

In respect to banking, the United Kingdom is known to be the busiest on earth, and transacts one-third of the business of the world. The total of capital and deposits used in the banking of all nations amounts to 2,508 millions sterling, of which no less than 965 millions belong to the British Empire, representing a proportion of 39 per cent. But there is a considerable amount of capital employed by the native bankers of India, amounting to many millions sterling, of which the sum cannot be precisely stated. On the whole it seems that considerably more than one-third of the banking business of the world is done within the British Empire. The same proportion is shown by the sum total of capital and deposits of the banks. From this it follows that the average per inhabitant in the United Kingdom is 25*l.*, the average for the Continent of Europe being 4*l.*, and that of the United States being 10*l.* The only country to be compared with the United Kingdom is Australia, where the average is 30*l.*

The manufactures of the United Kingdom are valued at 818 millions sterling annually. Those of the Colonies are estimated at 59 millions. The value of the Indian manufactures cannot be stated, but must be large. The significance of this will be understood from the fact that a similar total for the rest of Europe gives 2,600 millions. In general terms it may be stated that British manufactures form one-third of those for all Europe put together. The great competitor is of course the United States, where the value appears to exceed that of the United Kingdom. The American manufactures are indeed wonderful, not only in their present magnitude, but in the rapidity of their progress, and in the prospect of their extension. Still it is difficult to institute a precise comparison, because some items are included in their total which are not reckoned in the United Kingdom.

Another test is that of factory steam power; this power in the world is represented by 7½ millions of horse-power. Of that total, 2¼ millions, or about 30 per cent., are British.

Again, it has been computed that if the main elements of national industry be taken together, namely, commerce, manufactures, mining, agriculture, carrying trade, and banking, the total, 2,000 millions sterling and upwards annually, is about the same for the United Kingdom and the United States.[1] But the United States are advancing the fastest, and are already passing ahead. Their population, however—55 millions of souls—is greater by 19 millions than the British 36 millions. The aggregate of industries shows an average of 51*l.* per head in the United Kingdom, against 42*l.* in the United States. The fact, then, that the United Kingdom, despite disparity of population, is still able to do nearly as much as its giant offspring, affords striking proof of sustained vitality in the mother country.

It is inferrible from this computation that the average of earnings per head in the United Kingdom is 35*l.* 4*s.*, and exceeds that in the United States (27*l.* 4*s.*) and that in Canada (26*l.* 18*s.*) But it is actually exceeded by the average in Australia, which reaches apparently the amount of 43*l.* 4*s.* per head, and is the highest in the world. Still the rate of earnings in the new countries founded by the Anglo-Saxon race approximates to that of the mother land, but the average rate for the Continent of Europe is only 18*l.* 1*s.* In other words, the British rate is more than double. France is the only large European country which at all approaches the United Kingdom in this respect, and together with France may be classed the little countries of Belgium, Holland, and Denmark.

It follows from these facts that the wealth of the United Kingdom in land, cattle, railways, and public works, houses and furniture, merchandise, bullion, shipping, and sundries, valued at 8,720 millions sterling, exceeds that of any European State, and is just double that of Russia. But it is exceeded by the corresponding figure for the United States, namely, 9,495 millions sterling.[2]

For the British Empire, however, must be added 1,240 millions for Canada and Australia, precisely computed on similar terms; and at least 2,500 millions for India, and other dependencies which cannot be precisely computed, and which may be below the reality. Thus the wealth of the British Empire apparently stands at the truly grand total of 12,460 millions sterling; which justifies the old expression that this empire is the richest State on the face of the earth.

[1] See Mulhall's *Balance Sheet of the World*, and *Dictionary of Statistics*. These figures have been largely adopted in the American Census Report of 1880.

[2] See *Contemporary Review*, December 1881, and *British Association Report*, 1883, p. 624. This figure is the most recent, but the amount has sometimes been put as high as 10,000 millions.

But the preponderance in this respect is not nearly so great as might be expected from the numbers of the population. The cause is this, that in one large section, India, the earnings and the value of labour are very much less than in Europe and North America.

The 8,720 millions of British wealth represent a sum seven times the annual income, namely, 1,247 millions, which seems to be a fair calculation. According to this the British people earn 14 per cent. on their capital, which rate is about the same as that of the United States. It exceeds the corresponding ratio on the Continent of Europe. But it is considerably surpassed by the ratios in Canada and Australia—18 and 22 per cent. respectively.

The construction of public works is a test of national progress; those works which may here be selected for mention are railways, electric telegraphs, and canals.

For the British Empire there are 38,000 miles of railway open, of which 18,000 miles are in the United Kingdom, and 20,000 miles in India and the Colonies. For the area and population of the empire this figure is not remarkable, inasmuch as in the world there are about 260,000 miles, of which the British Empire has only one-sixth. It is an astonishing fact that in the United States alone there are nearly 115,000 miles, more than double and nearly three times the mileage of the whole British Empire.

The extent of railways in proportion to population is larger in the United Kingdom than in any other part of Europe, but is much smaller than in the Colonies and in the United States. While there are 520 miles to every million of inhabitants in the United Kingdom, there are 1,920 in Australia, and 1,780 in Canada; but even the colonial proportion is overtopped in the United States, where the corresponding number is 2,106. But if the test of the value of railways be the amount of work done by them in proportion to their mileage, then in this respect no railways in the world equal the British. The average earnings per mile of a railway in the United States is 1,440*l.* In India the average of earnings (1,330*l.*) is about the same; in Australia (1,075*l.*) it is lower; and in Canada (790*l.*) it is still less. But in the United Kingdom it is more than double, being 3,800*l.* In the United Kingdom 18,000 miles of railway earn 69 millions sterling annually; in the United States 100,000 miles of railway earn only 136 millions. The general maximum speed of trains in the United Kingdom and the total mileage run by express trains are considerably greater in the United Kingdom than in any other country.

It has been computed, by adding together the number of passengers and of tons carried, that 46 per cent. of the railway traffic of the world is done by the railways of the British Empire. In abatement of this, however, it should be added that the distances run in the United Kingdom are less than on the Continent of Europe, and still less than in the United States.

Regarding electric telegraphs on land there are 86,000 miles in the British Empire, or nearly one-fifth of the sum total for the world. It is remarkable that the telegraphs in Australia—26,000 miles—are exactly equal to those in the United Kingdom. But in illustration of the difference between an old and a new country there are 31 millions of messages yearly in the United Kingdom, and only 5 millions in Australia. In other words, the telegraph does six times as much in the old country as in the new. Similarly in the United States the length of telegraph—121,000 miles—is amazing, but the messages are only 34 millions, just in excess of those in the United Kingdom. In other words, the work is more than four times as heavy in the United Kingdom in comparison with the United States. Besides the land telegraphs, there are submarine cables in the world, with the surprising length of 105,000 miles. Of these the greater part belong to the British Empire.

In regard to canals of navigation, there are about 6,000 miles in the British Empire. The significance of this will be appreciated by recollecting that for the world the total length is set down at 23,000 miles. Thus one-fourth out of the world's total is British. But in these figures there are not included the channels of irrigation in India, of which the length exceeds 20,000 miles. Of this length one-fourth consists of canals remarkable for their size.

After this review of material power, we may summarise the public debt of the British Empire. In this the first item is the regular debt of the Government, amounting to 769 millions sterling for the United Kingdom, and 293 millions for India and the Colonies, in all 1,062 millions. The amount seems enormous, but, happily, we may doubt whether it is excessive for so great an empire as the British. The amount is equal to five times what we have seen to be the annual revenue and receipts. It is computed to represent only 9 per cent. of the capital wealth of the empire.

The interest payable on it amounts to 41 millions, or 20 per cent. on the income of the Government. If the income of the population of the empire be taken into account, and it can hardly be computed at less than 1,700 millions sterling, then this interest on the debt will represent only a minute fraction.

Besides this debt of the Government there are the local and municipal debts, contracted for the sake of material improvement. These debts amount to 153 millions for the United Kingdom, and certain amounts for India, which may bring up the total to 160 millions. To this should be added 90 millions raised on a Government guarantee for some of the railways in India.

Thus we reach a total of 1,312 millions sterling for the public debt, Governmental and Municipal, for the British Empire.

A part of the Government debt raised in India is for State railways and canals, this part amounts to 40 millions sterling.

But in these figures there are not included the 187 millions sterling raised by companies for railways in the United Kingdom.

The subject of crime cannot be treated completely in this summary, but it may be stated that in the empire 675,000 persons are convicted annually of crime, of which number more than nineteen-twentieths pertain to India. This number amounts to two in a thousand of the total population, which represents a moderate proportion.

The total number of persons in the prisons is about 145,000, of which 31,000 belong to the United Kingdom and 103,000 to India. In the former the number represents less than one in a thousand of the population, and in the latter only one in two thousand.

In the United Kingdom it is remarkable that within the last fifteen years, that is between 1868 and 1882, the annual number of convictions in England fell from 15,033 to 11,699, and in Scotland from 2,490 to 1,944, notwithstanding the increase in population, indicating a satisfactory decrease in crime. The number of crimes reported approximates to that of convictions.

Two cognate matters must be mentioned in illustration of the condition of the people, namely, emigration and pauperism.

During the last half century 8½ millions of persons have emigrated from the United Kingdom, representing from 5 to 7 per cent. of the population. Out of this number 3 millions went to the Colonies, and 5½ millions to the United States. But this does not represent the total of arrivals in the Colonies, for during this time 650,000 went there from the Continent of Europe.

There has also been a considerable emigration from India within the last ten years, 190,000 natives having left their country to found new Indias in the tropical regions of the British Empire.

In older countries like the United Kingdom, pauperism is an evil and a sorrow from which younger communities are as yet exempt, and which has never existed in the East. In India there is no poor law, and there are none who come under the technical designation of paupers; the destitute and infirm in that country are relieved by private charity without State intervention. Moreover, the unprecedented measures of relief undertaken by the Government during the recent famines have not at all pauperised the population. Nevertheless, the number of paupers under relief in the United Kingdom must be stated at one million, or rather less than one-thirtieth part of the population. The cost of their maintenance amounts to 10 millions sterling annually, and this notwithstanding the extensive emigration which has just been summarised. But during the last generation the number has fallen from 1⅓ million to 1 million, while the expenditure has risen from 7 to 10 millions. Still, owing to increase of wealth, the burden is computed to have fallen from three pence to two pence in the pound of the national income.

I shall conclude this statistical summary by adverting to a group of subjects into which moral considerations largely enter, namely, thrift and education.

The savings banks in the British Empire have 90 millions sterling of deposits and about $5\frac{1}{2}$ millions of depositors, of which numbers eight-tenths are in the United Kingdom, and the remainder in India and the Colonies. The amount, though absolutely great, is not extraordinary for so wide an empire.[1] The amount of 80 millions for the United Kingdom compares moderately well with the total amount for the Continent of Europe, namely 338 millions, but unfavourably with Germany and with some thrifty little nations like Switzerland or Scandinavia. The comparison is still more unfavourable in respect to the United States, where the savings have risen to the noble sum of 202 millions. On the other hand, the development in the British Empire of friendly societies (including provident building and registered societies) has been wonderful. The registered societies in the United Kingdom are 18,200 in number, have 5,800,000 members, and 56 millions sterling of funds. There are also many unregistered societies, of which the statistics are unknown; the addition of these would, it is believed, bring up the total to 7 millions of members, or one-fifth of the population. In Australia there are 880 such societies, with 55,000 members, and nearly a million sterling of funds. In Canada there are 40 societies with 80,000 members, and more than five millions sterling of funds. The average of funds per member is 9*l.* in the United Kingdom and 13*l.* in Australia, but in Canada it is very high, being 63*l.*

The amount of life-insurance, 423 millions sterling of policies in the United Kingdom, exceeds that of any other country, but hardly exists at all in India. But of fire insurance, the amount in the United Kingdom is not remarkable.

The charitable expenditure in the British Empire can hardly be stated in full, but it is enormous. In the United Kingdom it amounts to more than 10 millions sterling annually, the income equalling this honourable sum. Of this income, about one-fourth is derived from endowments consisting of real and personal property.

The number of indoor patients (irrespective of those who receive outdoor relief) in the charitable hospitals of the Empire is not less than 450,000, of whom 145,000 belong to the United Kingdom, and 270,000 to India. This number is not remarkable in comparison with other nations. The fact is that in the United Kingdom the poor-law organisation provides for many who would otherwise be in hospital.

In regard to the Post Office, the letters posted annually in the world are returned at 5,200 millions; of this total there are 1,500 millions, or 34 per cent., in the British Empire. This is a smaller proportion than might be expected, the cause being that letter-writing is still in its infancy in India. But in the United Kingdom the average of letters per inhabitant is greater than in any other country.

Respecting education, there are 5,250,000 pupils at schools in the United Kingdom, 860,000 in Canada, 611,000 in Australia, and 2,200,000 in India, making up a total of 8,921,000 pupils in the British Empire. The number, though large absolutely, appears very small for so vast a population. The fact is, that in India, although education has made a remarkable progress within the last generation, yet the lee-way to be made up was enormous, owing to the neglect of many centuries, and many children of a school-going age still remain out of school. The number in the United Kingdom compares moderately well with the Continent of Europe, but unfavourably with some of the lesser kingdoms, where the progress is most satisfactory. But the comparison attains special interest when made with the United States, where a truly noble progress is exhibited, and where the number of pupils reaches to 10 millions, the annual expenditure being 17 millions sterling. Doubtless the returns in the United States are more complete for the higher

[1] In some of the Colonies there appears to be some difficulty in discriminating the savings banks depositors from ordinary depositors.

branches of education than in the United Kingdom, but that would not make any considerable difference in the comparison of such high figures as these. Thus the extraordinary fact remains, that in respect of educational statistics the United States are numerically in advance of even the British Empire.

The religious missions to non-Christian nationalities constitute a bright feature in the British Empire. The statistics of the Roman Catholic missions are not fully known, but their operations are very considerable. The income of the various Protestant missionary societies is hardly less than three-quarters of a million sterling annually, and the number of European ordained missionaries maintained by them is about 900. This is exclusive of a considerable number of reverend missionaries employed within the British Empire by societies in the United States. The number of native Christians under their care, together with children at school, cannot be less than a million.

In conclusion, the statistical summary under the three heads, the area of the empire, the inhabitants, and their works, has been presented. From it the following inferences are to be drawn regarding the British Empire:—

The area of the British Empire is enormous, amounting to at least 8½, perhaps even to 10, millions of square miles, or nearly one-fifth of the habitable globe. The lesser part only is cultivated or occupied, some portion being uncultivable; but the cultivable portion ready for cultivation or occupation is vast enough to support an indefinite increase of population.

The great length of coast line, mostly inhabited by a seafaring population, and dotted from point to point with large harbours, offers maritime advantages in an unequalled degree.

The population of the Empire, amounting to 305, perhaps to 315, millions of souls, is vast. Still the imperial area is on the whole but sparsely populated, with an average of only thirty-three persons to the square mile, notwithstanding the mighty aggregate of the people, as the population is most unequally distributed, being extremely dense in some regions.

The lesser proportion of the population belongs to the Caucasian fair, dominant, and Christian race; the majority consists of the coloured Aryan Asiatic race, professing the Hindu and Muhammadan religions. The proportion of the Mongolian Buddhist race and of the aboriginal races is small; while the entire Hindu people, and half the Muhammadan world, are under the British crown.

Although in the United Kingdom the population is largely urban, still in the Empire, as a whole, it is chiefly rural.

The total of yearly revenue and receipts, Governmental and local, amounting to 264 millions sterling, is unequalled, but falls at the moderate rate of £1 [illegible] sterling per head of the total of British subjects.

Of the total sum collected by authority from the people, one-fourth is for local purposes, immediately concerning the rate-payers; three-fourths being for Governmental purposes.

Of the Governmental taxation one-fourth only is direct, such as land and property taxes; and three-fourths indirect, such as customs and excise, which grow by natural increment; but the local taxation is for the most part direct.

The armed forces, by sea and land, though numerically large, show a very moderate ratio to the area and population; the section of the people absorbed in military employ being extremely small, and the military expenditure, compared with the imperial revenue, being the cheapest in the world, with the exception of the United States.

The total of armed forces on land, nearly a million of men, is apparently great, though its unity and organisation are not complete. But the proportion (more than two-thirds of the whole), belonging to the fair or European races, is satisfactory.

By sea the number of ironclad war-vessels ready for action indicates a degree of naval preparedness hardly to be matched by foreign nations.

The total police force of all kinds is very moderate, indicating a peaceful and law-abiding disposition in the people.

The mercantile marine has nearly half of the steam tonnage, of the carrying power, of the port entries, and of the freight earnings of all the nations together, and two-thirds of the shipbuilding.

While the ocean-borne commerce of the United Kingdom is maintained at its maximum, that of India, though large, is relatively low, while that of the Colonies is amazingly high.

About one-third of the world's commerce is contained within the British Empire.

The average of ocean-borne commerce per inhabitant in the United Kingdom is considerably higher than in any other large State of the world, but is exceeded by the average of the busy little kingdoms of Belgium and Holland.

About one-third of the banking business of the world is done within the British Empire, justifying the claim of London to be the first of all banking centres.

The average of annual earnings per inhabitant in the United Kingdom is approached by that of its offspring in America, but is more than double that on the Continent of Europe.

In wealth, consisting of land and cattle, railways and public works, houses and furniture, shipping, merchandise, bullion, and sundries, the British Empire is the wealthiest State on earth, but its preponderance in this respect is not nearly so great as might be expected from the number of its population, because the wealth of India is relatively small.

The ratio of earnings on capital in the United Kingdom equals that of the United States, and exceeds that of the Continent of Europe. But it is surpassed by the ratio of Canada and Australia.

Respecting the aggregate of national industries—agriculture, commerce, banking, manufactures, mining—taken in combination, the United Kingdom is beginning to fall behind the United States, though the British Empire, on the whole, preserves the first place ; but despite disparity of population the mother land still achieves nearly as much as its gigantic offspring, and the energetic genius of the progeny still survives in the parent.

The mileage of railways, on the whole, is not remarkable, being apparently small. But the work done by the railways is exceedingly great, far surpassing relatively that shown by any other nation, and the speed of the trains is generally greater.

The length and size of canals for navigation and for irrigation are unsurpassed.

The decrease of crime and of pauperism is satisfactory in the United Kingdom, while pauperism hardly exists in the other dominions of the Empire, and the charitable funds raised in the United Kingdom are enormous.

The number of patients in the hospitals, though large, is not remarkable relatively to the size of the Empire.

Regarding thrift, the growth of savings banks is but moderately great, being less than in some small European States, like Switzerland and Scandinavia, and much less than in the United States; but the development of Friendly and Provident Societies, and of life insurance, is probably greater than in any other nation.

The sum total of education is not great relatively to the Empire at large, mainly because India has much way to make up, the proportion there being behind that of Europe, and much behind that of the United States; but the results of the Post Office and the electric telegraph indicate an unequalled activity.

The efforts made in the United Kingdom for the support of religious missions to non-Christian nationalities are honourably sustained.

The following Papers were read:—

1. *What makes the Rate of Wages?* *By* E. ATKINSON.

In the consideration of wages, a distinction must be made between the rate of wages which is stated in terms of money and the absolute wages which induce the labourer to do the work; such absolute wages consisting in what the money will buy—food, fuel, shelter, clothing—and the proportion saved for future use. Furthermore, when considering the question of wages, attention needs to be given to the proportion of the population of any given State or nation who depend upon wages—that is to say, the proportion of any given population who are in the position of the employed rather than of the employer. If we consider the annual product of this country as a unit or single subject of distribution, it will be apparent that this product, whatever its value may be, is converted into terms of money by bargain and sale, and is distributed among the people who consume it in greatest measure by way of wages. That is to say, the greater part is consumed by those who work for wages. The annual term fits the case, because the year represents one succession of seasons. A small part of the product of a previous year has been brought over to begin the work of the present year upon, and a small part of the present year's product is carried over to the next year to start the work of that year. Substantially, each year's subsistence depends upon each year's work. The world, and even the most civilised State in the world, is always within less than one year of starvation, never having a full year's product of food on hand at any one time, and so the most civilised nation is always within two or three years of becoming naked. In fact, the entire capital of the richest State—to wit, all the railroads, mills, works, warehouses, dwelling-houses, and goods and wares of every kind in existence—bears a market value not exceeding the value of two, or, at the utmost, of three years' product of the same State. Hence it follows that all profits, all wages, all taxes, are and must be derived from the market value of the annual product. Now the absolute law brought into action by the force of competition is this:—*In proportion to the increase of capital, profits diminish relatively, while wages increase absolutely.* If this principle can be sustained it is a complete answer to all the nonsense which certain American politicians attempt to palm off upon the credulity of well-meaning but uninformed men and women. How can it be sustained? The most complete proof of this law will be found in the table at page 830, in which are given both figures and graphical illustrations of the law.

The table has been constructed from data obtained as follows:—The founders of the cotton manufactories of this country—Messrs. Patrick T. Jackson, Francis C. and John Amory Lowell, Kirk Boott, George W. Lyman, Samuel Batchelder and others—were men of great foresight and business capacity. They proceeded cautiously, both in constructing their factories, in establishing the kind and quality of the goods to be made, and especially in the method of keeping the accounts. Through the kindness of friends, many of the earliest cost-sheets of some of the principal factories have come into the author's hands, from which records he has been able to take the actual days of labour, the sum of money paid and the product, both in quantity and value. To these tables, relating to the earlier years, he has been enabled to add the data of more recent years from personal knowledge in the management of factories and by the kindness of others. From among these various tables he has sorted the facts which are contained in the foregoing statements. They are mainly taken from the records of two factories which have been continuously employed on one fabric. They cannot, however, be imputed to either of the two, and they do not disclose the actual results of the business of either corporation, but they are exactly consistent with the facts, and they show the general result more accurately than if the figures of a single factory had been taken. It was said that by the force of competition profits diminish and wages increase. That is to say, the competition of capital with capital works effectively in reducing the ratio of profit which the capitalist can secure from any given product, while on the other hand the competition of labourer with labourer utterly fails to reduce the rate of wages; but, on the contrary, in the face of such competition, the proportion of product falling to the labourer steadily increases. This seems to be a paradox, but an examination of the tables will show the simple reason. Let the column on page 831, the comparison of 1830 with 1884, be first considered. It required $332,000 in money to construct the mill, with auxiliary buildings and dwelling-houses, of a factory of a little over 8,000 spindles. Such a mill would cost at this time less than one-half as much; but, by taking the history of several separate factories which have never failed and the stock of which has never been reduced, it appears that a sufficient proportion of the earnings has been set aside and expended in the increase of the productive units of the spindle and the loom, to the end that the ratio of dollars has been reduced 75 per cent., or from $40 to $10 per spindle. Each spindle of the greater number has become 22 per cent. more effective. Each spindle and each loom requires less arduous attention. The proportion of operatives per thousand spindles has been reduced 64 per cent., and the work of the lesser number is very much less severe now than the work of each of the larger number was at the beginning. The productive capacity of each of the operatives per day (the day of 1830 having been from 13 to 14 hours and the day of 1884 being from 10 to 11 hours) has increased 214 per cent. A part of the benefit of this vast change has gone to the consumers of the goods. The price of raw cotton happened to be almost exactly the same in 1840 as it was in 1883, and the standard sheeting was sold in 1840 at 9 cents per yard and in 1883 at 7 cents per yard, at which latter price it paid a fair profit. But the less price at which it can be sold to-day pays no profit whatever, the export demand for China having been interrupted by the French war, and the export demand for Africa having been interrupted by various causes.

Now, what has been the course of wages? The wages of the farmers' daughters of New England, to whom it was a profitable opportunity to enter the cotton mill in 1830 and to work there in 1840 from 13 to 14 hours per day, were $164 a year in 1830, $175 a year in 1840, and $190 a year in 1850. In fact, the wages of women were much less than these figures show, as these figures give the average of men, women, and children, including overseers. Good weavers really earned only 48 to 50 cents per day in 1830 to 1840. The proportion of men was much greater and of children much less prior to 1850 than it is now. Contrast these wages with the present. The average earnings of men, women, and children for the shorter hours are now $290 a year. Skilful female weavers earn now more than male overseers and second hands earned in 1830. There is now, 1884, some temporary disturbance, and there may be a temporary reduction in the rate of wages by the piece. But hard times are the best schoolmaster. If the rate of wages is reduced, improvement and invention will be applied to the machinery, and in spite of present depression, the sum of wages for the year 1885, even at a less rate by the piece, will be higher than in the year 1884. In witness of this, turn to the column on page 830, and see how the law of increasing wages has been progressing from 1830 to 1884, subject to the temporary aberration caused by the use of paper money, when wages apparently increased, but the cost of living increased a great deal more. Now, what is the effect upon profits? Assuming that 10 per cent. constituted such a rate of profit in 1830 as to have induced the construction of a factory, and that 10 per cent. would be a high rate of profit at the present time; also bearing in mind that, so far as the author knows and believes, there is no cotton factory in New England which has paid 10 per cent. per annum, on the average, upon its original capital for a period of fifty years—we find that it required 13 per cent. of the gross sales to be set aside in the year 1840, at the rate of 118 cents per yard of cloth, in order to secure to capital 10 per cent. upon the investment. I will not go back to the earlier date of 1830, when it required a very much larger share of product to compensate capital at the rate of 10 per cent. At the present time, 6 per cent., or four-tenths of a cent per yard, set aside from the sales annually, will yield 10 per cent. upon the capital.

There is scarcely an article which could serve so well as a guide and standard for this investigation as a standard sheeting. It has been made in the same way, of substantially the same weight, from the same stock, from the beginning to the end, and the accounts have been kept in the same manner, according to the exact methods of account established by the careful men under whose supervision the mills were constructed. On this showing it is absolutely demonstrated that all the improvements and inventions of the last fifty years have gone to the benefit of the consumers of the goods and the operatives in the factory,—in largest measure to the latter,—while the share which has fallen to capital has diminished in forty years from 14 per cent. of the gross product to 6 per cent. or less.

Now, let the principle which is sustained by these facts be applied to the general subject of wages. It will be admitted by everyone that if there is any branch of industry, either in agriculture, manufactures, mining, or mechanical work, which offers a fair expectation of 10 per cent. on the investment, unless it be of some extra hazardous or dangerous kind, into that branch of work capital will flow in ample measure. Now, as a rule, in all the diverse arts and manufactures to which machinery is applied, taken as a whole, the gross value of the annual product is twice that of the capital invested. This is proved not only by the figures of the United States census, but by the extremely close figures of the Massachusetts census of 1875. Now, if capital will rush into any branch of industry in which it can secure 10 per cent., and if 5 per cent. of the product will yield 10 per cent. upon the capital, it follows of necessity that the other 95 per cent. of the product must go to the labourers who do the work, because it cannot go anywhere else. There are only two classes to whom the proceeds of sale can be devoted after the taxes are paid, and those two classes are the capitalists and the labourers. If five parts of the product satisfy the capitalist so fully that new capital rushes in to compete for the opportunity of doing the work, then the other 95 parts must go to the labourer, or to the distributor. In my treatise, however, in order to be perfectly safe, I have assumed that ten parts of the annual product fall to the capitalist and only ninety parts to the labourer, or to the distributor. Now, it appears that in proportion to the increase of capital, the work of the labourer is rendered more effective, and his wages rise continuously, because he obtains a constantly increasing proportion of an increasing product. The more effective the capital, the less the number of persons needed for the work, and the larger the product. It therefore follows that any interference or retardation in the accumulation of capital, while it hurts the capitalist, harms the labourer a great deal more. It is therefore of the utmost importance to the labourer that justice should be done to capital—no more, no less. If labourers receive 90 to 95 parts of all there is produced in one year, and cannot have any more without interfering with the accumulation of capital and thereby diminishing the product of next year, they get all they can have, whether it be much or little, and their wages cannot be increased except by an increase of the general product. The general product can only be increased by the co-operation of more adequate capital with more skilful labour. It certainly cannot be increased by legislation, because legislation produces nothing. It can check production and reduce wages materially, and meddlesome legislation generally works in that way.

Now, then, what are the facts in respect of wages in America? The rate of wages is much higher in money than in any other country, and if subsistence be considered as a whole, the purchasing power of wages is greater for each dollar than in any other country. According to Mr. Wright's recent most valuable investigations, a dollar will buy less shelter and somewhat less clothing, but more food, than it will inEngland, and a dollar will buy more in England than it will anywhere on the continent of Europe. What makes the rate of wages in this country, and why are they higher here than elsewhere? It is for this reason: by the co-operation of capital and labour, intelligently applied to the greatest natural resources, the result of each year's work is a larger product of grain, cotton, machinery, timber, fabrics and wares, in ratio to the number of labourers employed, than can be attained anywhere else, and when the 90 or 95 per cent. of this huge project is converted into terms of money by sale, the resulting sum of money leaves for each person employed a larger amount than can be attained by the working people in any other country. One of the great reasons for this—perhaps the paramount reason —is that the United States are free from the burdens of passive war since slavery was abolished; free from the blood-tax of a standing army, which takes at least ten parts in every one hundred produced on the continent of Europe; free from the burden of the artificial system of land tenure in Great Britain, under which the mass of the people has been deprived of land; free from the equally artificial system of the compulsory sub-division of land which controls most of the continental nations, under which allotments have become so small that effective machinery cannot be applied to it, whence it follows that the minimum of product results from the maximum of arduous labour; we are also free from the restrictions of caste and privilege. It is, then, beyond doubt, a fact, that even if their wages are low at the present time, they are yet progressively increasing, and have increased steadily and regularly every year for the last fifty years, subject only to the inevitable chances and changes of short crops and commercial crises. Whatever the rate of wages may be, the sum of the wages or earnings of those who perform the work of production and distribution is 90 to 95 parts in 100 of all there is produced.

The author was unable to give facts as to the diminishing profits in other arts than the one he has named, but the increase of wages is well proved by the statistics of the census of Massachusetts and the census of the United States. Two examples may be given in respect to two classes of work which requires the services of a high class of mechanics. In one large piano-factory, the rate of wages of five classes of skilled workmen in 1843 was $562 for the year; in 1880, for the same work, $824 for the year. In another large piano-factory, the wages of twelve classes of skilled workmen have been compiled, and the progress in rate has been as follows: 1853, $11.32 per week, gold; 1860, $12.33, gold; 1866, $14.75 per week, currency; 1872, $18 per week, currency; 1878, $14.66 per week, substantially in gold; 1880, $17.50 per week. At the present time wages are as high in gold as they were in 1872 in currency. In one large establishment making table-cutlery, eight classes of workmen averaged, in 1859, $1.50 per day in gold. The same eight classes in 1880 averaged $2.15 per day in gold. In another large establishment making edge tools, ten classes of workmen averaged in 1850, $1.60 per day; in 1880, $2.26 per day. The author had carefully chosen processes of industry, to wit: standard cotton sheeting, pianos, table-cutlery and edged tools, which have been affected in the least measure by the changes in the duties on imports. With the exception of pianos the other three subjects of investigation depend measurably upon the export trade, as well as upon the domestic consumption for the establishment of the rate of wages. This selection has been made in order that the subject might not be confused by considerations relating to the tariff. Finally, it appears that in the census for the year 1880 the population of the United States numbered a little over 50,000,000. Of this population (disregarding fractions), 17,400,000, in round figures, were found to be engaged in some sort of gainful occupation; the rest consisted of women who did the work of families, of retired persons, and of children. Of this number, substantially 150,000 were employed in the service of the Government, leaving 17,250,000 producers, who, by exchanging products with others, also obtained the means of living, and thereby became consumers. Of this number the census discloses the fact that 1,050,000 were employed in what may be called mental rather than manual work. They consisted of clergymen, lawyers, teachers, artists, chemists, engineers, officials of railroads, banks, and insurance companies, officials of manufacturing and other corporations, merchants, traders, and dealers. In this list capitalists living wholly upon the income of capital are not included. How many the capitalists number the census does not disclose, but they are relatively very few, and their possessions represent but a relatively small part of the total wealth of the country, this wealth being more widely diffused, and enjoyed by a greater number of persons, than in any other country in the world. Deducting 1,050,000 of those engaged in gainful operations, we have the remainder 16,200,000 who constitute the actual working class. Seven millions of these were farmers and farm-labourers, the rest artisans, mechanics, clerks, salesmen and saleswomen, labourers, factory-operatives, domestic servants, and other wage-earners. The proportion of employed to employers, aside from agriculture, is at least 15 to 1. The rate of wages, which measures their share of the annual products, is therefore the paramount social question of the hour. If it can be measured, and if it can be found in the aggregate their wages as a whole constitute from 90 to 95 per cent.

of all that is produced, then all contention between labour and capital may well be laid aside. It is, of course, a matter of immense difficulty to make such computation. By various ways, each proving the other, which cannot be stated in the space at his disposal, the author thinks it may be considered substantially proved that the value of the annual product of the census year was the maximum $10,000,000,000. In this computation, $1,000,000,000 is included as the value of the domestic consumption on farms by farmers and labourers which never enters into the commercial statements, $9,000,000,000 representing that part of the product which was bought, sold, and distributed. Five per cent., or $450,000,000, is set aside from this sum to represent the profits of capitalists as a distinct class. We will set aside $450,000,000 as the maximum estimate of the small savings of industrious people, making a total set aside for the maintenance and increase of the capital of the United States of $900,000,000. He has assumed 10 per cent. of a commercial product of $9,000,000,000 as the maximum national profit which can be set aside for the maintenance or increase of capital. In the census year this would have been substantially at the rate of $18 per head of the population. If we apply this computation to the average population of the last thirty years, no sum of accumulated capital can be found in the United States corresponding to $18 per head. It is a maximum estimate rather than a minimum. The remainder constitutes the earnings of all who are engaged in gainful occupations, amounting to $8,100,000,000.

Now comes the main difficulty of ascertaining how the sum was subdivided. By various methods the author has reached the conclusion that the average of each person engaged in the mental or administrative part of the work would amount to between $1,000 and $1,100, and that the next remainder to be sub-divided among artisans, mechanics, farm-labourers, domestic servants and the like would yield to each from $400 to $450. Having come to this conclusion by way of an estimate of the value of the total product, the proof in detail became necessary. The first standard is taken from the railroad. In the year 1880, one man out of every ten employed in any kind of gainful occupation aside from agriculture was employed in the construction or operation of a railroad. In the operation of a railroad every class is represented. The returns of a railroad are absolute, being taken from the books of the last previous financial year. From these returns it appears that 418,957 men were employed upon the railroads of the United States in their operation, not including construction. The sum of their wages was $195,350,000, averaging to each person for the year $466. On subdividing this, it appeared that all those who were engaged in the administration, or as general officers and clerks, earned $1,015 each, and that those who were engaged in the executive work, being 95 per cent. of the total number, earned $450 each. It will be borne in mind that these are men, and that in the remainder of the gainful occupations the earnings of two and one-half millions of women and children are included at less rates than the rates earned by men. By setting aside $1,050 to each person of the 1,050,000 engaged in the general work of administration, there remains for the rest, numbering 16,200,000, the sum of $7,000,000,000 to be divided, which gives each one $432. The total of all national, state, and town taxation was over $700,000,000 in 1880, or 8 per cent. on the commercial products. Deduct in proportion, and the net income of each workman is $400. Each one of these persons to whom $400 a year is assigned on the average as the rate of his earnings sustains substantially two others. It therefore follows that if these wages are high as compared with other countries, as they are, or low as compared with what it would be desirable they should be, they yet represent all there is produced that can be distributed among those who do the work. They represent an increasing share of an increasing product which, under the law I have propounded, constantly falls to the labourer as years go on. This average is fully sustained by all the special reports of the census of the United States in which the wages or earnings of persons employed in all the different arts and manufactures are given, after adding to the apparent sums disclosed by the census such sum as seems fit in each case to carry the term of the census employment up to that of a full year.

What the author has undertaken to prove, therefore, is that the law of competition carries to the capitalist a constantly diminishing ratio of profit from each year's product, and to the labourer a constantly increasing share. This rule was formulated by Bastiat many years ago in the following terms: 'In proportion to the increase of capital, the absolute share of product falling to capital may be augmented, but the relative share is diminished, while, on the other hand, the share of the labourer is increased both absolutely and relatively.' All the facts which I have been able to consider sustain the rule. The recent investigation made in England by Robert Giffen, of which I was informed about a year ago on my visit to that country, disclose the same sequences of diminishing rates of profit and increasing rates of wages, accompanied by increased purchasing power for every unit of wages, for the last fifty years of English history.

If, then, our national wealth has increased $1,500,000,000 a year for twenty years, including the rise in the value of land, what does it come to by the unit of the individual? One-half at least is the increased value of land, the other half consists in added wealth, or $750,000,000 a year; but this great sum if equally distributed would give less than $20 *a year to each person.* What proportion of the people of this country have saved $20 each year, or $60 a year to each workman for twenty years? The average tax upon each person—combining national, state, and municipal taxation—has been very nearly, if not quite, $20 *per head.*

What proportion of this tax does each man, woman, and child contribute? Have these taxes been paid by the same persons who have received the wealth? These are grave questions which working men and women may fairly ask. The question which each man who earns his daily bread by means of his daily work needs to have answered more than any other is this—'How soon and in what way am I to be relieved of the heavy, and in a large measure useless, burthen of taxation which finds me poor, keeps me poor, and leaves me poor; which takes from me all hope of saving, and deprives me of a part of the comforts and even of the necessaries of life?'

There is no mercy in these statistics. By so much as some working men and women earn more than $400 a year must some other working men and women earn less, if that is the measure of all there is; and on what each $400 will buy three persons must be sustained (to be exact, 29-10ths). Shelter, subsistence, and clothing for each person must be provided out of what £146 a year, or *forty cents* per day, will pay for. It is appalling, but it is true. In order to increase this rate but 5 cents a day at the present time, one thousand million dollars' worth of increased product must be made, and a market must be found for the increase.

Such a sum is twice the value of our wheat crop, ten times the value of our production of pig iron or of our wool clip, three times the value of our cotton crop, nearly twice the value of all our textile fabrics. To put it another way: in order that each wage-earner may get 15 cents a day higher wages, and that each person may have for consumption what 5 cents a day more will buy, more than he has now—we must add to our present product the equivalent of our present wheat crop, of our production of pig iron, and the value of all our textiles—a sum-total of $1,050,000,000. Ten hundred and fifty million dollars a year will give 5 cents a day to 58,000,000 persons, and no more.

Yet at this rate of 40 cents a day on the average, the people of the United States are the most prosperous in the world, because 40 cents a day will buy more than it will in any other country.

It is *inequality* in the wages of those who do the work of the world which calls for the attention both of the student and of the statesman, and inequality in what the wages will buy. Wholesale work, as it may be called, both in production and distribution, is done at the smallest fraction of charge—at low-labour cost, but at high rates of wages to skilled workmen. It is the common labourer who suffers most, and it is retail distribution on which the highest charge is suffered.

(See Tables on following pages.)

THE LAW OF COMPETITION: IN ANY GIVEN PRODUCT, PROFITS DIMINISH, WAGES INCREASE.

The following deductions have been made from the accounts of two New England Cotton Factories, both constructed prior to 1830, and operated successfully and profitably since that date, mainly on standard sheetings and shirtings—No. 14 yarn. The figures given, from 1840 to 1883 inclusive, are absolute, being taken from the official accounts of mills, of which the sole product has been a 36-inch standard sheeting. The figures of 1830 are deducted from a comparison of the data of two mills. The figures of 1884 are deducted from nine months' work in 1883–4.

WAGES PER OPERATIVE PER YEAR.

1830	164 gold
1840	175 gold
1850	190 gold
1860	197 gold
1870	275 cur.
1870	240 gold
1880	259 gold
1883	287 gold
1884	290 gold

PROFIT PER YARD NECESSARY TO BE SET ASIDE IN ORDER TO PAY 10 PER CENT. ON CAPITAL USED.

1830	2.40c. gold
1840	1.181 gold
1850	1.110 gold
1860	.688 gold
1870	.760 cur.
1870	.660 gold
1880	.481 gold
1883	.434 gold
1884	.408 gold

YARDS PER OPERATIVE PER YEAR.

1830	4,321
1840	9,607
1850	12,164
1860	21,760
1870	19,293
1880	28,000
1883	26,641
1884	28,032

Changes in the machinery affected production.

COST OF LABOUR PER YARD.

1830	1.900 gold
1840	1.832 gold
1850	1.556 gold
1860	.905 gold
1870	1.425 cur.
1870	1.240 gold
1880	.930 gold
1883	1.080 gold
1884	1.070 gold

COMPARISON OF 1830 WITH 1884.

In this comparison the statements are based in part upon the figures of each mill. Both appear to have cost about $40 per spindle, including dwellings for operatives. More than one kind of goods were made in each for a time, but the figures have been adjusted to standard sheetings, an average having been computed by the yard and pound.

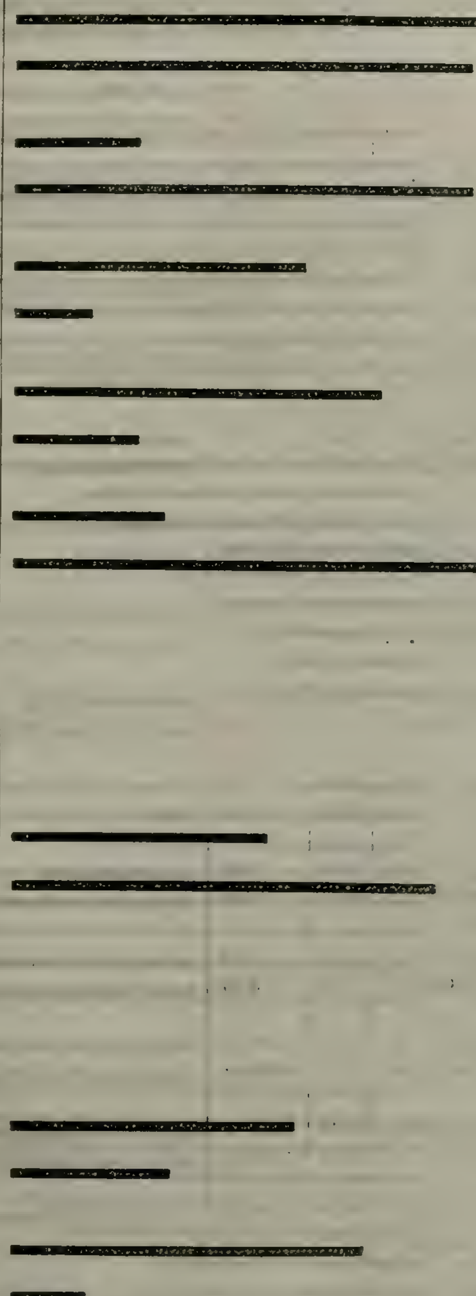
Fixed capital	1830	$332,000	Decrease,
	1884	$310,000	3.7 per cent.
Spindles	1830	8,192	Increase,
	1884	30,824	276 per cent.
Fixed capital per spindle .	1830	$40.50	Decrease,
	1884	$10.07	75 per cent.
Operatives per 1000 spindles	1830	49	Decrease,
	1884	17 2-10	64 per cent.
Pounds per operative per	1830	9.94	Increase,
day	1884	31.22	214 per cent.

The hours of labour in most of the factories in 1830 were 14 per day.

Wages per operative per	1830	$164	Increase,
year	1884	$290	77 per cent.

The wages per hour in 1884 are more than double those of 1830.

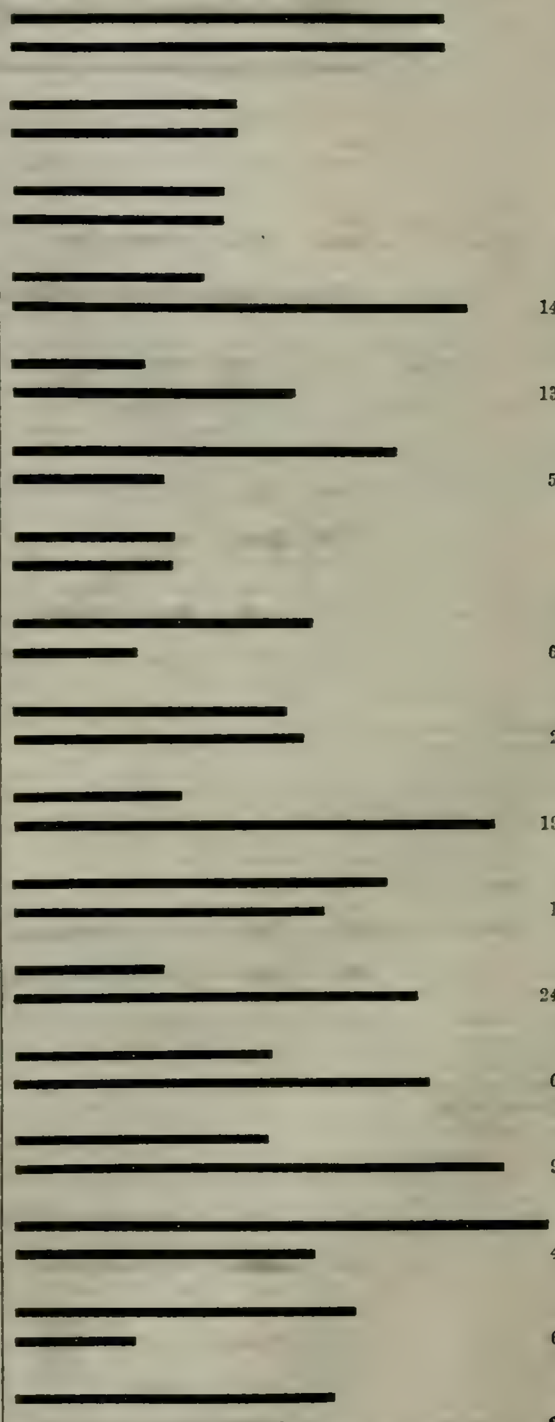
Wages per yard	1830	1.90 cts.	Decrease,
	1884	1.07 cts.	44 per cent.
Profit per yard at 10 per	1830	2.40 cts.	Decrease,
cent. on capital	1884	.41 cts.	83 per cent.



COMPARISON OF 1840 WITH 1883-4.

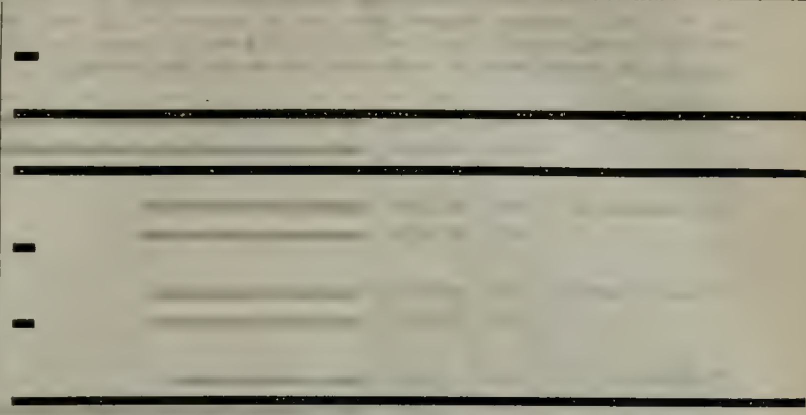
This comparison will not show the full reduction in the cost of labour per yard which may be expected in 1884–5, because changes have been in progress which, when completed, will increase the capacity of the mill about 15 per cent., and it is a well-understood rule that, while such changes are being made, the current work of production is done at a disadvantage.

I.—Capital . . .	1840	$600,000	
	1883	$600,000	Same.
II.—Fixed capital .	1840	$310,000	
	1883	$310,000	Same.
III.—Active capital .	1840	$290,000	
	1883	$290,000	Same.
IV.—Spindles . . .	1840	12,500	Increase,
	1883	30,824	146 per cent.
V.—Looms . . .	1840	425	Increase.
	1883	1,000	135 per cent.
VI.—Fixed capital	1840	$23.20	Decrease,
per spindle .	1883	$10.06	57 per cent.
VII.—No. of opera-	1840	530	
tives emp. .	1883	527	Same.
VIII.—Operatives per	1840	42 4-10	Decrease,
1,000 spindles	1883	17 20-100	60 per cent.
IX.—Lbs. per spindle	1840	0.456	Increase,
per day . .	1883	0.556	22 per cent.
X.—Lbs. per opera-	1840	10 76-100	Increase,
tive per day .	1883	31 20-100	190 per cent.
XI.—Hours work	1840	+13	Decrease,
per day . .	1883	11	15 per cent.
XII.—Lbs. per opera-	1840	0.83	Increase,
tive per hour	1883	2.83	240 per cent.
XIII.—Wages per op-	1840	$175	Increase,
erative pr. yr.	1883	$287	64 per cent.
XIV.—Wages per op-	1840	4.49 cts.	Increase,
erative pr. hr.	1883	8.80 cts.	96 per cent.
XV.—Wages per yd. .	1840	1.82 cts.	Decrease,
	1883	1.08 cts.	41 per cent.
XVI.—Profit per yd.	1840	1.18 cts.	Decrease.
10 % on capital .	1883	0.43 cts.	63 per cent.
XVII.—Price of goods,	1840	9.04 cts.	Decrease,
cost cotton same	1883	7.04 cts.	22 per cent.



In the mountain section of the southern United States the people are still clad in homespun fabric Five women—two carders, two spinsters, and one weaver—can produce eight yards per day.

Product of 5 persons 1 year in No. Carolina . .	2,400 yds.
Product of 5 persons in New England . . .	140,000 yds.
Wages in New England at 1 08-100 cts. ℔ yd.	$287.00
Wages as they would be in N. Carolina at 1 08-100 cts. ℔ yd.	$5.19
Cost ℔ yard in N. England at $287 ℔ yr. each operative	1.08 cts.
Cost in No. Carolina at $287 ℔ yr. each operative	58.49 cts.



The rule of diminishing rates of profit and increasing rate of wages, of necessity ensuing from the progress of invention, is fully sustained by these tables. As the capital is increased both in its quantity and in its effectiveness, the absolute share of product falling to capital is increased, but the relative share is diminished. On the other hand, the share of the labourer is increased, both absolutely and relatively. Labour takes, of necessity, a constantly increasing proportion of an increasing product. In this example, the wages of the operatives have increased since 1840, 64 per cent. per day and 96 per cent. per hour; since 1830, 77 per cent. per day and + 100 per cent. per hour. High wages in money have ensued as the necessary result of the low cost of labour.

It will be observed that in 1840 the price of standard sheetings being 9 cents a yard it required 1.18 cents to be set aside for profits, or 13 per cent. of the price, in order to pay 10 per cent. upon the capital. Next it required 1.83 cents to be set aside, being 20 per cent. of the whole price to pay wages at the average rate of only $175 a year to each operative. In 1884, the price being 7 cents a yard, it required less than 6 per cent. of the gross sales, 0·40 cents a yard, to be set aside in order to pay 10 per cent. upon the capital, while 1.07 cents being set aside as the share of labour, or a fraction over 15 per cent. of the gross sales, yielded to the operative $290 in gold. The goods cannot now be sold at 7 cents, and there is little or no profit for the time being. But while 10 per cent. was a moderate rate of profit in 1840, it is an excessive rate in 1884. The business would extend with great rapidity if there were a positive assurance of 6 per cent. upon the capital or a quarter of a cent a yard and less than 4½ per cent. of the gross amount of sales.

But it may be said, having assigned 0.40 cents to profits, and 1.07 cents to labour out of 7 cents a yard gross value, there remains 5½ cents a yard to be accounted for. This of course represents the money-cost of cotton, fuel, starch, oil, supplies, taxes, cost of administration, transportation of the goods to market, and the cost of selling them at wholesale.

Does this all go to labour, or is there also a profit to be set aside on these elements?

Our space would not suffice to treat each one of these subjects, but it may be said, First, the cotton is substantially all labour; there is no large margin of profit at the present time in raising cotton, which is mostly produced by small farmers. Second, the other items constituting the materials form a very small part of the total cost, and are subjected to profits in small measure only in respect to fuel and oil.

The cost of transportation yields to the railroads less than an average of 5 per cent. of the capital invested, and cotton fabrics pay but a small fraction of their value even for very long distances. The cost of administration constitutes a very small part of the cost of the goods, and in the general treatise of wages belongs to a class by itself rather than to be considered as profits. The charge for selling the goods at wholesale does not exceed 1 per cent. to 1¼ per cent., and a large part of this is distributed among the clerks and salesmen who do the work.

If the subject is analysed,—first, as a whole, and, second, in each department,—it will appear that at the present time the proportion of profit which can be set aside from the sale of coarse cotton goods sufficient to cover profits in all the various departments of the work, is less than 10 per cent. of the wholesale market value of the product, and 90 per cent. is the absolute share of the labourers who do the work both in respect to materials used and to the finished product.

It is also necessary to remember in respect to the cotton factory that the value or proportion of capital to a given product is greater than in almost any other branch of industry. The proportion of capital to product being $1 of capital to each $1 or $1.50 of product, according to the weight of the fabric and the quantity of cotton used. In the boot and shoe factory, on the other hand, the ratio of capital to product is about $1 to $3; therefore in the boot and shoe business a much less proportion of the gross sale needs to be set aside as profit on the business, to induce its being established.

On the whole, so far as the manufacturers of New England are concerned, the average of capital to the gross value of the products is one dollar capital to two dollars product; therefore 3 per cent. of the gross sales set aside as profit will yield 6 per cent. per annum upon the capital invested in the buildings and machinery, which are applied to the conversion of raw or half-manufactured material into finished forms ready for final consumption.

2. *The Post Office Savings Bank System of Canada.* By J. CUNNINGHAM STEWART.

The history of Post Office Savings Banks in a new country being wanting in what—as applied to the Post Office Savings Bank system of Great Britain—may be termed the 'pre-historic element,' the records of the Post Office Savings Bank in Canada are without those earlier annals which are so attractive in the study of the parent system. They become a somewhat bald statement of figures, and of results achieved since the year 1868 when, public attention having been directed to the success of the Post Office Savings Banks in England, a scheme, in its main features a reflection of the British system, received legislative sanction in Canada.

From 1868 to 1878 the progress of the Post Office Savings Banks in Canada was slow. Since 1878, and up to the present time (July 1884), the increase has been rapid. There are now 343 Post Offices authorised to receive deposits, with 66,682 depositors' accounts in the ledgers of the Bank, and the balance standing to their credit is $13,245,552, an average of $198.63 (say 40*l.* sterling) in the name of each depositor. There have been in all 852,143 deposits and 410,259 withdrawals; 223,834 persons have opened accounts, of which 157,152 were subsequently closed.

The deposits were held among the following classes, arranged in the order of the most numerous and wealthy; viz., *Farmers, Married women, Single women, Mechanics, Trustees and minors, Labourers, Widows, Clerks, Tradesmen, Miscellaneous.* Farmers are one-fifth of the whole numerically, and own one-third of the entire deposits.

The proportion of depositors to population is:—

In Ontario 1 to 34; in Quebec 1 to 156.

In measuring the success of the Post Office Savings Bank by that of its prototype, the different conditions of the two peoples—the old nation and the young—must be borne in mind. In the older country social and class lines are strongly marked, and trades and callings are pursued in such fixed grooves as to narrow the outlet for individual energy. In the new dominion, on the other hand, there are a restlessness and a movement which are destructive of artificial barriers. There are openings which attract the energetic and ambitious, and to every man are there possibilities in the acquisition of real property, sufficient to absorb all surplus wages. The wonder, on examination, is that the Canadian Postal Savings Banks have attained measurable success at all.

In addition to the $13,000,000 accumulated in the Post Office Savings Bank, the Chartered Banks and their 222 agencies have deposits amounting to $87,000,000, although what proportion of this is in the *Savings Bank* departments of the Banks, does not appear. Then there are ninety-three Building and Loan Societies receiving deposits at interest, whose liabilities to upwards of 30,000 depositors, according to latest returns, were $15,000,000. The old-established Savings Banks in the cities of Montreal and Quebec have, in round figures, $9,250,000 in the names of 42,297 depositors.

The plan of collecting the *minimum* deposits (one dollar) by means of postage stamps affixed to a form provided for the purpose, has not commended itself to the Canadian authorities. Neither in this way, nor in the issue of pamphlets on thrift, has the department attempted a paternal treatment of the people, which would hardly be understood in Canada.

The Post Office Savings Banks in Canada are maintained at a cost to the country of $4\frac{1}{10}$ per cent. on the balance due to depositors. Of this charge the interest allowed to depositors represents about 3·85 per cent., and the expenses of management 0·25 per cent. The declared rate of interest is 4 per cent., no interest being allowed for any period less than one calendar month.

The absence of loss is noticeable. Fourteen out of the sixteen years of the Savings Bank's history have been absolutely free from casualty.

The mode of computing interest, also the form of Depositor's Ledger Account, are noticeable features in the Canadian system. Interest is computed prospectively, a decimal system and a 4 per cent. rate rendering the computation of interest by this method remarkably simple. The plan of computing interest prospectively, now followed in the Savings Bank departments of all Canadian Banks, was first introduced in Canada by the Post Office Savings Bank.

The form of Ledger Account is remarkable principally from its dispensing with the process of ruling off, and adding the debtor and creditor sides at the close of each year. The saving of labour effected permits the annual task of adding the interest in depositors' accounts and of 'balancing' the ledgers being carried on with extreme rapidity. The interest was added to the 66,682 accounts open on June 30, 1884, and the accounts themselves balanced in three days—*i.e.*, on the first three days in July—without interruption to the regular daily work on those days.

In the Canadian system such is the daily proof upon the accuracy of the ledger entries, that no further or periodical check is employed, except that annual verification which the abstracts from the ledgers made in July of each year afford.

The relation between labour and clerical force bears a striking analogy to the conditions in the British Savings Bank department. In Canada there is one clerk to each 3,200 depositors' accounts; in England one to each 3,100. In Canada there is one clerk to each 7,900 transactions; in England one to each 8,770 transactions. These figures bear perhaps the best testimony to the good organisation of the Canadian service, the British Post Office Savings Bank being universally looked upon as a model of successful administration.

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3. *Dominion Savings Banks.* *By* T. D. Tims.

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4. *Loans and Savings Companies.* *By* W. A. Douglas.

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5. *Irish Emigration.* *By* S. Tuke.

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6. *The British Empire in North America and in Australasia.* *By* W. Westgarth.

The author, one of the earlier colonists of the still youthful Victoria, first President of the Melbourne Chamber of Commerce, and the senior member for Melbourne in the first Legislature of the colony, claimed full acquaintance with one principal part of his subject, Australasia, and, with regard to Canada, he had visited it thirty years before, and has now returned to witness with due interest its great progress. He opened his subject by pointing to three principal colonial territories of the Empire; namely, British North America, Australasia, and South Africa. He was to deal only with the two first, which, however, were by far the more important, and gave promise of being, in the future, even the greatest of the entire Empire. He had spent seventeen years of his earlier life in Australia, and was now, as he said, revisiting Canada. The Canadian Dominion included, in its recent auspicious federation, all of British America north of the United States, with the sole exception of the still separate colony of Newfoundland, which, however, it can hardly be imagined, is to continue permanently thus outside. Australasia embraces, in the colonial sense, the Australian main, Tasmania, New Zealand, and Fiji. In the geographical sense it would include also New Caledonia, belonging to France, the Loyalties and New Hebrides groups, and, above all, the great territory of New Guinea, with the smaller islands on its eastern flank. South-Eastern New Guinea, unclaimed by the Dutch, is at length to be added to the British Empire, after some protracted discussion between the Colonial Office and the Australasian colonies. These colonies are not yet federated like the Dominion, but action has already been taken in that direction. The author next alluded to the accelerative rate of all modern progress, and forecasted the great advance and the vast and prosperous interests which the Dominion and Australasia would present even within fifty or a hundred years hence. He remarked, in favour of the Canadian future, that the cooler and more bracing climates brought eventually the highest and most vigorous civilisation. This had been the law of human progress in the past, as man, by his invention and adaptability had gradually altered and improved the original rudeness of nature. But Australasia, with her more genial clime, went the fastest ahead at first. Her progress had, in some respects, been even greater than that of Canada. Her commerce was 595,000,000 dollars yearly, against that of Canada's 221,000,000 dollars. Her public revenues were 110,000,000 dollars, against Canada's 36,500,000 dollars. But he greatly qualified Australasia's larger figures by certain explanations. Her public debt, too, in her go-ahead way, was also very much greater. Although much younger, and with as yet a third less of population, her railways were already 7,000 miles, as against Canada's 9,000. She had two cities, Sydney and Melbourne, already larger than Montreal, which had 190,000, against 230,000 in Sydney and upwards of 300,000 in Melbourne. On the other hand, the Dominion was far ahead in her great shipping interest, and stood, in fact, fourth amongst the maritime states of the world. He instituted a special comparison in the respective products and exports. While those of Canada were chiefly timber, breadstuffs, and animals, including large proceeds of the fisheries, those of Australasia were mainly wool and gold. The wool increased in an almost incredible proportion. The gold, owing to its large quantity at first—for some years ten to twelve millions sterling yearly in Victoria alone, besides substantial amounts in New South Wales, Queensland, and New Zealand—produced extraordinary effects upon the former colony's progress in commerce and population, and in the values of its properties. As the phrase was, the gold had precipitated Australia into a nation. But there were two serious drawbacks to the attractiveness and prosperity of Australasia, namely, its convict origin, which had left to it an ungainly history, and the liability of the vast interior of the Australian mainland to periodical and severe drought. The convict system, although still lingering in West Australia, had happily ceased a generation ago in the more thickly-settled eastern section. The liability to drought might possibly be much mitigated by science and capital in the future; but probably it was more or less a permanent feature, due to the irremediable peculiarity of physical constitution—a comparatively flat and waterless interior, causing scant and irregular rainfall, and pervaded at times in summer by hot and desiccating winds. Some remarks followed on the physical features of both countries, on their respective aboriginal populations, and on their interesting natural history, with especial reference to the extreme peculiarities of that of Australasia. The author concluded by glancing at the question of the unity of the Empire, and the possibility, and even probability, of its disintegration under the present system of conceding a practically free self-government to the Colonies, without any concurrent provision of a representative government for the whole Empire. The Colonies were consequently growing up into a separate political life, and even the most cordial and loyal feeling might be insufficient when the real strain came. Happily this danger now excited very general attention; the bundle of sticks is not so fastened as to confer upon the Empire all its dues in permanency and power. What are our grandchildren to say if, through our negligence and indifference, they are born to a lost Empire, and above all, how will history judge us?

FRIDAY, AUGUST 29.

The following Papers were read:—

1 *Media of Exchange: some Notes on the Precious Metals and their Equivalents.*[1] *By* JOHN B. MARTIN, *M.A., F.S.S.*

Gold, or the pursuit of gold, has from all times lain under a ban, but the political economist recognises the fact that the pursuit is common to all time and every race, and that, unless its distribution be altogether unjust, the prosperity of a country goes hand in hand with its increase of wealth. The present paper does not embrace so wide a scope as the nature and distribution of wealth, but deals with some points concerning the nature of the substances to which the word 'money' is more commonly applied, or their equivalents; and the phenomena which attend the use of them. The qualities inherent in gold and silver have caused them to be accepted from the earliest time in almost every quarter of the globe as a medium of exchange. The acquisition of gold and silver exercises an uncontrollable fascination; to acquire them appears synonymous with getting richer, to part with them seems a loss of wealth. Hence the 'gold-fevers' of California and Australia, which have no doubt stimulated the development of the country; but, with the exception of some lucky prize-winners, have not enriched the majority of the venturers. Hence, too, it has been an aim of statecraft to attract the import of bullion and to discourage its export; but the true nature and functions of gold and silver are now better understood, and they are recognised to be merely commodities which, neither as regards each other nor in reference to other commodities, can be of fixed value. Their comparative steadiness in exchangeable power is mainly due to the small proportion which the annual increment bears to the total of the world's stock, and in this respect they differ in a marked degree from articles of food or manufacture; but at the same time the purchasing power of gold appears on the whole to have increased steadily. The oscillations of prices observable during brief cycles of years are the subject of great difference of opinion among experts, and their cause is only partially due to increase or decrease in the out-put of gold and silver.

The precious metals are of comparatively little service for the needs of home trade until they are converted into coin: in this latter condition the advantages are obvious, the disadvantages are less patent. The question as to the rights and responsibilities of the Executive power in the matter of coining are the subject of controversy, especially in view of the fact that any excess over its bullion value that coin may possess necessarily disappears at the frontier. At the best a mint-charge is a tax on the mine. To make any charge beyond the cost of manufacture is a dangerous temptation that has before now often overcome rulers to the confusion of the trade of their country. The loss by wear and tear is another drawback to the use of a metallic currency, for the loss is total and irreparable.

The admitted advantages of a metallic currency do not prevent it from being inconvenient in the settlement of large transactions, or in transport in considerable bulk. Hence has arisen the widespread use of Bank-notes, originally certificates for bullion or coin deposited with a goldsmith of good credit. In many European countries State-banks were founded by the grant of issuing powers from the State to an association of individuals who had made advances to the public exchequer. The most complete State-bank is that of Russia; England, France, and Germany have only quasi-State banks; Switzerland and Italy most closely approximate to the National Bank system of the United States. But paper money can never be, it can only represent, money; the absorption of paper money in any country depends on a variety of causes, such as wealth, habit, stability of government, and especially on the extent to which the banking system is developed. A comparison of the gold value of the paper circulation per head in various countries shows some singular

[1] Printed *in extenso* for private circulation only, by Blades, East, & Blades, Abchurch Lane, E.C.

apparent anomalies, whose explanation must be sought in the causes alluded to. To increase the volume of paper money when the point of saturation has been reached is impossible, and its result can only be *nominally* to raise prices, and to expel bullion from the country.

The development of a good banking system has the greatest effect in economising the use of the precious metals: the use of the Post Office for transmitting small sums, and the growth of savings banks, has the same tendency. On the other hand, an increase of population and wealth, and an accompanying tendency to a rise in wages, act in the opposite direction. It is extremely difficult, perhaps impossible, to say what is the effect of the sum of these forces.

Many attempts have been made to improve on the existing system, and the decimal system and international coinage, closely allied topics, have a vast literature of their own. There is a gradual tendency to unification; for some time the United Kingdom and the United States, and far more recently Germany and Italy, have had a national currency; but as long as in England alone we have almost as many measures of wheat as we have markets, it is at least sanguine to expect a change in our system of currency, or the adoption of an ideally perfect system, such as is attributed by Montesquieu to a tribe of Central Africa.

2. *National Debts.*[1] *By* Michael G. Mulhall.

Starting from the time of the Treaty of Utrecht (1713), we find the debts have risen thus:—

	Millions sterling						
	1713	1763	1793	1816	1848	1870	1884
Great Britain	54	147	370	841	773	801	756
France	48	110	32	140	182	468	995
Germany	—	—	—	53	40	148	334
Russia	—	—	30	50	90	280	555
Austria	10	15	20	99	125	340	508
Italy	—	—	—	25	36	374	438
Spain	7	11	20	52	113	285	330
Portugal	—	—	1	8	17	59	107
Holland	—	—	70	110	114	76	84
Belgium	—	—	—	—	18	28	78
Denmark	—	—	—	4	12	13	12
Sweden and Norway	—	—	—	—	1	6	20
Greece	—	—	—	—	10	18	18
Turkey	—	—	—	—	—	92	148
Roumania	—	—	—	—	—	—	27
Servia	—	—	—	—	—	—	4
Europe	119	283	543	1,382	1,531	2,988	4,414
United States	—	—	17	26	48	496	305
Spanish America	—	—	—	—	17	135	195
Canada	—	—	—	—	—	17	38
Australia	—	—	—	—	—	37	116
India	—	—	9	29	51	108	160
Japan	—	—	—	—	2	10	67
Egypt	—	—	—	—	—	37	113
South Africa	—	—	—	—	—	2	23
The World	119	283	569	1,437	1,649	3,830	5,431

[1] Published in full by Messrs. Routledge, Ludgate Hill, London.

From the Treaty of Utrecht till the French Revolution—a period of eighty years—the debts of nations rose 450 millions, that is, almost six millions a year. During the ensuing twenty-two years, down to the battle of Waterloo, there was a rise of 868 millions, or nearly forty millions per annum. From Waterloo down to the present the increase has been 4,000 millions, or almost sixty millions yearly. From 1848 to 1884 the debts have risen almost 3,800 millions, or 105 millions per annnm, and the money found employment as follows:—

Peace	Millions sterling	War	Millions sterling
Russian Serfs	85	Crimean	305
Light-houses and Harbours .	38	United States	474
Roads and Bridges	720	Franco-German	382
Railways and Telegraphs . .	870	Russo-Turkish	211
British Colonies	288	Iron-clad Ships	126
Sundries	104	Sundries	375
	2,105		1,873

If we sum up all under four periods we find the account stands thus:

Periods	Millions sterling		
	Peace	War	Total
Before 1713	—	119	119
1713–1815	—	1,318	1,318
1815–1848	162	50	212
1848–1884	2,105	1,677	3,782
Total	2,267	3,164	5,431

Thus it may be said that 60 per cent. of the existing debts stand for war expenditure, and 40 per cent. for reproductive works.

The British National Debt was a great burthen sixty years ago, but now it is felt by no one. In 1817 it was equal to 35 per cent. of the national fortune; at present it is only 8 per cent. The following table shows its rise and decline:—

Year	Debt	Wealth	Debt ratio	
			To Wealth per cent.	Per Inhabitant
				£
1702	16	490	3·3	3
1763	147	1,100	13·4	16
1797	413	1,800	22·9	40
1817	841	2,400	35·0	42
1860	826	5,560	14·9	28
1884	756	9,030	8·4	21

The British debt is at present less than five years' savings, for we find that the accumulations of wealth between 1870 and 1880 averaged 154 millions per annum. And if we compare the annual charge for service of the debt with the national earnings, we find that the earnings of eight days cover the former, which is less than in most countries, viz.:—

	Millions sterling		Days of earnings to cover debt charge		Millions sterling		Days of earnings to cover debt charge
	Debt charge	Annual earnings			Debt charge	Annual earnings	
Great Britain	29	1,247	8	Greece	1	23	15
France	39	965	15	Turkey	5	105	17
Russia	20	760	10				
Austria	24	602	15	Europe	170	5,455	11
Germany	13	850	6	United States	12	1,420	3
Italy	17	292	20	Canada	2	118	6
Spain	9	188	18	Spanish America	10	390	9
Portugal	3	48	21	Australia	5	133	14
Belgium	3	120	9	India	7	440	6
Holland	3	104	10	Japan	4	290	5
Denmark	3	47	21	Egypt	5	45	40
Sweden and Norway	1	104	3	South Africa	1	22	16
				The World	216	8,313	9

The burthen of annual charge for the continent of Europe is 141 millions, which is equal to twelve days' earnings, against eight in the United Kingdom; therefore the debts of the Continent are relatively 50 per cent. heavier than in Great Britain. On the other hand, the United States require only three days' earnings for service of their debt, whereas in Australia the relative burthen is double what it is in Great Britain.

The relative magnitude of debt appears in comparing it with wealth as in the following table:—

	Millions sterling		Debt ratio to Wealth per cent.
	Debt	Wealth	
United Kingdom	756	9,030	8·4
France	995	8,340	11·9
Germany	334	6,403	5·2
Russia	555	4,363	12·7
Austria	508	3,693	13·8
Italy	438	2,371	18·5
Spain	330	1,609	20·6
Portugal	107	375	28·5
Holland	84	1,005	8·4
Belgium	78	828	9·4
Denmark	12	372	3·0
Sweden and Norway	20	991	2·0
Greece	18	213	8·5
Europe	4,235	39,593	10·6
United States	305	10,335	2·9
Canada	38	680	5·6
Australia	116	634	18·3
Argentine Republic	29	368	7·9
Uruguay	12	81	14·8
Total	4,735	51,691	9·3

National debts are likely to go on increasing fully 100 millions a year, but public wealth in Europe increases four and a half times faster, as seen by comparing 1884 with 1848. The increase of debt is not necessarily an evil.

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3. *Canadian Finance. By* J. McLennan.

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4. *On the Production and Consumption of Meat in the United Kingdom. By* Major P. G. Craigie, *F.S.S., Secretary of the Central Chamber of Agriculture of Great Britain.*

Few subjects come more legitimately within the sphere of this Section of the British Association for the Advancement of Science than the food supplies of the people, and few subdivisions of the food question generally have at the present time a closer interest to consumers and producers alike, than attaches to an inquiry into the sources, the dimensions, and the future of our supplies of meat. Although the English people have ever been a meat-eating race, little statistical inquiry has been directed into the amount annually consumed in the United Kingdom, or into the conditions of the profitable production of meat. Attention has, however, been recently drawn to these matters by the growing dependence of the British consumer on meat reared beyond the sea, and by the losses, direct and indirect, which have unfortunately attended the introduction of foreign contagious diseases along with the live-stock imported from abroad to supply our lack of native produce.

Only for the past 16 years have we any accurate data for contrasting the number of meat-producing animals with the growing volume of our population.

In 1868 the population of the United Kingdom was 30,618,000 souls, residing on a superficial area of 78,000,000 acres, whereof 45,653,000 acres only were accounted for as 'under cultivation.' It would not be quite accurate, however, to suppose that two-fifths of the surface of the country contributes nothing to the meat supply. Animals are undoubtedly depastured on many of the mountains, moors, and marsh lands, especially in Wales, in Scotland, and in Ireland, which are officially included in the 'uncultivated' area.

In 1883 the population had increased by 5,000,000 persons, or over 16 per cent. in 16 years. Neither the so-called cultivated area of the kingdom, which appears to have been augmented by 2,000,000 acres, or 4 per cent., in the same interval, nor the number of meat-yielding animals kept by our farmers, have kept pace with this growth of population. The cattle were more numerous in 1883 than in 1868 by just a million head, or 11 per cent., and the pigs by 800,000, or 25 per cent.; but on the other hand the sheep stock of the country had become smaller by upwards of 7,000,000 animals, or a loss of more than 20 per cent.

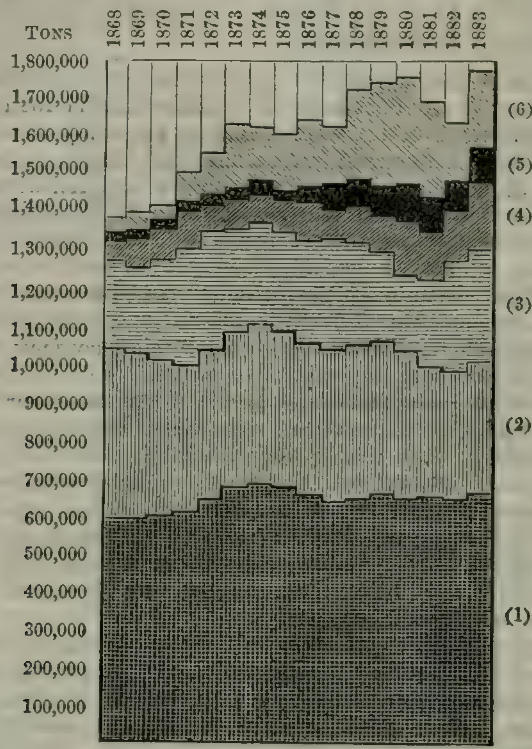
No official data exist whereby to determine the average weight of meat yielded annually by our flocks and herds at the two periods contrasted, but on the basis of an assumed or standard yield in pounds of dead meat for each class of stock, it is possible to present, as I have tried to do by a diagram, the fluctuations in the supplies annually produced at home. Adding to this estimate the known and officially recorded weight of foreign meat landed alive or dead on our shores in each year, it is clear we possess for the 16 years, 1868–83, inclusive data from which it is easy to construct a graphic representation of the changes which have taken place in the consumption of animal food. We can thus compare the gross increase with the increasing number of mouths to be fed, and by discriminating as far as possible between the sorts of meat grown or imported, the relative consumption of beef, mutton, or pig-meat, may be observed.

The diagram I have constructed represents in each of sixteen annual columns placed side by side the weight in tons of the year's supply, divided into six classes of meat. These are, reading upwards: (1) home-grown beef, including veal; (2) home-grown mutton and lamb; (3) home-grown pig-meat of all descriptions; the aggregate of these three lower divisions showing, of course, the whole native production. The next Section (4) represents, equally in tons, the proportion annually supplied by our entire live imports whether of cattle, sheep, or pigs;

(5) gives in tons each year's imports of beef and mutton, the official returns being too imperfect to allow of a separate classification of these items for the earlier years, while the last section (6) represents that part of our foreign supply which has most largely developed, namely, imported pig-meat such as bacon and pork.

MEAT SUPPLY OF THE UNITED KINGDOM IN TONS.

Distinguishing Home Produce of Beef, Mutton, and Pig-meat and Foreign Live and Dead Imports.



Before drawing deductions from these figures, I should state that of course more methods than one are possible in estimating the home produce. In default of any officially accepted scale, I venture to adopt with but slight variation, as sufficient at all events for comparative investigation, the scale proposed 13 years ago by a well-known agriculturist, Sir H. M. Thompson, and corroborated in various particulars at later dates by the inquiries of Sir James Caird and other statists. By that scale one-fourth of the cattle enumerated on each 4th of June, and two-fifths of the sheep are assumed as going annually to the butcher, while as far more pigs are slaughtered in a year than could be counted on any given day, 116 per cent. are taken as the proportion killed. The weight of meat is arrived at by adopting for the cattle of all ages an average of 600 lb. per head, the sheep I have taken at 70 lb. and the pigs at 134 lb. The equivalent weight representing the meat derived from imported live animals is arrived at by taking the average weights recorded for the first time by our Agricultural Department in their Report for 1883. While of course the weight of all forms of imported dead meat is given in the records of our Custom House authorities.

The selection of a fixed ratio of annual production depending solely on the numbers of our stock may of course be challenged. Prices, competition, climatic conditions, or disease, may make the home meat sent to market vary greatly from year to year, and it may be urged that the imported supplies should be taken as furnishing the only absolutely known weights, that one invariable standard of individual consumption should then be assumed, and the total, which would then rise regularly with the growth of population, would leave a varying balance representing the home produce to fluctuate accordingly. I am, however, disposed to think that there is quite as much to be said as to a probable fluctuation in the amount of meat consumed by our people one year with another, as may be urged for a fluctuation in the ratio of production from the enumerated herds of any period, and at all events for comparative purposes I offer the result of my own estimate, until by closer inquiries something better and more definite is arrived at.

The lessons of the diagram as it stands, taking first of all the various sections of the supply in detail, are these. The production of beef has been nearly uniform, after the first four years, 1868–71, of the period. In these years our herds averaged $9\frac{1}{4}$ million head of cattle, yielding only 615,000 tons of meat a year. Since that time we have never raised less than 651,000 tons, or more than 688,000 tons per annum—that largest outturn occurring once only, in 1874, one of the proverbially 'fat years' of British agriculture. Clearly, therefore, the native beef supply at all events has not kept pace with the population. The yearly ration of the British consumer, so far as home-produced beef is concerned, was $44\frac{1}{2}$ lb. in 1868. It subsequently reached indeed 47 lb. in 1873–5, but speedily shrunk again to 42 lb. in 1882, and stood at $42\frac{1}{2}$ lb. last year. Until 1876 the foreign supply of beef imported alive only once reached 4 lb. per head of our people; usually the quota was nearer 3 lb. Since that date the transatlantic trade in live animals has added materially to that figure. In 1880, 7 lb. of beef per head was imported; in 1881 and 1882, owing to a smaller transatlantic supply, 6 lb. was about the total, while last year about $8\frac{1}{3}$ lb. of beef per head was obtained by imported live cattle. The salt beef imported is quite an insignificant item. It furnished only ·87 of a pound in 1868, and was just the same in 1883, and only once in sixteen years has it reached a pound per head. The growth of the trade in fresh beef is very different. This branch of the dead meat trade now supplies England with more tons of meat than we received from all the live cattle imported in 1868. The foreign fresh beef was then 227 tons only, whereas in 1883 it was over 40,000, and a 10 per cent. further increase is shown in the first half of 1884. From being but a fiftieth part of a pound per head, it has risen to $2\frac{1}{4}$ lb. per head. On the basis of these estimates it appears that we eat some 6 lb. more beef per head now than we did sixteen years ago, the consumption having risen from about 48 lb. to 54 lb. per head, but notwithstanding this two pounds less of each person's yearly ration is raised on our own soil.

The state of the case as regards mutton cannot be determined with the same accuracy, owing to the failure of the customs returns to indicate separately the amount of our importations of fresh and preserved mutton. In this case, however, the reduction in home supplies is very remarkable. The year 1868 showed larger flocks in the United Kingdom than have ever been enumerated since, so that 445,000 tons of mutton may be assumed to have been yielded from our pastures that year, enough to give each unit of the population an annual allowance of $32\frac{1}{2}$ lb. Only in one other year, 1874, did the home supply reach 30 lb. a head, and since then our flocks have been greatly reduced owing to the combined effect of losses from disease, especially that known as liver-fluke, the low value of wool, and the generally impoverished condition of our farmers, so that on the same scale we produced only 354,000 tons of mutton in 1883, equal to a ration of $22\frac{1}{4}$ lb. per head. Nor has the loss in this case been supplied from abroad. The live imports of sheep in 1868 were not quite equivalent to 10,000 tons of mutton or under three quarters of a pound per head. This rose indeed to 30,800 tons in 1876, or 2 lb. a head, but the supply fell off again until 1882, when 31,000 tons were received, and 1883, when 30,812 tons were accounted for. This is equivalent to rather less than 2 lb. of foreign live mutton per head of our existing population. The dead meat imports of mutton have never till the last few years been considerable, and, as I have shown, they are not even now properly distinguished. The special trade in frozen carcases of mutton, for the most part though not exclusively from our Australasian colonies, largely as it has lately been developed, only furnished three quarters of a pound to each man, woman, and child in the year 1883.

The supply of what I have called pig-meat—*i.e.*, bacon, pork, and hams—has varied much. The home produce of 1868 was 221,000 tons, equal to a little over 16 lb. per head of the people; it rose as high as 290,000 or 20½ lb. in 1872. In 1880 it sank to 199,000 tons, or less than 13 lb. per head, and for 1883 it may be taken at 277,000 tons or 17½ lb. per head. A great increase has taken place, however, in the foreign supplies of bacon, ham, and pork. There seems to have been but 39,450 tons received in 1868 as against 202,900 last year, and even that was by no means up to the figures of 1878–81, when from 234,000 to 287,000 tons were imported, the year 1880 being remarkable for the consumption of over 18½ lb. of foreign pig-meat against under 13 lb. of British and Irish growth. It is quite clear that, placing the home and foreign supply together, much more pig-meat is used by the population than formerly, the 19 lb. per head consumed in 1868 being now over 30 lb.; and the foreign portion, which sixteen years ago was less than 3 lb. per person, has become virtually 13 lb. per person.

Looking at the total supplies of all classes of meat, therefore, the aggregate is greater than in 1868 by something like 29 per cent., or 400,000 tons of meat. This is a larger increase than can be caused by the growth of population, for which 217,000 additional tons would have sufficed; more meat we may safely conclude, therefore, is being eaten than was the case in 1868, and this agrees with our every-day experience. But it is almost wholly an increase met by importation, not by home production, as the table I subjoin very clearly shows.

Aggregate Meat Supplies.

Year	Home	Foreign	Total	Home per Head	Foreign per Head	Total per Head
	tons	tons	tons	lbs.	lbs.	lbs.
1868	1,274,000	99,914	1,373,914	93·20	7·31	100·51
1869	1,246,000	139,297	1,385,297	90·25	10·13	100·38
1870	1,281,000	131,885	1,412,885	91·97	9·45	101·42
1871	1,305,000	189,991	1,494,991	92·77	13·50	106·27
1872	1,344,000	207,714	1,551,714	94·57	14·61	109·18
1873	1,352,000	270,688	1,622,688	94·28	18·87	113·15
1874	1,369,000	250,418	1,619,418	94·57	17·30	111·87
1875	1,342,000	258,449	1,600,449	91·78	17·68	109·46
1876	1,327,000	316,669	1,643,669	89·08	21·44	111·42
1877	1,330,000	295,326	1,625,326	89·07	19·78	108·85
1878	1,322,000	396,795	1,718,795	87·61	26·30	113·91
1879	1,292,000	442,046	1,734,046	84·73	28·99	113·72
1880	1,238,000	517,632	1,755,632	80·40	33·69	114·09
1881	1,230,000	459,218	1,689,218	78·88	29·45	108·33
1882	1,278,000	353,532	1,631,532	80·84	22·44	103·28
1883	1,307,000	467,482	1,774,482	82·17	29·39	111·56

The head rate of consumption, which apparently stood at a little over 100 lb. per head at the beginning of the period, has risen to upwards of 111 lb. now, but whereas the British or Irish farmer supplied over 93 lb. out of the average individual consumption of 100 lb., he now furnishes little over 82 lb. out of 111 lb. We rely on the colonist or the foreigner for 29·4 lb. per head now, whereas sixteen years ago we had to purchase from him 7·3 lb. only. These are great changes. The foreign supply has not only filled up the deficiencies of our produce so far as beef and mutton, taken collectively, is concerned, so that the head rate of consumption of these commodities remains almost exactly as it was before, at somewhat over 81 lb. per person, but it has further enabled us to indulge more liberally in the various forms of pig-meat by raising the head rate in this respect from 19 lb. to over 30 lb. per person.

It is not without interest to contrast the two forms in which these foreign supplies have reached us. In the earlier years of the sixteen more than half of our foreign supply reached us alive. Now, vastly as the live importations have increased, that of dead meat has much more rapidly developed. All the live animals disembarked on our shores on the average of recent years do not furnish as much as one-third of the foreign meat supply. While the advance in live importations is 270 per cent. that in dead meat is 450 per cent.

If I had endeavoured to arrive at the total production of meat in the United Kingdom in an opposite manner to that adopted, by assuming that the consumption varied only with the population, and by a uniform rate per head, and assuming as a standard the 100 lb. limit of consumption current in 1868, it would have seemed that the home produce had fallen off not only relatively but absolutely. But such a mode would have made it appear that equal stocks of animals on our farms were not producing anything like the same amount of meat as before. No one conversant with the advance of agricultural practice, the growing weights of our fat stock, and their earlier maturity, will readily accept such a conclusion Indeed, but for the repeated invasions of disease, and especially the spread of foot-and-mouth disease, with its serious and lasting effects on the breeding powers, a marked increase in annual outturn might have been looked for.

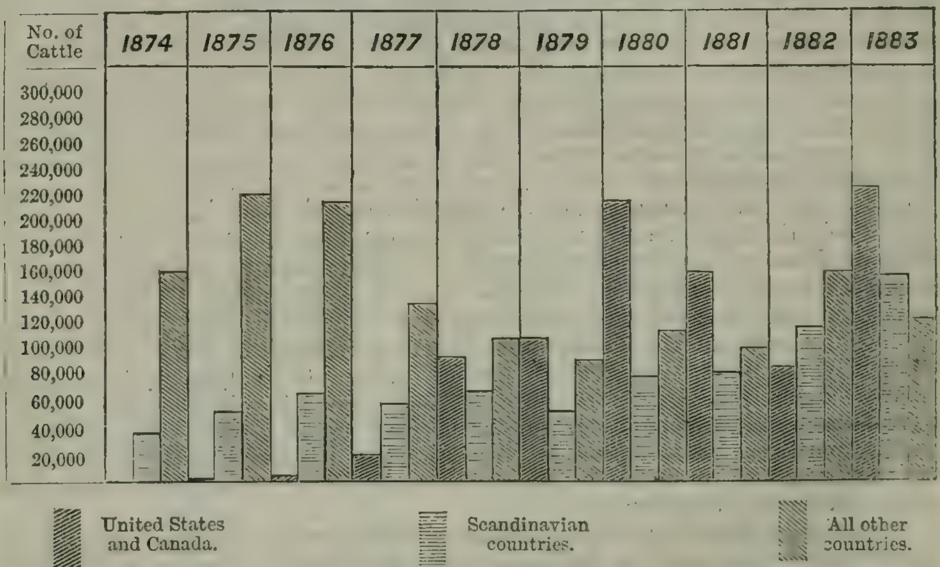
There is, however, another consideration which should not be overlooked. What I have called our home production is not, strictly speaking, sustained solely by British acres. The soils of other lands are made tributary to our stock production. There is now a very large importation and use of foreign feeding stuffs linseed, cotton seed, and other cakes, maize, and so forth, which plays a considerable part in the fattening of native stock. Without these external helps we should not turn out the 1,300,000 tons yearly on which I have reckoned. Sir John Bennet Lawes, than whom no man is more fitted to pronounce an authoritative opinion, sets down from 40,000 to 50,000 tons of meat yearly as representing the annual result of imported feeding stuffs. Although not a very large share of the whole it would probably place the outturn of 1883 behind that of 1868, and the cost and sources of such additional food must necessarily be a consideration not to be left out of sight by those who are recommending the English farmer to undertake to fatten a vastly increased supply of lean store stock from the prairies of the far West. Nor is the addition to the productive capacity of our soil due to the use of foreign manures an unimportant consideration in the production of meat. Upwards of 2,000,000*l.* are being now annually spent on guano and imported manures, and between 8,000,000*l.* and 9,000,000*l.* are yearly paid for such feeding stuffs as I have named, independent of the purchase of maize and other foreign grains for feeding purposes. It is hardly possible therefore to refuse to recognise in these considerations conditions which may seriously check the profitable fattening of an unlimited supply of butcher meat.

Especial interest has attached of late to the sources of our foreign supplies so far as these are furnished in the shape of living animals. The risk of importing disease and the necessity for the most stringent precautions have, doubtless, in some degree restricted a still larger importation of foreign live stock, and possibly these very proper restrictions have given a fillip to what I must regard as the superior form of that dead meat trade which, as has been shown, has most remarkably increased of late. Still, however, as long as it remains profitable, we are likely to have live animals sent across the ocean, and the recent changes in the quarters whence we derive our main supplies are sufficiently striking to attract attention. In presenting these also in a graphic form a lesson may be taught to the exporters of cattle from the side of the Atlantic where this paper is read as to the pre-eminent necessity of the most complete sanitary system of protecting their own stocks if they mean to dispose of their surplus in Great Britain, and if their trade is to be a growing one.

In the diagram subjoined I divide the imports of live cattle during the past decade into three classes, represented by three parallel columns in each annual division: (1) those coming from the American Continent, whether Canada or the United States; (2) those from the three Scandinavian countries, viz., Denmark, Sweden and Norway; and (3) the imports from all other European countries.

The transatlantic trade in cattle only becomes appreciable in 1876. But since 1877 the receipts of live cattle from the United States have risen, though with some remarkable fluctuations, from 11,500 to 154,600, and the Canadian quota from 7,600 to 53,200 head. The Scandinavian group of countries which sent us only 36,000 head in 1874 increased steadily till their supply is now close upon 147,000 head. On the other hand, those older countries, such as France, Belgium, Holland, Germany, Spain and Portugal, whence ten years since we drew 156,500 head of stock out of 193,000, have, after a very slight increase in 1875 and 1876, dropped both absolutely and relatively to the whole supply to a distinctly inferior position as a source of beef provision to Great Britain, the total having fallen in 1879 to 87,800 head, and standing in 1883 at 118,000 head out of a total of 473,000. From having sent us four-fifths of all our foreign cattle they are reduced to providers of less than a fourth of the imports. This change of trade is in a large measure due to the prevalence of one form or another of contagious disease. The Scandinavian countries by resolute efforts freed their territory from contagion and reaped the reward in a healthy export trade. The relative freedom from disease, which, except in a few districts of the United States, has distinguished the American continent, has up to this time enabled Great Britain to purchase largely of the surplus of the American and Canadian cattle men, but on the other hand those

SOURCES OF LIVE CATTLE IMPORTS.



districts of the world where disease is rife or imminent must be regarded by the United Kingdom with more or less suspicion, and as the whole foreign supply is but a fraction of the country's food, the British Privy Council is bound most narrowly to watch and check importations even from suspected sources. The live stock trade must for the future be carried on, if it is not to give place wholly to one in dead meat, mainly with those countries who possess and cherish a clean bill of health, and show themselves alert in keeping disease from their borders.

I could show the same features in the case of our imports of sheep. Although there has been nothing like the same increase in the total receipts as in the case of cattle in the past ten years, the sheep supplies from all quarters numbering 985,000 head in 1876, and 1,113,000 in 1883, the transatlantic share has risen from zero to 18,000 head, and the Scandinavian from 16,000 to 125,000, while the receipts from all other quarters which were not far from 800,000 head in 1874, are but a few thousands over that figure now.

Of the whole live imports which Great Britain receives at the present time it is instructive to note that a yearly ration of something like $3\frac{2}{3}$ lb. out of the whole $10\frac{1}{2}$ lb. comes from the United States, while Canada furnishes another $1\frac{1}{4}$ lb. for each man, woman, and child in the United Kingdom. It cannot therefore be inopportune to impress on a Canadian audience the lesson which these figures teach, and to urge them zealously to preserve their flocks and herds from disease, whether for their own safety or for the prospect of trading with the mother country in the matter of meat supply.

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5. *British and Canadian Agriculture. By* Professor J. P. SHELDON.

The competition of the old and new countries is growing keener, and contains certain elements which were never expected by our fathers. The volume of this competition will become much greater on the part of the new country, but we cannot foretell the lines on which it will be developed, or the surprises that may be in store. The transatlantic trade in fresh meat and in live animals, developed in these last ten years, is a striking instance in point, and may be supplemented by other unlooked-for surprises. The export of cheese from Canada has greatly increased, while that in butter has decreased, of late years; this is owing, as butter is now made and packed in Canada, to the superior advantages which cheese affords for transit purposes. By improved methods of packing butter, however, Canada ought to win over a good portion of the West Indian butter trade, which at present belongs almost entirely to Denmark. The competition of Canada with England in the future will be more in the form of animals and their products than in that of grain; her exports of wheat prove already that she is devoting herself more to live-stock and dairying. The competition of India in the domain of wheat-raising will be more serious to Canada than ever that of Canada was to England, and prices of breadstuffs are destined to contract still more. India, with her suitable climate and abundance of cheap labour, can produce wheat at a very low cost. While the eastern provinces of Canada are, in many parts of them, well adapted for live-stock farming, and for the production of dairy goods, which may also be said of the vast district comprised in what is termed the 'foot-hills of the Rockies,' the great plains of the North-West Territory, themselves also well suited to stock-raising in many parts, promise to become the chief granary of the American continent. The laying down of land to grass in England is still going on, and the number of live-stock is increasing. Wet seasons have impoverished British farmers, who, however, are better shielded now by law against confiscation of improvements. Agricultural tuition is improving, and it is by improved practice and the help of an increasing population, that the English farmer may hope to meet foreign competition. The present position of the English labourer will not compare unfavourably with that of the labourer in Canada, save that the Canadian has a better chance of raising himself to better things. But, in any case, the English labourers of to-day are better fed, better clothed, better housed, better paid, and better taught than their fathers were; and, with due sobriety and economy, he can raise his family better than they could, and also lay by a store against a rainy day.

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6. *The Position and Prospects of British Agriculture.*[1]
By Professor W. FREAM, *B.Sc., F.L.S., F.G.S.*

The present critical position of British farming has been induced by a series of wet seasons, accompanied by the widespread disease of live stock, and one of the chief results has been a lowering of farm rents. The acreage under corn crops, and particularly wheat, has continued to decrease, while that under permanent pasture has increased. During the six years 1878 to 1883, 340,659 acres have been brought into cultivation, but during the same period the increase in permanent pasture has been 1,223,126 acres, or nearly four times as much, so that 882,467 acres which in 1878 were under other cropping are now in permanent pasture. The former number (1,223,126 acres) somewhat exceeds the area of Lancashire, the sixth in size of the English counties, while the latter number (882,467 acres) represents an area larger than that of Wilts, the thirteenth in size of the English

[1] Published *in extenso* in the *Agricultural Gazette, North British Agriculturist, Montreal Herald*, &c.

counties. In 1878 we grew 3,381,701 acres of wheat, and in 1883 only 2,713,282 acres, the latter year showing a decrease of 20 per cent. on the former.

Our import of wheat from all sources in 1879 was 59,368,140 cwt., and since then the average increase has been 1,000,000 cwt. per annum. But while the imports from the United States and Canada have diminished, those from India have undergone an enormous increase, British India having sent us less than 1,000,000 cwt. in 1879, and upwards of 11,000,000 cwt. in 1883.

The principles involved in the laying down of land to permanent pasture are becoming better understood, the number of species of grass employed is more restricted, and there is an increasing determination to employ nothing but clean, pure, and fertile grass-seeds, so that seed-adulteration is largely checked. Of plants new to agriculture, comfrey has secured a limited recognition, while the weed spurrey, now recommended to be grown for ensilage, has all its way yet to make.

A determined crusade is being made against crop-destroying insects. The last serious attack of turnip-fly, in 1881, is estimated to have cost English and Scotch farmers as much as 671,936*l.*; and in 1882 the English hop-growers lost through the ravages of the hop-aphis 1,300,000*l.*, not less than 200,000*l.* of which represents wages lost to the hop-pickers.

Ensilage is receiving a fair trial at the hands of British farmers, and is most likely to prove successful, if at all, on farms where a large number of stock have to be wintered. But silage can never become the marketable commodity that hay is, on account of its perishable nature, and from the fact that 80 per cent. of its weight is water.

Foot-and-mouth disease has proved a dreadful scourge during recent years, but the farmers' demand that British ports should be closed against live stock from infected foreign countries was certainly not prompted by the desire, or rather the intention, of introducing the thin end of the wedge of Protection. The majority of our farmers are reconciled to Free Trade, because they regard it as the inevitable.

The price of wool continues to decrease, and this article is now little more than an agricultural bye-product. Importations of colonial wool completely swamp the home growth. On the other hand, the price of pedigree live stock is well maintained, and it is in supplying the markets of the world with the best strains of bovine and ovine blood that one of the brightest outlooks of the future is to be sought.

Dairy-farming is largely on the increase, and this, combined with breeding, is the most profitable development British agriculture is likely to see in the near future. Great and important improvements have been introduced in the practice of dairying; the supply of milk to large towns is a rapidly-increasing industry, but our produce in cheese and butter still lacks that uniformity of character which it is desirable it should possess.

Looking forward, it is probable that rents, except on first-class dairy-farms, will continue to decline, and the rent of land at home will approximate to that of land easy of access in the Colonies. Farmers will possess a better technical education than heretofore, land owners will take a more direct interest in the cultivation of the soil, and land agents will, through the efforts of the Surveyors' Institution, be better qualified to discharge the important duties that devolve upon them. Home railway-freights on home-grown agricultural produce will probably be modified to a sufficient extent to at least place our own farmers on a level with those in other countries. Permanent pasture will go on increasing, and the acreage under corn will diminish, though never become evanescent. Dairy-farming and stock-breeding are the sheet anchors of the future.

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7. *The Agricultural Resources of Ontario.* *By* JOHN CARNEGIE.

This paper does not, as its name implies, deal with the resources of the entire province, but only with the southern, and already moderately well-developed, portion of it. Although the part dealt with contains only about one-fifth of its entire area, or about 25,000,000 acres, yet it is claimed that, owing to favourable climatic conditions, within this area a greater variety of crops can be grown with profit than in any other equal area of the American continent, thus rendering it peculiarly adapted to the pursuit of a mixed husbandry, which it is claimed is, in the long run, always the most profitable. In support of these claims, figures taken from the last census returns for Canada and the United States are cited, and by them it is shown that, even when placed in juxtaposition with the seven largest producing States, in each of seven cereals, Ontario, notwithstanding she is thus brought into competition with twenty-two States, succeeds in securing a first place as a producer of barley, and peas, and beans; a third place as a producer of oats and buck-wheat; a fifth for rye; and a sixth for yield per acre, and an eighth in quantity, for wheat; thus obtaining an honourable position in six out of the seven—a position unattainable by any State in the Union—while the great State of Illinois only obtains three firsts and a second, and then disappears from the comparison altogether. Figures taken from the reports of the Ontario Bureau of Industries and the Illinois State Returns for the year 1882 are also given, showing that in the yield and value of yield per acre, the crop of wheat, barley, oats, rye, corn, buck-wheat, and potatoes in Ontario so largely exceeded that of Illinois in that year as to make an aggregate difference of over $15,000,000 in favour of the Ontario farmer, equal to $47 per head of those engaged in agricultural pursuits, while the Washington returns show a still larger balance in his favour.

Figures are also submitted showing that during the ten years ending with 1880 the production of the different fruits had increased from 100 to 250 per cent., and that the manufacture of wine from the grape was rapidly increasing; while the opinions of eminent pomologists are cited to prove that Ontario's display of fruit at the centennial in 1876 'was the most instructive and comprehensive exhibit of fruits' made at that exhibition.

Stock-raising is then referred to, and it is claimed that the climate of Ontario has proved itself favourable to the development of healthy and vigorous animals, while the awards gained by Canadian stock-raisers at the great Christmas shows at Chicago prove that Ontario bred and fed cattle and sheep can more than hold their own with those of the prairies and great corn-growing States.

With regard to the future, it is pointed out that less than 11,000,000 of the 25,000,000 acres under consideration is returned as 'cleared,' while even in the county of York, in which the capital of the province is situated, 20 per cent. is still 'uncleared.'

In conclusion, the writer calls attention to the statement of the Hon. D. A. Wells, that, 'north of Lakes Erie and Ontario and the River St. Lawrence, east of Lake Huron, south of the forty-sixth parallel, and included within the Dominion of Canada, there is as fair a country as exists on the American continent—nearly as large in area as New York, Pennsylvania, and Ohio combined, and equal if not superior as a whole to those States in agricultural capacity. It is the natural habitat on this continent of the combing-wool sheep, without a full, cheap, and reliable supply of the wool of which species the great worsted manufacturing industries of the country cannot prosper, or, we should rather say, exist. It is the region where grows the finest barley, which the brewing interests of the United States must have if it ever expects to rival Great Britain in its present annual export of over eleven million dollars' worth of malt products. It raises and grazes the finest cattle, with qualities especially desirable to make good the deterioration of stock in other sections, and its climatic conditions, created by an almost encirclement of the Great Lakes, especially fit it to grow men. Such a country is one of the greatest gifts of Providence to the human race, better than bonanzes of silver or rivers whose sands run gold.'

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8. *On the Agricultural Resources of Nova Scotia.* *By* Major-General Laurie, *D.C.L.*

The first settlements in Nova Scotia were established for military reasons, and early settlers were mainly Loyalists from the United States—mostly professional men, disbanded troops—or crofters from the Highlands; none of whom had any knowledge of farming. Hence the little progress and low state of agriculture in the provinces, of which the agricultural capabilities are great. In 1818, Mr. John Young, under the title 'Agricola,' stirred up the farmers, but shipbuilding has so engrossed the attention of the people that more than half a million tons of wooden vessels are owned in the province; and mining, milling, and fishing draw the people from agriculture. But Nova Scotian produce is much larger than returns show, as its fishermen, as well as those from the United States, provision for the season in its ports, and several hundred steamers calling for bunker coal lay in food-supplies. The western part of Nova Scotia largely feeds St. John, New Brunswick, whilst Cape Breton sends to Newfoundland all it requires; and as Nova Scotia lies nearest to England, its especial products of cattle and fruit should and must command the best prices.

Taking the census of 1881, the yield of wheat has almost doubled since 1851, rising to half a million bushels; oats to nearly two million bushels; potatoes from two million bushels to seven-and-a-half million; turnips to one million from less than one third; other roots 336,000 bushels, an increase of 1,000 per cent. Hay has doubled, and now yields 600,000 tons. Butter from 3,500,000 to 7,500,000 lbs. Cheese shows 1,000,000 lbs. In 1851 apples were imported, but in 1881, 9,000,000 bushels were raised; other fruits increased very largely. Hops grow splendidly, but costly labour checks the cultivation. Grapes only appear in 1871 as 8,000 lbs., but in 1881, 35,000 lbs. are returned, the climate being found well suited for them. 300,000 cattle and 400,000 sheep were owned in 1881; 63,000 cattle and 151,000 sheep were sold for consumption in that year. The area, 13,000,000 acres, has a large proportion of lake, and the south-coast is rocky; but most of the land is cultivated with very *good* returns, and 2,000,000 acres have been improved, 1,000,000 being under crop, an increase of above 100 per cent. since 1851. The many thousand acres of dyke lands at the mouths of the rivers and heads of bays are most productive, and never require manure.

After eighteen years' experience on a new farm, I can testify to the productiveness of the soil and climate of Nova Scotia. Cattle live well at pasture from June 1 to October 15, and will hold their own a month longer. Oats and wheat usually mature in 100 days, and last year 25 acres of spring wheat gave me 25 bushels to the acre. Barley about 40 bushels, oats about 45 bushels, potatoes about 275 bushels; swedes from 500 to 800 bushels; but not on a southern slope, so I consider we are near the limits of turnip cultivation. Green corn as a fodder crop does wonderfully well, and in storing some as ensilage last year, I weighed out the crop at 20 tons to the acre. On 170 acres of land I raise food for 100 fatting cattle, besides 10 horses; but I buy oil-cake. Permanent grass-fields becoming choked with moss, dyke-land farmers depend on hay as the principal crop, the dyke produce maintaining the upland parts; but upland farmers who have copied this plan cannot maintain the farms in heart; crops fail, farms and farmers grow poorer.

Rotation is necessary. This means implements and teams; it means capital invested; but capital sees the farmer unprosperous, and is frightened away. Technical training is a necessity, not merely from books, but combined with practice; and the Government must earlier or later furnish this—an agricultural school and a model farm.

Ontario has a college where working farmers are taught science, and educated men are taught manual labour; but it is important to have an establishment in each province, as climate and conditions vary.

There is ample room for men of small capital in Nova Scotia; young men, with from 500*l*. to 5,000*l*., may in farming establish a comfortable home, and good returns for their time and means. I consider that, with capital invested and knowledge applied, a very bright future lies before the agriculture of Nova Scotia.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Reports and Papers were read:—

1. *Report of the Committee for defraying the expenses of completing the final Report of the Anthropometric Committee.*—See Reports, p. 279.

2. *Report of the Committee for continuing the inquiries relating to the teaching of Science in Elementary Schools.*—See Reports, p. 283.

3. *The Interdependence of the several portions of the British Empire.* *By* Stephen Bourne, *F.S.S.*

The growing importance of the Colonial dependencies of the British Crown entitle them to the foremost consideration of every assembly occupying itself with economic and statistical questions. Especially is this the case on the present occasion with everything which concerns the welfare of Canada; and if in this paper these are put prominently forward, it is because the subject is too wide for treating of other colonies with the same fulness. Although not amongst the earliest settlements brought under the Crown, it is the one in closest proximity to the mother country, and, if we except India, that containing the largest population and covering the greatest area; the one, too, possessing probably the best capability of ministering to the wants of England, particularly in the way of food. For these reasons it may be deemed more or less representative of others. It is proposed therefore to inquire what the trade is between the two, to conceive what it might become, and to see what proportion that bears to the Dominion traffic with the whole world.

Successive tables set forth (*a*) the imports and exports of the United Kingdom since 1871, specifying the total from and to the Colonies, and those from and to Canada; (*b*) the trade of the United Kingdom for 1883 compared with population in groups of countries and colonies; (*c*) the trade of the Dominion since 1873; (*d*) the values for 1883 of Canadian produce exported and (*e*) imported, classified as to origin or uses.

These several tables show (*a*) that, adding imports and exports together, England's colonial trade has averaged 160,000,000*l.* per annum, and is 24 per cent. of the whole 660,000,000*l.*; and that of the colonial portion 12½ per cent.—20,000,000*l.*—has been with British North America; (*b*) that in 1883, out of 427,000,000*l.* of imports, 328,000,000*l.* were from foreign countries and 99,000,000*l.* from colonies, of which 12,000,000*l.* came from North America; the export figures being in like manner 240,000,000*l.*, 156,000,000*l.*, 84,000,000*l.*, and 9,000,000*l.* respectively; (*c*) that of all the articles of Canadian produce exported in 1883, nearly one-half—10,000,000*l.*—finds its way to the United Kingdom, which in return sends back two-fifths—11,000,000*l.*—of all the goods Canada draws from beyond her own shores, those she imports being slightly more than she exports; (*d*) that the Canadian produce exported in 1883, and (*e*) the foreign goods she imported, may be thus classified:—

	Exports	Imports
Produce of the Mine	£620,000	£1,570,000
" " Fisheries	1,720,000	190,000
" " Forest	5,140,000	350,000
Animals and their Products	4,250,000	1,850,000
Agricultural Produce	5,610,000	1,840,000
Manufactures	710,000	18,020,000
Miscellaneous	880,000	1,830,000
	£18,930,000	£25,650,000

Fully one-half of the supplies Canada renders to Great Britain consists of food;

timber, furs, and oils making up four-fifths of the remainder. Of her imports, one-fourth may be classed as raw material, for the support of textile and other industries; another fourth, manufactured iron; a third fourth, articles of food; and the remaining fourth, manufactured articles of sundry descriptions.

With these figures, it is easy to see what are the chief articles of interchange. But when once the railway across the continent is completed, there will be facilities for bringing more of the land under cultivation, and for sending its produce away. The mining output, especially in coal to the Pacific, is likely to be great, and it is quite impossible to conceive to what an extent the whole may grow.

On the other hand, the United Kingdom will need increasing supplies of food, and though her Southern and Eastern possessions may have the same capacity for producing these, the contiguity of North America, and its geographical position in the same zone, make it peculiarly appropriate for the feeding-ground of England.

But beyond England's need for importing, she has other wants—that of the lands to receive her growing population which she may find in her colonies; and the occupation for her accumulated manufacturing power which she may expect to create through those whom she sends forth. Thus the increase of the species may be rendered a blessing rather than a curse.

For both to fully benefit by this mutual dependence, there ought to be the most unfettered interchange of the commodities which each grows or makes, and whatever may be said as to protection against foreigners, nothing in the shape of protective duties ought to impede or divert commerce between portions of the same Empire. Revenue duties stand upon a different footing; but they should be raised upon imported and home products alike. It would be a great step if in all the colonies and the mother country the same articles were subjected to customs and excise duties at similar rates, and the whole money so raised were appropriated to defraying the cost of defence.

It is scarcely to be questioned that absolute free trade, at least between all parts of the Empire, must ultimately exist, although it is possible that special circumstances may for a limited period require or justify that general economic principles should give way to particular necessities.

As regards foreign countries, the selfishness which induces them, whilst availing themselves of all the advantages of free trade with us, to withhold from us the corresponding benefit, should be met, not by protective duties, but by an absolute refusal on our part to trade with them at all. Figures prove that they really depend more upon us than we on them, and due notice to this effect, so given as to afford no hope of reversal, would in all probability bring about the result without any actual stoppage. England might depend upon the resources, and rely upon the loyalty, of her colonies to sustain her in this conflict.

The consideration of these questions leads up to the far greater one which is now attracting, and may soon absorb, the attention of statesmen, both home and colonial. This is the absolute necessity for some form of federation which may bind together more closely the various portions of the Empire, and so counteract any tendency towards disintegration.

But whatever may be the result of deliberation on this proposition, or the form it might ultimately assume, why should not the Dominion at once seek for an actual incorporation into the United Kingdom? In point of distance, when measured in time, she is scarcely farther off than was Ireland when she became a part of the Kingdom. By means of the electric telegraph, instantaneous communication with the Pacific will very shortly be established. With trains crossing the land from shore to shore, and the magnificent floating islands which our steamers will shortly, if they have not already, become, the Continent and Atlantic will be bridged over more effectually than the Irish Sea was at the beginning of the century. Our Eastern possessions are so different in race, climate, and position, that they must, for a lengthened period at least, constitute a different empire though under the same sovereign. Our Southern settlements are more remote, though perhaps not so much so as to necessitate their remaining in a different category. But the upper portion of the northern American continent has so many points in common with the British Isles that it would be easy to weld them into one body. It is already evident at home that local governing bodies must assume somewhat of the rule which is now exercised by the Imperial Parliament; and much existing organisation in Canada need not be destroyed. It would be a grand day should she become as much an integral part as Scotland and Ireland now are, by the United Kingdom becoming that not of Great Britain and Ireland, but of Great Britain, Ireland, and North America. Canada seems already ripe for the discussion of such a question. Australasia may ripen whilst it proceeds, and, together with the smaller dependencies, be included in the scheme before final effect is given to the decision.

4. *The Factory Acts. By* R. WHATELY COOKE-TAYLOR.

The object of the paper is to discuss both the proper sanctions for factory legislation and the means of making it most efficient and useful. Many of the advocates of Factory Acts have never comprehended, still less formally announced, the sound basis, both economic and historic, on which such legislation reposes. Much of this misunderstanding has arisen from a double interpretation of the word 'labour,' which at one time was used as a mere abstract term, implying a purely impersonal force, and at another time as the embodied effort of sentient beings. It is in this latter sense, as 'the human element in industrial production,' that political economy is concerned with the Factory Acts; and one object in studying that science is to obviate whatever—like the unimpeded force of competition—is harmful to humanity in economic tendencies. Hence the scientific basis for Factory Acts. There is equally an historic basis, inasmuch as industrial production has from time immemorial been under some exterior control—whether of the State, of some industrial labour corporation, or of custom.

With respect to the question how they can be made most operative and useful, this matter is considered under three heads. First, the objects of factory legislation; second, the subjects of it; third, the methods of enforcing its decrees. The objects are properly women, children, and young persons, but circumstances are conceivable which would make men proper objects too. Under the second head is considered the range which factory laws should take, the industries and occupations with which they should interfere. A very wide latitude is advocated for them to the extent of including legislation for shops, and even for some kinds of services, as railways and the Post Office. It is argued that having departed so far already from their original intentions, no logical resting-places short of those mentioned can be found. On the other hand, the proposal for interfering specially with the employment of married women in mills is condemned. On the subject of the proper method of inspection, the paper advocates a combination of local and central supervision. The result to aim at is aggregate justice, not absolute uniformity. Localities can best decide on the precise requirements of the several industries located there, and officers from the central authority should see that on the whole the law was fairly observed. The sanitary and educational authorities of the district should furnish the means for putting the sanitary and educational portions of the law into effect in the first instance, and what little supervision would still remain unprovided for could be furnished between them, or would result spontaneously from the impulse of other enactments relating to industry.

5. *The Phosphate Industry of Canada. By* ROBERT C. ADAMS.

Mineral manures were suggested by Liebig in 1840, he having observed the effect of sulphuric acid in making minerals soluble.

As a ton of wheat takes sixteen pounds of phosphoric acid from the soil, this must be replaced to ensure future production. Phosphates are obtained from Spain, England, Norway, France, West Indies, South Carolina, and Canada.

Canadian apatite was mentioned in 1827. In 1847 Dr. Hunt reported it in New Burgess, Ontario. About 1860–3 mining was begun there, and continued intermittently. In 1875 mining was begun in Ottawa County, and work has increased constantly, large deposits being discovered.

Prices have fluctuated 50*s.* per ton, from 116*s.* to 60*s.* per ton of 80 per cent. quality.

Pure specimens of apatite contain about 92 per cent. of phosphate of lime; cargo lots usually average 75 to 80 per cent.

Low freights are obtained by ships taking phosphate for ballast under deal cargoes at from 2*s.* 6*d.* to 10*s.* per ton.

The use of phosphates finely ground, without acid, is being considered, and efforts are being made to concentrate the phosphate from low-grade ores. Factories are to be started near Montreal to make superphosphates. Phosphate lands have sold as high as $1,250 per acre.

Experiments made by Lawes showed that the use of superphosphates increased the yield of an acre from two tons of turnips to eight tons. The use of this article as a fertiliser increases constantly as knowledge increases and soil becomes exhausted.

The exports of phosphate increased from 5,462 tons in 1877 to 17,000 in 1883.

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6. *The Fisheries of Canada.* *By* L. Z. JONCAS.

The principal points referred to in this paper were:—

1. Extent of the Canadian fisheries; their importance as a source of maritime wealth and commerce; and as keeping in active training an independent and spirited class of sea-faring men.

2. Extent of the Canadian maritime coasts and of numerous inland seas of the Dominion. Varieties of fishes found in them. Immense field for industry and enterprise.

3. Value of the Canadian fisheries both commercially and economically. Statistics. Number of men they employ. Their rapid growth. The amount of their annual products. Comparison between them and the Great Britain and United States fisheries. Canadian mode of fishing compared with that of other countries. What the Government of Canada has done to further develope its fisheries. Fishery *bureaux*, societies, and commissions.

4. Answer to the question, would not the Canadian fisheries soon be exhausted if they were carried on more extensively? Fishing in the Canadian waters by foreigners and by native fishermen for the last three hundred years. Abundance of fish. Natural history of the commercial fishes of Canada. The arctic current washing the Canadian coasts and bringing food for the commercial fishes. Opinion of scientists on the matter. Area of the Dominion coasts washed by the arctic current. Theory regarding migrations of fish.

5. The most important fishing-grounds and different fisheries in Canada.

6. Cod-fishery: its importance, its value. Habits of the cod. Cod-fishing season in the Canadian waters. Bait for cod. Mode of cod-fishing. Encouragements given. Markets for the cod will never fail; and why. Statistics.

7. Industries inherent to the cod-fishery. Guano. Cod-roes: what quantity Canada could furnish; markets for this article. Manufactures of ropes, lines, nets, hoops, &c. Cooperage.

8. Herring-fishery. Appearance of the herring on the Canadian coasts. Abundance of this fish. English herring-fishery compared with Canadian. Modes of preparing herring for market.

9. Mackerel-fishery: its value: fleet of vessels engaged in it. Improvement in the building of vessels. Modes of preparing the mackerel for market. Markets where Canadian mackerel are sent.

10. Lobster-fishery. Enormous catch. Danger of over-production. Regulations. How hard it is to revive a shell-fishery.

11. Oyster-beds. Oyster-fishery.

12. Seal-fishery.

13. Salmon-fishery. Reasons of its decrease. More protection wanted. Fly-fishing season too long. Pisciculture. Annual yield of Canadian salmon-fishery. British Columbia salmon-fishery. Fresh-salmon trade. Statistics.

14. Lakes fisheries. Trout, white-fish, sturgeon, bass, pike, maskinonge, &c. How carried on. Steamers employed in the lakes fisheries. Annual value. Where the fishes are sent to, and how sent.

15. Canadian fisheries a great inducement for emigrants to come in this country.

16. Commercial and economical considerations relating to the Canadian fisheries.

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7. *On the Application of Scientific and Practical Arboriculture in Canada. By* Professor Brown.

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8. *The Distribution of Canadian Forest Trees. By* A. T. Drummond.

The author pointed out that there are ninety-five species of forest trees in Canada. The Province of Ontario has sixty-five species, of which sixty-one are found in the districts bordering Lake Erie. Of these sixty-five species fifty-two extend eastward to the Province of Quebec, thirty-five are found on the easterly and westerly sides of Lake Superior, whilst only fourteen range westerly into the prairie country at and beyond the Red River. Again, in British Columbia there are thirty-five species, of which only seven extend eastward beyond the influence of the Rocky Mountains, and with one exception those seven are well distributed over the whole Dominion. Only three of the Canadian trees are identical with European species,—the chestnut, white birch, and yew. Canada may be divided into four great forest areas or zones, which may for convenience be termed the zones of the (1) Douglas fir, occupying central and southern British Columbia; (2) poplars, covering the whole country from the most northern limit of the growth of trees southward, east of the Rocky Mountains, to the South Saskatchewan, Qu'Appelle and Winnipeg rivers, Lake Nepigon and Anticosti, in the Gulf of St. Lawrence; (3) white and red pine, extending from Lake of the Woods and Lake Nepigon to Anticosti, thence to the Georgian Bay, Lower Ottawa River, and Nova Scotia; (4) beech and maple, occupying those parts of Ontario and Quebec lying south of the zone of the pines. Along the shores of Lake Erie is what might be almost regarded as a fifth zone, very circumscribed in area, but having within it several outliers of the forests of the Middle States. The frequent peculiarities in range of forest trees in Canada are due to physicial conditions and differences in climate, resulting from differences in these conditions. The northern half of the American continent consists, on the one side, of enormous stretches of continuous land, and has, on the other, in its midst, immense areas of water and widely and deeply indented shores, Labrador and the great section of country lying between Hudson Bay and the Great Lakes and the Gulf of St. Lawrence being virtually one immense peninsula. The double effect of a northern latitude and the presence of these great bodies of water is very marked in the lower general temperature, the shorter summers and more severe winters. These influences check the northern range of forest trees beyond the outlet of Lake Superior, and, with the aid of the branch Labrador current, prevent their extension down the St. Lawrence below Quebec. The great chain of lakes from Superior to Ontario have not only their effect on temperature, but, by their great width, create a barrier to the northward extension into Canada of many United States forest trees. A remarkable feature in forest distribution is the fact that immediately west of Lake Superior many of the most important trees, as white pine, bass wood, red oak, and sugar maple are no longer found. The prairie appears to form a barrier to westward distribution. The prairies were probably at one time covered with trees which have been destroyed by fire. The effect of this has been to create a less rainfall, a quicker drainage from the soil, a dry atmosphere, and constant exposure to high prairie winds, all of which appear to be inimical to many forest trees. British Columbia has a distinctive forest area of its own. The trees are largely of the pine family, and, with seven exceptions, do not range east of the Rocky Mountains. They are similar to those of Oregon and Washington, and the direction of the mountain ranges and similar moist climate has favoured this. The white pine, yellow pine, and Douglas spruce are more or less known to commerce, but there are several other British Columbia trees which are as yet comparatively untried. In the near future the lumber trade there is likely to attain large proportions. Referring to the North-west prairies, the future cities and towns could exist only where abundant water was present, and thus the supply of water in the rivers was of vast importance. To preserve a constant and uniform supply it was absolutely necessary to have the sources of each important stream examined. If forests already exist there, then reserve a large area of them from public sale; if they do not, then the Government should at once promote the planting of forests or institution of national parks at such points. There are numerous rivers requiring such attention.

The paper was illustrated by a large map showing the forest areas and northern range of leading trees.

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9. *The Forests of Canada.* *By* ROBERT BELL, *M.D., LL.D.*

The writer, who has had extensive opportunities during the last thirty years of becoming personally acquainted with the forests of the Dominion east of the Rocky Mountains, endeavoured to give an account of their extent, general characters, peculiarities, value, means of preservation, &c. Viewing the forests of the continent as a whole, only the northern portions come within the Dominion, a large part of which lies beyond the limit of trees of any kind. The central and eastern forest region of Canada and the United States presents the greatest variety of species. In the north a wide border of coniferous trees, which becomes constantly smaller and more limited in species as we approach the verge of the forests, stretches across the continent; while toward the south deciduous forests prevail, but are interspersed with large areas of pines of various kinds. The sombre coniferous forests of the north are continuous over vast regions, which from their high latitudes and the poverty of their soil will never be cultivated to any great extent. This great coniferous belt has a crescentic form, curving southward from Labrador to the far north-west, keeping Hudson's Bay on its northern side. The distribution of our forests appears to be governed almost entirely by existing climatic conditions, although it may be modified to some extent by the geological character of different districts; and some of the peculiarities of their present distribution may be due to former conditions affecting their dispersion. Beyond the northern limit of the forests on the mainland of the continent there is a large triangular area to the north-west and another to the north-east of Hudson's Bay, called the barren grounds, which are destitute of trees solely on account of the severity of the climate, as the other conditions do not appear to differ from those of the adjacent wooded regions to the southward. The treeless regions of the Western States and the south-western part of the north-west territories of Canada are called plains as distinguished from the prairies, which often are partially wooded. The latter occupy an immense space between the plains and the forest regions to the east and north-east. The plain and prairie conditions are also due to climate, and not, as some have supposed, to fires having swept away formerly-existing forests. This is shown by the contours of the lines marking the western limits of the various kinds of trees which prevail in the east, as well as from the absence of water-courses, which would exist if sufficient rain had fallen in comparatively recent times to have maintained forest growth.

Although the Dominion embraces about half of the continent, only some ninety out of the 340 species of the forest trees of North America were found within her borders, including the Pacific slope. Yet the area under timber in Canada was perhaps as great as that in the United States. It is, therefore, evident that the forests are less diversified in the north than in the south. This is in accordance with the general law of the greater richness of the flora of warm countries; but it may be due also in part to the fact that in the north we have greater uniformity of physical and climatic conditions over wide areas than in the south. For example, we have a similarity in these conditions from Newfoundland to Alaska, and hence throughout the great distance of 4,000 miles we find the same group of trees. Again in the great triangular area of the North-west, between the United States boundary, the Rocky Mountains, and the Laurentian region, embracing over 600,000 square miles, very little difference could be observed in the climate, the soil, or the general level of the country, and hence the same group of trees—only about half a dozen in all—are found throughout this immense tract. In striking contrast with this is the fact that on the same farm lot in the south-western part of the province of Ontario one may often count as many as fifty different trees. The richness in variety of the native trees of Ontario and the adjacent States is owing to the fertile soil and the favourable conditions as to summer temperature, constant moisture, and the absence of intense cold in the winter. The writer exhibited a map showing the northern and western limits of the principal forest trees of the Dominion east of the Rocky Mountains. From this it appears that the range of species is not according to the mean annual temperature or precipitation, but rather to the absence of extremes of heat and cold, and great dryness. For these reasons a number of the trees of the province of Quebec and northern Ontario do not range west into Manitoba, although the annual means of temperature and precipitation are nearly the same in both. This map also shows in a striking manner that the northern limits of our various forest trees are by no means parallel to one another, although locally some groups may be nearly so for a certain distance. Some of them pursue extraordinary or eccentric courses, which are difficult to account for. The most remarkable of these is the white cedar, which in the central part of its trend reaches James' Bay, but drops suddenly to the south at the Gulf of St. Lawrence in the east, and on reaching the longitude of the head of Lake Superior in the west. Yet the climate and other conditions appear to be the same for some distance both east and west of these lateral boundaries. An outlying colony of the white cedar is found at Cedar Lake near the north-western part of Lake Winnipeg. Colonies or outlying patches of other trees have been noted in different localities, such as of the basswood and sugar-maple at Lake St. John, north of Quebec, of the grey elm on the Missinaibi River, near James' Bay, and of the hemlock spruce at Thompson, near the west end of Lake Superior. Rivers and lakes, by supplying heat and moisture and warding off summer frosts, often promote the growth of trees on their immediate banks which are not found elsewhere in the surrounding country. Instances of this may be seen along the North Saskatchewan, where the negundo, green ash, grey elm, white birch, alder, &c., thrive only on the river banks. In the cold regions, the white spruce grows to a much larger size on the shores and islands of rivers flowing north than elsewhere. It has been found that exotic fruit trees and other introduced plants can be successfully cultivated around the shores of the larger lakes, especially on their southern sides, which will not grow at a short distance inland. On the other hand the immediate proximity of the sea, with a lower summer temperature than the land, is unfavourable to the growth of timber in the north. The habits of some trees are much modified in different latitudes. Species which grow in warm dry soil in the north may be found in cold, heavy, or wet land in the south. The larch, balsam, white cedar, white pine, white birch, &c., are examples of this tendency. Some species extend far to the south of their general home along mountain ridges, while others seem to refuse to follow such lines. The existence of extensive swamps, the shelter of hills, or the elevations which they afford, are therefore to be regarded among the minor elements governing the distribution of trees.

The peculiarities in the outline of the northward limit of the white cedar and other species of trees may throw some light on questions as to the direction from which they have migrated or been dispersed. In some cases which the author has studied, the trees appear to have reached the most northern limit possible. For example, in its most northern range, the first tender leaves and shoots of the black ash are blighted almost every year by the spring frosts; the trees are of small size or stunted in height, and only occasionally bear seed. Sir John Richardson mentions that on the barren grounds, outlying patches of dying spruces were sometimes met with far out from the verge of the main forest, and that he saw no evidence of young trees springing up beyond the general line of trees; from which he infers that the latter is retreating southward. A similar condition is said to exist in Siberia.

In tracing the northern limits of several of the trees as laid down on the author's map, it would be observed that the northward variations from the general direction usually corresponded with depressions in the country, while the southward curves occurred where the elevations were greatest. The height of land dividing the waters of the St. Lawrence from those of Hudson's Bay had a general parallelism with the northern limits of many of the species; but as the watershed is not marked by any great elevation or by a ridge, the circumstance referred to may be owing simply to the accident of its trend coinciding with the average course of the isothermal lines.

The author divides the trees of the Dominion east of the Rocky Mountains into four groups in regard to geographical distribution, namely: (1) A northern group, including the white and black spruces, larch, Banksian pine, balsam-fir, aspen, balsam-poplar, canoe-birch, willows, and alder,—these cover the vast territory from the northern edge of the forests down to about the line at which the white pine begins; (2) a central group of about forty species, occupying the belt of country from the white-pine line to that of the button-wood; (3) a southern group, embracing the button-wood, black walnut, the hickories, chestnut, tulip-tree, prickly ash, sour-gum, sassafras, and flowering dog-wood, which are found only in a small area in the southern part of Ontario; (4) a western group, consisting of the ash-leaved maple, bur-oak, cotton-wood, and green ash, which are scattered sparingly over the prairie and partially-wooded regions west of the Red River and Lake Winnipeg.

The distribution of our forest trees affords us one of the most obvious tests of climate, and although it may not be more reliable than that of the smaller plants, it is more noticeable by the common observer. In the older provinces of Canada the settlers are often guided to a great extent in their selection of land by the kinds of trees it supports, a thrifty growth of beech and sugar-maple, for instance, being generally considered a good sign; but such tests must necessarily be only of local application. In the prairie region timber may be entirely absent from the finest soil, while the least hardy trees of the west flourish in the stiff clay-banks or among the stones along the rivers.

The map which has been referred to is useful in defining the extent of country over which each kind of timber was to be found. But in estimating the quantities which may be yet available for commercial purposes in the regions still untouched by man, various circumstances require to be considered, such as the favourable or unfavourable conditions of soil, &c., the proportion which has been destroyed by fire, and other causes. The amount of timber which has been destroyed by forest fires in Canada is almost incredible, and can only be appreciated by those who have travelled in our northern districts. The proportion of white and red pine which has been thus swept away in the Ottawa Valley and in the St. Maurice and Georgian Bay regions is estimated by the lumbermen as many times greater than all that has been cut by the axe. Yet all this is insignificant in quantity compared with the pine spruce, cedar, larch, balsam, &c., which has been destroyed by this means in the more northern latitude all the way from the Gulf of St. Lawrence to the Nelson River, and thence north-westward. It is true that the commercial value of this timber was not so great as that of the more southern pine regions which have also been partially destroyed. The total quantities destroyed are almost incalculable, but even a rough estimate for each hundred or thousand square miles shows it to have been enormous, and of serious national consequence. The writer had traversed these great regions in many directions, and could testify to the widespread devastation which had taken place. Nearly every district was more or less burnt, the portions which had been overrun by fire usually exceeding those which remained green. These northern coniferous forests were more liable than others to be thus destroyed. In the summer weather, when their gummy tops and the mossy ground were alike dry, they burn with almost explosive rapidity. Small trees were thickly mingled with the larger ones, and they all stand so closely together that their thick branches touch each other so that they form a sufficiently dense fuel to support a continuous sheet of flame on a grand scale. Before a high wind the fire sweeps on with a roaring noise, and at a rate which prevents the birds and beasts from escaping. After a time the burnt district becomes overgrown, first with shrubs and bushes, then with aspens and white birches, among which coniferous trees by-and-by appear; but finally, at the end of a hundred and fifty years or more, they regain possession of the burnt tract. This process of alternation of crops of timber appears to have been going on for centuries, but in modern times the fires must have been more numerous and frequent than formerly. These fires are undoubtedly due occasionally to lightning, but most of them are traceable to the carelessness of white men and demoralised Indians. In the partially-inhabited regions, most of the forest fires originate by the settlers burning brush and log-heaps in clearing the land. It may be asked if we have no means of stopping this fearful destruction of the timber of the country. Laws on the subject do exist, but no means appear to be provided for enforcing them. The author recommended a reform in this respect, before it be too late. Crown lands of real value for agriculture should be separated for the purpose of administration from those which are acknowledged to be useful only or principally for their timber, and settlement should be prohibited within the latter. Heretofore, the great consideration of Government was the peopling of the country, the timber being looked upon as of secondary importance, and it was willingly sacrificed in the interests of the settler, who came to regard it as his natural enemy. The time has come when we must change all this. In the absence of forest guardians and proper regulations, lumbermen have often to submit to a species of blackmail from discharged employés and pretending settlers in order to keep them off their limits. Indians sometimes burn the forests off each other's hunting-grounds from motives of revenge, but as a rule the fires which they start are from carelessness or indifference. When cautioned in a friendly way, they are willing to exercise greater care, and the beneficial effects of this course are already manifest in the region between Lake Winnipeg and Hudson's Bay where the author had remonstrated with them on the subject. He suggests that the annuities which they receive from Government be withheld as a punishment for burning the woods, or that a bounty be paid each year that no fires occur. In this way the Indian chiefs and headmen may be made the most efficient and earnest forest guardians we could possibly have.

Fires are not so liable to run in forests of full-grown white and red pines, and such as those of southern Ontario, which have suffered comparatively little from this cause, but have now been mostly cut down and utilised by the lumbermen. Hardwood forests are seldom burnt to any great extent, except when the soil is shallow and becomes parched in summer, as, for instance, on the flat limestone rocks of Grand Manitoulin Island and the Indian Peninsula, through much of which fires have run, burning the vegetable mould and killing the roots, thus causing the trees to fall over even before they have decayed. Hence the term 'fire-falls' applied in such cases.

In regard to the future supplies of timber which may be available in Canada, the greater part of the white oak and rock elm had been already exported. The cherry, black walnut, red cedar, and hickory had likewise been practically exhausted. Red oak, basswood, white ash, red cedar, hemlock, butternut, hard maple, &c., as well as many inferior woods, were still to be found in sufficient quantity for home consumption. A considerable supply of yellow birch still exists, and in some regions it is yet almost untouched. Until recently there was an indistinct popular notion that the white pine, our great timber tree, extended throughout a vast area in the northern parts of the Dominion, from which we might draw a supply for almost all time. The author's map showed, however, that its range was comparatively limited. Although it was found over an extensive area to the north-westward of Lake Superior, it was very sparsely distributed, of smaller size, and poorer quality than further south. Our principal reserves of white pine, as yet almost untouched, are to be found in the region around Lake Tenniscoming, and thence westward to the eastern shores of Lake Superior. This region lies partly to the northward of the height of land. There is also more or less red pine in the district referred to. When the exportable white and red pine shall have become exhausted, as it must before many more years, we have still vast quantities of spruce and larch, which may even now be regarded as the principal timber available for this purpose in the future. But our stock of these woods is to be found mostly in the great country which drains into James' Bay, whose numerous large rivers afford facilities for floating timber to the sea, and in the country thence westward to Lake Winnipeg. Fine white spruce is likewise found in some localities in the North-west Territories between the prairie regions and the country of small timber to the north-east. The Banksian pine, which ranges all the way from New Brunswick to the Mackenzie River, is often large enough for sawing into deals, and will afford large quantities of good railway ties.

If the vast northern forests can be preserved from fire in the future our supply of small timber is practicably inexhaustible. When larger trees elsewhere shall have become scarce, much of it may some day be sawn into boards, scantling, joists, rafters, flooring, &c. Supplies of timber for railway-ties, telegraph-poles, mines, fencing, piling, small spars, cordwood, charcoal, paper-making, &c., may be drawn from these immense districts for all time, since the greater part of the regions referred to are not likely to be required for agricultural purposes, and by a proper system of cutting a new growth will spring up to replace the timber removed, and in its turn become available to keep up the supply. The practically interminable extent of these forests will allow ample time for the smaller trees which may be left on any ground cut over to come to maturity before it is again called upon to furnish its quota. Some of the woods of the more southern districts of Canada, which have had but little value hitherto, except for fuel, only require to be better known to be utilised for many purposes.

The people of Canada have heretofore been accustomed to such an abundance of wood, and to the idea that trees stood in the way of the progress of the country, that tree-planting has as yet made but little progress among us. A beginning has, however, been made in the last two years in the provinces of New Brunswick and Quebec, where 'Arbor Days' have been proclaimed. In Ontario an Act was passed in 1883, and a fund set apart, for the encouragement of tree-planting along highways. The time has arrived for more vigorous action by the general Government and the local Legislatures looking to the improvement and preservation of the forests which still remain in Canada, and for the partial restoration of those which have been destroyed.

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10. *Forests—their Value Meteorologically and as National Reserves.* *By* G. P. Hughes.

The author taking a retrospect of the Primeval Forest, and regarding it geologically, pointed out that civilisation and the arts must ever remain indebted to the vast embedded forests of pre-glacial times. He referred to some of the instances we have in Great Britain and America of forests perpendicularly fossilised by subsidence into tranquil waters, thereby furnishing a means by which the age of the formation may be calculated, and the structure of the trees be observed. He referred to the dependence of man in all ages of his history upon the forest for material for houses, ships, implements, and the production of heat, calling attention to the denudation of most eastern countries once famous for civilisation and the arts, and to the wasteful destruction of valuable timber even in our day. The result has been greater climatic changes, and in the tropics a barren wilderness, where once great States held sway. He advocated planting the creek and reservoir margins in Northern Australia and tropical India, and quoted authors to back up his own opinion, that among improvements to landed property, planting offers the most certain returns in material, shelter, and ornament.

He gave a sketch of a course of study for a school of forestry, and advocated State aid or privileges to such institutions, in order that our national forests may be supplied with scientific heads of departments.

He made an appeal to British America to set aside forest reserves adequate for all future requirements.

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11. *The Future Policy of Forest Management in the United States.* *By* F. B. Hough.

TUESDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Internal Communication by Land and Water.* *By* Cornelius Walford, *F.S.S.*

The paper set forth that, from the earliest dawn of commerce, the sea had been the great highway of nations, while rivers had constituted the means of internal communication. Steam had during the present century alike facilitated maritime locomotion on the ocean and on rivers.

All countries were not equally circumstanced with respect to rivers. Economy of water-carriage would always commend its use as to certain classes of goods. England had spent very large sums during the last and early part of the present century in perfecting her means of internal water communication, in improving the navigation of rivers and constructing canals; and her manufacturing industries had greatly benefited thereby. Amongst the nations of the earth who owed most to their rivers were China, India, and Egypt; amongst the European nations, Russia and France.

But some of the nations of the world, having no facilities of water-carriage, had become great in commerce. Persia was an instance. She had indeed on her two extremes the Indus and the Euphrates, with the Tigris as an affluent of the latter. In the Euphrates valley was located Babylon and Bagdad, famous in the annals of commerce. But in the interior had been many flourishing cities. How had they become so? By the agency of mercantile caravans. These had played a great part in the history of commerce.

Egypt, as we know from Scripture history and other sources, occupied at a very early period a front rank in commerce and civilisation. She was the centre of the early trading nations, as geographically she was, in a certain sense, the centre of the earth. The seas of the world met at her shores; and by land caravans travelled to all the more important parts of Europe, Asia, and Africa. Cairo thousands of years ago was the centre of the caravan routes, as she is to-day in a more limited degree. From 'Grand Cairo' caravans traded with Persia, India, and China, with the important cities of northern Africa, with Palestine, Asia Minor, Turkey, and Russia, as far as the Baltic. It was not known in the then state of geographical knowledge that navigation (by way of the Cape of Good Hope) was possible between the Eastern and the Western Oceans. Hence, in B.C. 1600, Sisostrus (better known as Rameses III., builder of the Pyramids) caused the first Suez Canal to be cut—3,470 years before the opening of the present canal. Egypt thus commanded the known water-ways of the world. She monopolised the trade of India for thousands of years, until the discovery of the Cape route by Vasca da Gama, the Portuguese navigator, in 1497. Even imperial Rome had to obtain her silks and Oriental luxuries from the Egyptian caravans, trading through Persia to India and China.

Next in order of history came the road-makers and bridge-builders—the ancient Romans. They constructed roads and bridges for the purposes of conquest, as Napoleon I. made fine roads over the Alps for like purposes in modern times. The conditions of transport in Russia, in India, and the United States, were next reviewed in some detail. Everywhere railways were more or less rapidly usurping the functions of internal communication. In Russia, indeed, railways had been and were being constructed, largely from military motives; but they were, none the less, facilitating commerce. In India the rivers were being devoted to irrigation, main trunk lines of railway had become an admitted necessity, partly for military purposes, but greatly in view of transporting food-supplies, and so of averting famines. The food-supply of India was always adequate to the wants of the aggregate population if proper facilities of transport existed. The railways of India were being carried forward with great practical sagacity,—were in fact being made to pay; and the water-ways were also being carefully tended for irrigation and local transport.

The question of transit in the United States was next considered. Formerly the rivers—and no country was so favourably placed with regard to these—had all the interior carrying trade. Railways had grown from 23 miles in 1830 to 9,021 in 1850. In the next decade (1860) they stood at 30,635 miles, against 10,433 in the United Kingdom. In 1870 they had reached a total of 52,914 miles; by 1880, had increased to 93,671; and at the present moment reached somewhere about 120,000 miles. They had, however, been overdone; during the first half of the present year no less than twenty-one lines had passed into the hands of official receivers, and others were approaching the same unfortunate goal. These railways had been constructed largely upon borrowed capital. The foreign creditor suffered; the commerce of the country had benefited; but the system could not go on. The land grants which had led to the construction of many of the lines had greatly aided settlement; but they too would come to an end.

What was the practical lesson Canada might learn from all this? Her facilities of water-carriage were good on the eastern side of the Dominion; bad in the central provinces and territories, except for purposes of internal navigation; very fair on the west. But political necessities had rendered a trunk line across the continent imperative, and the arrangements had been carried out with wonderful sagacity and enterprise. The Canadian Pacific Railway might be regarded as of vast importance with respect to the integrity of the United British Empire. It affords direct communication on British territory from the Atlantic to the Pacific. Other railways could not be made under like conditions; but if lines were laid out judiciously, in regard to the wants of the country, local capital might be available. The author thought the water-ways of the country ought to be utilised largely in the matter of grain exports, in view of cost and competition with other countries.

On a general survey of the entire question the author was of opinion that there was already some tendency to reaction, and that railways would not continue to monopolise transit as they had of late been doing. The question of cost would intervene. The cheapest mode of transport, other things being equal, would triumph. The projection of the Manchester Ship Canal might be regarded as a case in point. This argument only applied to articles of merchandise. For personal transit, as also for the mails, facilities of transport would go on increasing indefinitely. Some of the Atlantic steamers were now being adapted almost exclusively for the conveyance of passengers and mails. General cargo might be carried much more economically at less speed. Overland transit to India was now coming to the front in a more practical shape than it had heretofore assumed. Faster trains and slower steamboats would then be possible. The telegraph would regulate the commerce of the world in articles of produce, and render more economic modes of transit possible. Narrow-gauge railways, tramways for commercial purposes, and electric motors, were all tending in the same direction. The paper contained a good deal of statistical detail in support of some of these conclusions.

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2. *Transport by Land and Water.* *By* E. Wragge *and* Alexander McDougall.

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3. *On Land Laws.* *By* Emile de Laveleye.

Among the laws which regulate the social organisation of a country, there are none more important than those which relate to real property. It is on these that depends, firstly, to a great extent, the more or less abundant yield of food products, which determines the number and well-being of the population; secondly, the distribution of wealth, the equality or inequality of conditions; thirdly, political institutions and the forms of government; the diffusion of landed property being favourable to the establishment and maintenance of a democratic *régime*, as in Switzerland, Norway, and the United States, the concentration of property leading, on the other hand, to the aristocratic *régime*, as was the case almost everywhere under the old *régime* of France and is still to-day in England. There can, then, scarcely be a subject more deserving of the attention of the economist and the legislator.

What end ought legislation to have in view in regulating property in land? The same end at which the whole organisation of society should aim, viz., to enable the largest possible number of persons to share in the benefits of civilisation—morality, education, freedom, and well-being—these benefits being raised to their maximum.

In order that land laws may conduce to this result, they must be such as to cause the maximum quantity of produce to be obtained from the soil, and to ensure that this produce shall be shared amongst the largest number of persons in proportion to the useful labour of each, as equity prescribes.

It is clear that this result will only be attained when the land is cultivated by the owner.

If a landowner possesses a vast extent of land worked by tenants, whatever may be the form of tenure—whether slavery as in antiquity, *métayer* cultivation and forced labour as in the middle ages, or farming competition rents as at the present day, the distribution of the produce will always take place in much the same way: he who works and produces will first retain what is necessary to enable him to maintain life and to bring up children to take his place; what remains, that is to say, the net produce, will go to the landowner in the shape of rent. This system, then, is in conflict with what we have laid down as our *desideratum*, in two ways. In the first place, it does not instigate to the greatest possible production, since it does not give to the producer the entirety of his product; secondly, it reserves the principal advantages of civilisation for a single privileged person, whilst it shuts them out from the greater number.

Under the system of small properties, cultivated by the owners, this stimulus to strenuous and intelligent industry which, according to Arthur Young, 'turns sands into gold' is brought out to its fullest extent, for those who make improvements have the full profit of them; and, moreover, the net produce, instead of being monopolised by the few, is distributed amongst a large number of families.

On behalf of large properties many considerations are urged. In the first place, we are told the working expenses are relatively smaller on a large farm. That is true, but on small properties the gross produce is greater. Now, as Adam Smith has shown, a nation lives on the gross produce, not on the net produce.

In the second place it is asserted that the employment of elaborate and costly machinery, such as steam ploughs and threshing machines, is impossible under the system of small properties. This is a mistake. In Flanders, where the ownerships of holdings are of very small extent, expensive machinery is bought, either by a society of cultivators, or by an individual who lets it out to the small farmers in turn.

It is further urged that the great proprietors will set an example of good farming. In England, it is true, it has often been so; but on the Continent agricultural progress has been principally due to the small proprietors. And, moreover, good methods of culture might easily be disseminated by schools of agriculture, as has been done in Wurtemberg and in Denmark, for instance.

After all, the verdict of experience is unmistakable. Everywhere, except perhaps in England, where the conditions are quite exceptional, districts where large property prevails are inferior from every point of view to those where small property is the rule: in quantity of live stock, gross produce, income, multiplicity of roads, density of population, condition and value of the farms. To be convinced of this, it is enough to compare in France, the centre with French Flanders; in Italy, the Roman States and all the south of the kingdom of Naples and Sicily, with Tuscany and the Emilia; in Spain, Castille and even Andalusia, with the suburbs of Valentia and Barcelona; in Portugal, the Alemtezo with the northern provinces; in Austria, all the west with Hungary; in Germany, Eastern Prussia with Saxony and Wurtemberg; in Belgium, the eastern district with Flanders.

But it is to be observed that small ownership is only advantageous to the cultivator when he is himself the owner. A tenant will be much more ground down by a small than by a large proprietor, because the former, in order to live, is obliged to raise the rent as high as he can.

If it has been shown that small properties cultivated by the proprietors themselves is the system most favourable to good agriculture, and to an equitable distribution of wealth, it remains to inquire what are the laws which can found and maintain such a system.

It is obvious at the very outset that perpetual and limited entail, and also the law of primogeniture, securing all the real property to the eldest son, ought to be proscribed.

The French Civil Code seems to have in part attained the end aimed at. Nevertheless it has been found to involve certain disadvantages. In the first place, it has sometimes brought about an excessive subdivision (*morcellement*), but to a much smaller extent than is generally thought. And then it has not prevented the existence of a rural proletariat—that is to say, of a large number of landless folk. To remedy these evils, the greater part of the United States of North America have adopted an excellent measure, the Homestead Law, by virtue of which the farm buildings and an area of land sufficient to support a family are secured against distraint and forced sale, and constitute, as it were, the inalienable property upon which the family can be perpetuated. In Bosnia and Servia a similar law has existed from the remotest times. Six acres of land, the house of the cultivator and its out-buildings, and in addition the animals, stores, and seeds necessary to carry on the cultivation, are exempt from seizure. (For details, see the voluminous and instructive work of H. Rudolf Meyer-Heimstäten.) I consider that this measure ought to be adopted in all civilised countries.

The nationalisation of the land, as urged recently by Mr. Henry George, would not bring us any nearer to the desideratum, indicated above; since, far from augmenting the number of owners, it would suppress them all, converting them into tenants of the State. No doubt there would result this advantage, that the State, receiving the whole rent of the land, would be able to abolish the other taxes; at all events, in England, where the rent of land is estimated at 1,800,000,000 fr. (72,000,000*l.*), equal to the amount of the public expenditure; but not in France, where the net revenue from land is estimated at two milliards, and where the expenditure exceeds three milliards. This system, however, which was advocated by the Physiocrats, who would have had a single tax (*impôt unique*) on land, would meet with an invincible opposition in every country where property is owned by a large number of families. It would only be applicable in a country where the soil is in the hands of a small number of persons, as in Scotland. There the nationalisation of the land would be easily carried out, without any change being made in the economical life of the population. The agents of the landlords would pay in their net receipts to the treasury of the State, and everything would go on as before. The principle of property is evidently endangered by its excessive concentration, and all the more so because it appears to be contrary to the ideas of right and equity that a single individual should be able to dispose of the fortunes of the inhabitants of a whole district.

Without having recourse to spoliation, and without effecting a repurchase in the interests of the State, as has been proposed in the case of Ireland, an operation which would be financially ruinous, the land might be brought back into the possession of the communes or the nation, by means of a special tax on successions, the produce of which should be employed in buying estates offered for sale or expropriated.

In any case, countries which are fortunate enough to possess public lands, instead of selling them or handing them over to railway companies, ought only to let them on lease for long terms, ninety years say. They would thus lay up for future generations a treasure which would enable them to abolish taxes or to pay off debts so soon as the leased lands should fall into the possession of the State, together with such buildings and improvements as might be found on them. Absolute alienation is a robbery of posterity. Look at the prodigious fortunes which this system has accumulated in the hands of the families who own land in the West End of London. Why did not the State do as well for itself? So far as the stimulus to all kinds of improvements and buildings is concerned, a lease of 100 years with a new estate would be just as effective as the fee simple of it. Here is an unanswerable proof of the fact:—During the last forty years, more than fifty milliards of francs have been invested in the construction of railways on the Continent under concessions of from seventy to eighty years. When the French State resumes possession of the railways created by the companies, it will be able to pay off one-half of its debts. In Java the Dutch Government no longer grants public lands in perpetuity, but only for a long term of years. I venture to refer for the fuller treatment of this subject to my work on 'Primitive Property'—preface and chap. xxiv.

The problem (how to secure to each family a share of the land) had everywhere found its solution, in primitive times, in the village communities, of which the Russian '*Mir*' still furnishes us with an example. The territory of the commune in this case is collective property, divided at periodical intervals between all the families. This system is a perfect guarantee of equality of conditions, and prevents pauperism on the one hand, plutocracy (*divitisme*) on the other. Cavour was a great admirer of it. It has disappeared, nevertheless, because it did not offer an adequate return to anyone who was willing to make costly improvements. Just in proportion as farming has become 'higher,' has private taken the place of collective property. We have here an historic evolution of which we should take very careful account. At the same time the Swiss *Allmend* is also a collective property, subject to periodic redivisions between all the inhabitants of a village, and yet it is perfectly cultivated, as anyone can see by visiting, for instance, the *Allmend* of Bönigen, near Interlaken. This is due to the arrangement that each obtains his share for his lifetime. Now the man who is certain to retain possession of his land as long as he lives has a stronger inducement to cultivate it well than a tenant at will, or even than a farmer with a lease of nine or eighteen years. In the greater number of the Swiss villages the inhabitants find on the communal meadows enough to keep several head of stock, and in the communal forest wood for firing and building purposes. What makes bad husbandry is not collective ownership, but collective enjoyment or cultivation, because under this latter system he who improves or produces does not enjoy the fruit of his labour. The *Allmend* is an excellent institution. It dispenses with the workhouse. It prevents extreme poverty. By attaching a man to his native soil it prevents him migrating to the towns. The commune is thus an economic no less than a political institution. It becomes the organic cell *par excellence* of the social body (or body politic).

I think that there is so much truth in the opinion of Stuart Mill on the question of the 'unearned increment' as to warrant us in concluding that the land tax ought to be raised whenever the income from an estate increases independently of any exertion on the part of the owner. The State makes a road, the municipality opens up a new street, population becomes denser, new suburbs are built; is it right that the owners of the neighbouring properties should retain all the profit of these works, and make them an excuse for levying an ever-growing tax on the labour of others? It is contrary to the very theory of property itself, which bases property on labour.

Here, then, are the conclusions arrived at in this short summary:—

1. That the diffusion of property (amongst the largest possible number of families) should be encouraged, first by the division of inheritances, then by giving every facility and every security for the sale of real property.

2. That we should borrow from the United States and Servia the Homestead Law, which guarantees to families the retention of a small property sufficient to maintain them.

3. That communal property should be reconstituted by means of a tax on

successions, and that countries which have public lands should grant them on lease instead of alienating them in perpetuity.

4. That the economic commune should be re-established with the *Allmend*, as it has continued to exist in Switzerland from the earliest times.

5. That a land tax should be imposed and revised from time to time, in such a way that the increase of income which is the result of the energies and progress of the whole society should go, at least in part, to the profit of the State.

6. That compensation should be given by law to the tenant for all unexhausted improvements.

4. *Female Emigration. By* Miss MARIA RYE.

5. *Female Emigration. By* Mrs. BURT.

6. *Female Emigration. By* Mrs. JOYCE.

7. *Population, Immigration, and Pauperism in the Dominion of Canada. By* J. LOWE.

8. *On the Probability that a Marriage entered into at any Age will be Fruitful, and that a Marriage which has been Childless for several years will subsequently become Fruitful. By* T. B. SPRAGUE, *M.A.*

The author stated that this subject is of great practical importance in connection with disentail proceedings in Scotland. Any entail can now be cut off by paying to certain of the expectant heirs the calculated values of their expectations of succeeding to the estate. When the proprietor is a bachelor, or a married man without children, and the expectant heir is a brother, nephew, or remoter relation, the expectant interest of the latter is liable to be defeated by the birth of issue, and the probability of this has to be taken into account in calculating the value of the expectant interest. Scarcely any statistical information bearing on this point seems ever to have been published, and the author therefore found it necessary to compile statistics from the records of the British peerage. He extracted particulars of the marriages of 1522 men who were either peers at the close of the year 1870, or their near relatives—brothers, sons, uncles—the fathers being excluded for the obvious reason that, as they all left at least one son, the inclusion of them in the observations would give too large a proportion of fruitful marriages. Other precautions were taken, which are fully described in the author's papers on the subject, about to be published in the 'Journal of the Institute of Actuaries.'

The general results obtained from an examination of the circumstances of the 1522 marriages are shown in the following table:

Husband's age at marriage	Number of marriages	Of which became fruitful	
		Number	Percentage
16–29	806	678	84
30–39	457	363	79
40–49	151	101	67
50–59	65	33	51
60 and upwards	43	7	16
All ages . . .	1,522	1,182	78

In only about one-third of the cases could the wife's age at marriage be ascertained. For these the results were as follows:

Wife's age at marriage	Number of marriages	Of which became fruitful	
		Number	Percentage
15, 16	6	6	100
17–19	103	90	87
20–22	151	131	86
23–25	107	91	85
26–28	57	47	82
29–32	41	32	78
33–37	16	8	50
38–42	6	2	33
43 and upwards	11	0	0
All ages . . .	498	407	82

In both tables the percentages run with great regularity, and the results are very similar in the two; so that, notwithstanding the comparative smallness of the numbers involved, the results appear entitled to great confidence.

In order to solve the second question proposed, and obtain the probability that a marriage which has been childless for several years will subsequently become fruitful, it is necessary to tabulate the marriages according to the year in which the first child was born. This is done in the following table, which relates to the 806 marriages of men under thirty. It shows that 292 of these became fruitful in the first year after marriage, 256 in the second, 72 in the third, and so on, until we come to a single marriage which became fruitful in the seventeenth year, after which none became fruitful. Deducting from the total of 806 the 292 marriages which became fruitful in the first year, and the 4 which were dissolved by the death of either husband or wife, we have 510 unfruitful marriages subsisting at the beginning of the second year, of which 386 (or 76 per cent.) subsequently became fruitful. The figures in the last column are obtained by division from those in the two previous ones, and give the probability required, which, we see, steadily diminishes to 20 per cent. at the beginning of the sixth year, 10 per cent. at the beginning of the eleventh, and 1 per cent. at the beginning of the seventeenth, after which it vanishes.

Year after marriage	Became fruitful	Unfruitful marriages dissolved by				Existing at beginning of year	Of which became fruitful	Probability of marriage being fruitful
		Death of		Divorce	All Causes			
		Husband	Wife					
1	292	2	2	—	4	806	678	·84
2	256	1	—	—	1	510	386	·76
3	72	3	2	—	5	253	130	·51
4	16	1	—	—	1	176	58	·33
5	13	—	2	—	2	159	42	·26
6	5	2	2	—	4	144	29	·20
7	5	1	2	—	3	135	24	·18
8	4	1	1	2	4	127	19	·15
9	1	—	—	—	—	119	15	·13
10	3	—	—	1	1	118	14	·12
11	5	—	1	—	1	114	11	·10
12	1	1	2	—	3	108	6	·06
13	2	—	—	—	—	104	5	·05
14	—	2	—	1	3	102	3	·03
15	—	1	1	—	2	99	3	·03
16	2	2	4	—	6	97	3	·03
17	1	2	—	—	2	89	1	·01
18	—	2	1	—	3	86	—	·00
19	—	2	1	—	3	83	—	·00
20	—	1	2	—	3	80	—	·00
Total .	678	24	23	4	51			

9. *On the relative Dangers of Coal and Metal Mining in the United Kingdom. By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

Referring to a statistical table published in the reports of the inspectors of mines for the year 1883, the author pointed out that the figures given for the annual death-rates from accidents at mines under the Coal Mines Regulation Act and Metalliferous Mines Regulation Act, viz., 2·23 and 1·64 per 1,000 respectively, do not convey a correct idea of the relative dangers of the two classes of mines, because the proportion of the surface workers with a small risk is twice as great in the metalliferous mines as in the coal mines. A true estimate can only be formed by comparing the deaths from accidents among the underground workers. The average annual mortality from accidents for the ten years 1874 to 1883 then becomes 2·55 per 1,000 at mines under the Coal Mines Act and 2·38 at mines under the Metalliferous Mines Act; consequently the relative dangers are expressed by the ratio 51 to 47, instead of 3 to 2, as appears to be the case when the surface hands and accidents are included.

The author also showed that though the Coal Mines Regulation Act includes mines worked for ironstone, slate, and fireclay, the general conclusion would not be vitiated because the largest ironstone mines, those in the Cleveland district, have a death-rate which is higher than the average of the mines under this Act. His general conclusions were that an average coal mine is very little more dangerous than an average metal mine, and that certain mines worked for metals, such as those in the Cleveland district, and the tin and copper mines of Cornwall, are comparatively more destructive of life than collieries.

WEDNESDAY, SEPTEMBER 3.

The following Papers were read:—

1. *The Banking System of Canada. By* H. J. Hague.

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2. *Prospective Prices in Europe, America, and Asia. By* Hyde Clarke, *V.P.S.S.*

The author objected to artificial averages of prices as calculated to mislead, and stated that the effect of prices was rather to be gauged by great and governing commodities, such as corn, which supplies the food of labour, and steel (iron), which furnishes its instruments and machines. With regard to vegetable and animal commodities, and even to man, the primary influence was due to the physical phenomena of the universe, and their cycles and fluctuations. He was the first to point out, in 1847, the periodical laws affecting natural production, and thereby, as the consequences, panics and crises. This, now dealt with as the sun-spot period, had been worked out by Professor Jevons, but Mr. Clarke still advocated the terms of his original propositions as most practically meeting the requirements of economical science. Steel, reduced by the improvements of Heath, Bessemer, and Siemens, and not by currency variations, from 60*l.* a ton, and so to 40*l.*, and now to 4*l.* or 5*l.* a ton for rails, had become a factor of prices under new conditions. Corn raised on prairie lands of uncropped fertility, and moved by cheap transport on land and sea, must also be regarded as produced under another economical standard. Therefore, so far as these elements were concerned, in their vast field of influence they contributed to the fall in prices and depression now witnessed. There was, however, a great economical event in progress, and needful for contemplation, and that is the change of condition and prices now going on in India, China, and Indo-China, embracing populations of 500,000,000. In India within our own time prices and wages had enhanced double, treble, and fourfold under the operation of railways, and this must go on. If the United States with 50,000,000 had Indian prices, her trade would be a few millions of pounds a year. If India, instead of daily wages of twopence-halfpenny, were at the United States rates, the population could abundantly consume imported manufactures. It was, therefore, to the progress of the world they chiefly had to look forward with hope.

3. *Harmonies and Antagonisms in the Social Forces.* *By* W. H. Douglass, *B.A.*

Many writers on economics have taught that all the social forces are harmonious. The intention of the writer is to show that in the social forces there are certain antagonisms.

Most text-books teach that exchange value is an essential characteristic of wealth. But wealth is directly proportionate to satisfaction and inversely to toil. We measure wealth by the increase of the ratio $\frac{\text{satisfaction.}}{\text{toil}}$ As the numerator increases or the denominator diminishes, wealth increases and poverty diminishes. When toil $= 0$, then poverty disappears, value disappears; but according to the above definition wealth disappears. The definition is therefore illogical.

Harmonies.—The carpenter by attending to one pursuit produces more than he otherwise could. The blacksmith does the same. Therefore, when they exchange, each receives more, and each is therefore enriched. If one is rewarded better than the other, this attracts competition. If one is more burdened than the other, this repels competition. There are therefore three harmonies—mutual enrichment, equable reward, equable burden.

In general, the methods of production as to time, place, implement, and other agents, are all harmonious, tending to the public weal.

Antagonisms.—(1) Fuel on the American continent was not long ago very abundant. Consumption has been rapid, population has increased, the ratio of supply to demand has diminished. Hence the community is poorer in this commodity. The value has increased: therefore the holders of the stores of fuel are richer. Here is enrichment on one side, impoverishment on the other.

What is true of fuel is true of minerals and land.

(2) The methods of producing many commodities have been much improved, so that labour produces in much greater abundance. This induces intensified competition in selling. The natural products, minerals and land, cannot be increased; hence as demand increases with increased population there is diminished competition. Here is a second antagonism—diminished competition against intensified competition.

The product of the poorest land in cultivation marks the limit of the wages of unskilled labour. The surplus over the wage fund (without taking into consideration the modifying force of capital) goes to rent. After population attains a certain degree of density, any increase of population compels resort to inferior sources of supply. This tends to diminish production. But poorer land being cultivated marks a decrease in the wage-fund, leaving more to rent, a third antagonism.

These examples show that exchanges are of two kinds: 1st, harmonious; 2nd, antagonistic.

They show to some extent why the producers are not the possessors of wealth.

They teach two important lessons:—

1st. Incidence of taxation.—Avoid imposing taxes that will counteract the harmonies. Impose taxes in such a way that they may tend to correct the antagonisms.

2nd. In disposing of the public lands such conditions should be imposed that these antagonisms may be prevented.

4. *Notes on Friendly Societies, with special reference to Lapses and Malingering. By the* Rev. G. Cecil White, *M.A.*

The development and stability of friendly societies is a matter of general interest and has recently engaged the attention of the Convocation of Canterbury, who have reported in favour of the more general establishment of deposit friendly societies. They were led to this by certain defects of the more common system. One of the chief of these relates to lapses, by which a member who thus withdraws forfeits the whole balance of his previous contributions as well as future benefits. The percentage of members lapsing varies between 3 and 50 per cent. of the total number. In one society, however, which has a deposit as well as a benefit branch, the percentage of secessions in the former is only half that in the latter; yet were it otherwise the loss to those withdrawing would be comparatively slight, as the chief part of their deposit balance would be recoverable. Some steps in the direction of making allowance for paid premiums will have to be made sooner or later to give this form of thrift fair play, and those societies will be the wisest which do not hesitate to increase their contributions with the view of doing full justice to their members.

The average duration of sick pay in deposit and friendly societies also presents a marked contrast. In the society on the dual basis already alluded to, the average sickness in the deposit branch, which admits female and even unhealthy members, was less than one-half of that at the benefit branch, which is confined more exclusively to healthy members. This, which tallies with more general experience, shows that the deposit system practically discourages malingering, and so protects a man against the unscrupulous action of others in this respect.

It does not, however, protect him against himself. Members have occasionally exhausted their deposits, and consequently been unable to claim sick pay when they have required it, while the fact that a large number withdraw even from deposit societies proves that a man's fund in them is insecure against himself.

This, though a comparatively slight evil, makes one hesitate to press the general establishment of deposit societies, and to some extent accounts for the slow progress they have hitherto made. Other causes also have contributed to this result, among which may be noted the necessary complication of the rules, the absence of the social element in most of those at present existing, and the slight interest which the members have been led to take in their management.

It seems therefore desirable that instead of establishing new deposit clubs in competition with existing benefit societies, endeavours should be made to induce the latter to adopt the dual basis, if proper safeguards can be provided, and to learn from experience the respective merits of the two systems.

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5. *The Commercial Relations of Canada with Spain and her Colonies.* *By* DON ARTURO DE MARCOARTU.

The following statement of the imports and exports between the Dominion with Spain and her colonies in America (Cuba and Porto Rico) and in the Pacific Ocean (Philippine Islands) shows the increase of this international trade in spite of very heavy tariffs on both sides—

IMPORTS OF THE DOMINION OF CANADA FROM THE FOLLOWING COUNTRIES.

	1877	1878	1879	1880	1881	1882	1883
	$	$	$	$	$	$	$
Spain	278,093	277,429	343,849	236,528	399,684	462,219	584,972
Spanish Antilles . . .	563,451	417,173	575,969	1,711,462	1,899,813	2,136,168	1,856,897
Total	841,544	694,602	919,818	1,947,980	2,299,497	—	—
Spanish Provinces in Pacific Ocean . .	—	—	210	31,648	221,956	5,675	136,247
Total	841,544	694,602	920,028	1,979,628	2,521,453	2,604,062	2,578,116
Ports of Canada were .	96,300,483	91,199,577	30,341,608	71,782,349	91,611,601	112,648,927	—

Decrease of the total imports from $96,000,000 (rough figures) to $72,000,000 in 1880, and increase to $112,000,000 in 1882.

Increase of imports at the Spanish Peninsula from $278,093 to $584,972 in 1883.

Increase of the Spanish Antilles from $563,451 in 1877 to $2,136,168 in 1882, and to $1,856,897 in 1883 (in the same period of time from 1877 to 1881).

Increase.—The imports from the United Kingdom, from $39,000,000 to $43,000,000.

Decrease.—The imports from the United States, from $51,000,000 to $36,000,000. About the same amount of imports, in the years between 1877 and 1881—from France $1,410,772 in 1877 and $1,663,266 in 1881; and from Holland $202,577 in 1877 and $225,190 in 1881.

Increase of imports from Germany and Belgium more than 160 per cent.

EXPORTS FROM CANADA TO THE FOLLOWING COUNTRIES.

	1877	1878	1879	1880	1881	1882	1883
	$	$	$	$	$	$	$
Spain	62,159	47,816	50,596	66,726	46,653	108,072	164,825
Spanish Antilles	1,284,375	1,089,807	1,237,528	1,319,588	1,167,612	1,078,273	932,222
Total	1,347,034	1,137,623	1,288,094	1,370,315	1,214,265	1,186,355	1,097,147
Total exports from Canada	75,875,383	79,323,667	71,491,255	87,911,458	98,290,823	102,137,203	—

During this period of time we find—

Decrease of the exports to the Spanish Peninsula from $62,652 to $46,653 in 1881, and increase to $164,979 in 1883.

From 1877 to 1882—

Increase of the exports to the United Kingdom from $41,000,000 in 1877 to $53,000,000 in 1881.

Increase with the United States from $25,000,000 in 1877 to $36,000,000 in 1881.

Increase about 100 per cent. with France, and more than 100 per cent. with Germany and Holland, and near 300 per cent. with Belgium.

Since the great trade made by the Dominion with the United States and the United Kingdom and her colonies, Spain with her colonies came in order of importance before France, Germany, and other nations.

THE TOTAL OF IMPORTS AND EXPORTS OF CANADA WITH THE SPANISH PENINSULA AND HER COLONIES ARE AS FOLLOWS.

	1877	1878	1879	1880	1881	1882	1883
	$	$	$	$	$	$	$
Imports of Canada	841,549	694,607	919,818	1,947,980	2,299,497	2,604,062	2,578,116
Exports from Canada	1,347,034	1,137,623	1,288,094	1,370,315	1,214,265	1,186,355	1,097,147
Total	2,188,583	1,832,230	2,207,912	2,318,295	3,513,762	3,790,417	3,675,263

This statement shows an increase from $2,183,583 in 1877 to $3,513,762 in 1881,—that is to say over 60 per cent.,—and $3,675,263 in 1883, or over 68 per cent. in 1883.

At the same years were the—

	1877	1881	1882
	$	$	$
Total of imports on Canada	96,300,487	91,611,604	119,412,500
Total of exports from Canada	75,875,393	98,290,827	102,137,203
Total	172,175,376	189,902,027	221,556,703

Or an increase of $172,000,000 to $190,000,000 in 1881,—an increase of 10 per cent.; and to $221,000,000 in 1882, or an increase of 29 per cent.

So in the very years (from 1877 to 1881) that the total commerce (imports and exports) of Canada has increased 10 per cent., the commerce of imports and exports of Canada with Spain and her colonies has increased 60 per cent.; and between 1877 and 1883, that the total commerce of Canada has increased 29 per cent., the imports and exports of Canada with Spain and her colonies have increased over 68 per cent.

As the result of studying the condition of trade between Canada and Spain and her colonies, the author comes to the following conclusions:—

1. That the commerce between Canada and Spain and her colonies is less than it ought to be, taking into consideration the wants of the two countries, the diversity of their productions, and the short distance they are apart.

2. That a great deal of the trade is done indirectly through other countries, especially England and France in Europe, and the United States in America.

3. That the Spanish-Canadian commerce has been increasing from 1877 more rapidly than the total trade of the Dominion. In the meantime, from 1877 to 1883, that the total commerce of the Dominion has increased about 29 per cent., the commerce of Canada with Spain and her colonies has increased 68 per cent.

4. That the Spanish Government has not a single prohibition in her tariffs, and that Canada has maintained for many years prohibitionist duties upon the Spanish wines, as some of these commodities are charged with 120 per cent. of their value.

5. That the alcoholic scale is antagonistic to the national development of the commerce of Canada with Spain; it is contrary to the sound and practical principle of political economy for the revenue of the Dominion; is prohibitive for the consumption of the labouring classes in this country, and antagonistic to their temperance, their comfort, and their health; is itself unequitable within its degrees and duties, and is iniquitous in regard to the other spirit duties.

6. That the heavy customs' duties of Canada upon the molasses, juicy cane, and sugar are against the industry of the sugar-refineries in Canada, are against the employment of the workmen in this country, and against the health and comfort of all classes—especially against the labouring people.

7. That the duties on the tobacco are against the development of another important industry in this country.

8. That Spain must diminish her tariff upon some products from Canada, and give more facilities to exportation all over the Spanish territory for the grains, fishes, fruits, cattle, meats, coals, butter, cheese, woods, leather products and machinery; at the same time that Canada must give facilities to import into this country the wines, spirits, molasses, juice of cane, sugar, fruits, oil, coffee, tobacco, salt, and other products from Spain and her colonies.

9. That as has been proposed by the Canadian Government, and already asked for, some association of this country is necessary to establish at once a regular line of steamers between Canada, Cuba, and Porto Rico, and to improve the telegraph and postal communications between the Dominion and West Indies.

The author has no doubt that this line of steamers, the improvement of telegraph and postal communication, and a liberal treaty of commerce between Canada and Spain, will open, with great results to over 4,500,000 inhabitants of this country, a market for the consumption of 25,000,000 Spaniards, or five times the population of the Dominion. He is quite certain that the commerce will be tripled in a very short time.

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6. *Forestry.* *By* J. Beaufort Hurlbert, *M.D., LL.D.*

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7. *The Forests of Canada.* *By* J. Beaufort Hurlbert, *M.D., LL.D.*

The forests of Canada extend from the Atlantic to the Pacific. The mixed forests of deciduous and coniferous trees cover the southern parts of the Dominion, and go as high as latitude 50° and 55°, in longitude 80° and 90° west, and to north of 60°, in longitude 120°, in the valley of the Mackenzie River. These forests probably cover two millions of square miles; and the conifers to the north an additional million. The cone-bearing trees are found in a broad belt west of the Rocky Mountains, sweeping around the shores of the North Pacific and Arctic seas, down the coasts of Hudson Bay and Labrador, and across the lower St. Lawrence, keeping in the cooler and more humid climates of the Pacific, Arctic, and Atlantic oceans. Among these forests are also found white birch and poplar.

The deciduous trees cover the parts of the continent having high temperatures and more or less copious rains in the summer months. The maple, beech, basswood (*linden*), elm, oak (*Quercus alba*), ash, and some others, require a summer of from 63° to 65°: and the white wood (*Liriodendron tulipifera*), buttonwood (*Platanus occidsntalis*), pepperidge (*Nyssa multiflora*), sassafras (*Sassafras officinale*), and others, are found only in the south of Canada, where the summers are higher than 65°.

The conifers are also found among the deciduous forests, and in some places predominate; but where they are burned down or die, their place is almost exclusively taken by deciduous trees. About 1850 a very extensive forest of pines (*Pinus Strobus*), covering many million acres in the south-west of Ontario, died. When the writer passed through that region in 1862, not one live pine could be found, but poplars, oaks, and other deciduous trees had sprung up in the dead forest.

The uniform rainfall during the summer months in Canada and the eastern half of the United States, with summer temperatures varying from 50° to 80°, are conditions favourable to the growth of forest trees. The absence of rain in the western half of the Republic is a sufficient cause for the absence over extensive regions of all vegetation except the cactus and artemesia, or sage of the desert—emblems of an arid region. Much of this part of the continent is, like the desert of Sahara, rainless, treeless, and desolate.

Between this arid region and that of the regular summer rains to the north and east—the areas of the woodlands—lie the prairies. In these grass zones there is not rain enough for forest trees, but enough to keep alive the wild grasses. The tops of these die during the droughts of summer, but the roots have vitality enough to germinate under the rains of autumn and spring. Trees, however, which may have been killed by droughts have no such vitality. North of the parallel of 49°, east of the Rocky Mountains, there are about 120,000 square miles of prairie land. Between this and the north Saskatchewan, to latitude 53° and 54°, prairies predominate; north of that river two-thirds of the land is covered with forests. Along the eastern base of the Rocky Mountains, and extending up into their recesses, is a belt of conifers, the principal tree being the Douglas pine (this tree is, however, an *Abies*), and the white and black spruce. East of the mountains the watersheds are mostly covered with heavy forests of spruce, but the dry ground, where there are trees, with poplars (*Populus tremuloides*). The balsam poplar (*P. balsamifera*) grows to an enormous size on the Athabaska (latitude 55° to 58°) and Mackenzie rivers (north of 60°), often from seven to ten feet in diameter, and one hundred feet in height.

The forests of British Columbia west of the Cascade Mountains are very fine, and here the Douglas pine or spruce (*Abies Douglasii*) and giant cedar attain their greatest dimensions. On the western slopes of the Rocky Mountains are many species of pine and fir, which in the near future can supply the eastern plains with enormous quantities of timber.

The comparative value of prairie and woodland for agricultural purposes is a question often discussed. The absence of trees is undoubtedly caused by a climatic defect, and that defect is manifestly the deficiency of moisture. The areas of summer droughts in the Old and New Worlds, in Australia and South America, are identical with the treeless regions. This climatic defect must operate permanently and with increasing intensity upon plants where such lands are brought under culture. A climate destructive to trees could not be propitious to fruit-trees, and certainly not to any of the grains, grasses, and root-crops. Temperature and rainfall during the summer months are the conditions of climate most favourable to the productions of the earth. The absence or deficiency of one of these elements must necessarily render climates less propitious to plants. Forest lands are permanently the most profitable, and produce more abundant and more uniform crops. Prairies, in high latitudes, as in Minnesota and especially in Manitoba, have a greater rainfall and more humidity than the regions to the south and south-west, and sufficient to produce fine crops. But these are on the northern limits of the prairie lands. No doubt the preference is given to prairies from the greater facility in bringing them under culture, but the chief consideration should be the permanent quality of the soil and especially of the climate, and not the facility of beginning.

The conditions in Canada in connection with forests are very different from those in old countries where, through centuries of hewing and hacking, forests have been destroyed, and especially different from regions to the parts of the western prairies of America, and the desert areas of the Old and New Worlds, where, from the severe summer droughts, it is difficult, and in many parts impossible, to get trees to grow.

The most pressing want throughout the Dominion is the reservation of a certain percentage of the pristine forests. Many efforts have been made, for a quarter of a century or more, to induce the Governments of the provinces to require from the purchasers the reservation in forests of from one quarter to one half of every farm of 200 acres. So favourable is the climate in Canada to the growth of trees that when a field has been left untilled for a few years it is covered by many varieties of native woods.

Section G.—MECHANICAL SCIENCE.

President of the Section—Sir F. J. Bramwell, LL.D., F.R.S., V.P.Inst.C.E.

THURSDAY, AUGUST 28.

The President delivered the following Address:—

In a family of seven children there are two who are of paramount importance: the eldest, at the one end of the scale, important, because he is the heir, the first-born; and at the other end of the scale, the little Benjamin, important because he is the last, the youngest, and the dearest. The position of little Benjamin is not, perhaps, quite as honourable as that of the heir, and not, when the family breaks up, by any means as good; but while the family holds together, Benjamin receives an amount of attention and consideration that does not fall to the lot of any one of the intermediates, not even to the heir himself. But there is one risk about Benjamin's position, a risk that cannot appertain to the post of the first-born; little Benjamin may be deposed by the advent of a lesser Benjamin than himself, whereas the first-born becomes (if possible) still more the first-born for each addition to the family. Perhaps some of you may say, Be it so; but what has this to do with the address of the President of Section G? Those who make this inquiry, however, certainly have not present to their minds the change that has this year taken place. Up to and including the Southport meeting, Section G was the little Benjamin among the seven sons of the B.A. (I will not waste your time by giving the name of the Association in full, nor will I affront you by using an abbreviation which is occasionally improperly applied), but at Montreal appears Section H, and G becomes relegated among those uninteresting members of the family who are neither the important head nor the cherished tail. I grieve for Benjamin, and I think the present occasion an apt one for magnifying Section G. Apt for two reasons: the foregoing one, that H has deposed it from its position; the other, that we are meeting in Montreal—and in reference to this latter reason, let me ask, Is it not the fact that to the labours of the men who have been, or are (or ought to be) members of Section G is due the possibility of the meeting taking place on this side of the Atlantic?

At our jubilee meeting at York, I called the attention of the Section to the fact that in 1831, when the Association first met in that city, they arrived there laboriously by the stage-coach, and that practically the Manchester and Liverpool, the Stockton and Darlington, and some few others, were the only railways then in existence. I also called their attention to the fact that in 1831 there were but very few steamers. I find the total number registered in the United Kingdom in that year was only 447. If under this condition of things, the proposition had been made in 1832 at Oxford, as it was made in 1882 at Southampton, that the next meeting but one of the Association should take place in Montreal, the extreme probability is that the proposer would have been safely lodged in a lunatic asylum, for suggesting that that which might have involved a six-weeks' voyage out, and a four-weeks' voyage back, could ever be seriously entertained. Further, to give once more the hackneyed quotation, some few years after this, *i.e.*, in 1836, Dr. Lardner established to his own satisfaction conclusively, that no vessel could ever steam across the Atlantic the whole way. A striking instance of the mistakes made by scientific speculation; a branch of science widely differing in the value of its results from those branches which deal with absolute demonstration. Undeterred, however, by such adverse opinion, the engineers 'kept on pegging away,' experimenting, improving, and progressing, until the scientific speculation was met with the hard fact of the Atlantic voyage steamed the whole way by the 'Sirius' and by the 'Great Western' in 1838. The impossible was proved to be the possible, and from that day to this the advancement of steam ocean navigation has continued. The six-weeks' voyage, sailing westward of the year 1831, has become converted into but little over six days. And thus it is that that which would have been a mad proposition in the year 1832, became a perfectly rational one in 1882; and the deliberations of the General Committee on the proposition were not directed as to whether it would be possible to convey the members with certainty, expedition, and economy across the Atlantic, but as to whether it was expedient or not on general grounds to hold for the first time a meeting of the British Association elsewhere than in some city of the United Kingdom. I say again that the possibility of such a meeting is absolutely due to the engineer, and that therefore, on this ground, the present is an appropriate occasion to magnify G, the Mechanical Section of this Association.

It is true that the man who looks only at that which is on the surface may say, 'You arrogate too much to yourselves. You ignore (to which I say Heaven forbid!) the skill and daring of your sailors. You ignore commercial enterprise. You ignore the development of iron and steel manufacture, which have enabled you to build the steamers of the present day. You ignore the increased output of the best steam coal in the world, and you attribute the whole result to the engineer.' Such an objector would be in the condition of that man who, in answer to George Stephenson's question, 'What is causing that railway train to move?' said, 'Why, I suppose the coal that is burning in the locomotive;' and who was met by that grand and comprehensive answer, that it was the 'Sun,' for the coals were a consequence, and not a first cause. Similarly I venture to say that the mechanical engineer may lay claim to be the central source which has vivified and given rise to the improvements in the manufacture of iron and steel, in the construction of engines, and in the development of our collieries.

There are those I know who object that Section G deals too little with pure science, too much with its applications. It may be as the members of Section G might retort, that it is possible to attend so much to pure science as to get into the unchecked region of scientific speculation, and that had the members of Section G been debarred from the application of science, the speculation of Dr. Lardner might to the present day have been accepted as fact.

I have quoted it before, but it has so important a bearing on this point, and comes from a man of such high authority, that I cannot refrain from once more giving you Dr. Tyndall's views on this question.

'The knowledge of nature, and the progressive mastery over the powers of 'nature, imply the interaction of two things—namely, thought conceived and 'thought executed; the conceptions of the brain, and the realisation of those con-'ceptions by the hand. The history of the human intellect hardly furnishes a more 'striking illustration of this interaction of thought and fact than that furnished by 'the Association of Physics and Engineering. Take for instance the case of steam. 'Without knowing its properties, the thought of applying steam could not have 'arisen, hence the first step was physical examination. But that examination 'suggested practice, and the steam-engine at last saw the light; thus experimental 'physics was the seedling from which the steam-engine sprang. But the matter did 'not end here; the positions of debtor and creditor were soon reversed, for the 'stupendous operations of the steam-engine forced men of thoughtful philosophic 'minds to inquire into the origin of the power of steam. Guess succeeded guess, 'inspiration succeeded inspiration; the ever present fact of our railways, and our 'power-looms, and our steamships gave the mind no rest until it had answered the 'question, How are heat and steam, its instruments, related to mechanical power? 'Had the works of the engineer not preceded the work of the natural philosopher, 'this question would never have been asked with the emphasis, nor pursued with 'the vigour, nor answered with the success, which have attended it. It was the 'intellectual activity excited by the work which the civil engineers of England had 'accomplished that gave to philosophy the theory of the conservation of energy 'including the dynamical theory of heat. . . . The engineering genius of the future 'is certain to derive from this theory strength and guidance. Thus necessarily has 'thought originated fact, and fact originated thought. In the development of 'science these two powers are coequal; each in turn ceasing to be a consequence, 'and becoming a creative cause. The Atlantic cable also had its small beginnings 'in the laboratory of the physical inquirer. Here, as before, experimental physics 'led the way to engineering facts of astounding magnitude and skill. But here also 'the positions of debtor and creditor have been reversed, for the work of the 'engineer has caused the physical inquirer to pursue his investigations with a 'thoroughness and vigour, and has given to those investigations a scope and magni- 'tude which, without the practical stimulus, would have been impossible. The 'consequence is that the practical realisation of sending electric messages along the 'bottom of the Atlantic has been an immense augmentation of our knowledge 'regarding electricity itself. Thus does the human intelligence oscillate between 'sound theory and sound practice, gaining by every contact with each an accession 'of strength. These two things are the soul and body of science. Sever sound 'theory from sound practice, and both die of atrophy. The one becomes a ghost 'and the other becomes a corpse.'

I think all men, even although they be followers of science in its purest and most abstract form, must agree that these words are words of sound sense, well worthy of being borne in mind and of being acted on, and will, therefore, concur in the propriety of Section G dealing with engineering subjects generally as well as with abstract mechanical science. Once admitting this, I may ask—certain what the answer must be—whether there is any body of men who more appreciate and make greater use of the applications of pure science than do the members of this Section. Surely every one must agree that we engineers are those who make the greatest practical use not only of the science of Mechanics but of the researches and discoveries of the members of the other sections of this Association.

Section A, *Mathematical and Physical Science*. The connection between this Section and Section G is most intimate. With any ordinary man I should have referred, in proof of this intimate connection, to the fact that the President of A this year is a member of the Council of the Institution of Civil Engineers, but when I remind you that it is Sir William Thomson who fills this double office, you will see that no deduction such as I have hinted at can be drawn from his dual functions, because the remarkable extent and versatility of his attainments qualify him for so many offices, that the mere fact of his holding some one double position is no certain evidence of the intimate connection between the two. But setting aside this fact of the occupancy of the chair of A by a civil engineer, let us remember that the accomplished engineer of the present day must be one well grounded in thermal science, in electrical science, and for some branches of the profession in the sciences relating to the production of light, in optical science and in acoustics; while, in other branches, meteorological science, photometrical science, and tidal laws are all important. Without a knowledge of thermal laws, the engineer engaged in the construction of heat motors, whether they be the steam engine, the gas engine, or the hot-air engine, or engines depending upon the expansion and contraction under changes of temperature of fluids or of solids, will find himself groping in the dark; he will not even understand the value of his own experiments, and therefore will be unable to deduce laws from them; and if he make any progress at all, it will not guide him with certainty to further development, and it may be that he will waste time and money in the endeavour to obtain results which a knowledge of thermal science would have shown him were impossible. Furnished, however, with this knowledge, the engineer starting with the mechanical equivalent of heat, knowing the utmost that is to be attained, and starting with the knowledge of the calorific effect of different fuels, is enabled to compare the results that he obtains with the maximum, and to ascertain how far the one falls short of the other; he sees even at the present day that the difference is deplorably large, but he further sees in the case of the steam engine, that which the pure scientist would not so readily appreciate, and that is, how a great part of this loss is due to the inability of materials to resist temperature and pressure beyond certain comparatively low limits; and he thus perceives that unless some hitherto wholly unsuspected, and apparently impossible, improvement in these respects should be made, practically speaking the maximum of useful effect must be far below that which pure science would say was possible. Nevertheless, he knows that within the practical limits great improvements can be made, he can draw up a debtor and creditor account, as Dr. Russell and myself have done, and as has been done by Mr. William Anderson, the engineer, in the admirable lecture he gave at the Institution of Civil Engineers in December last on The Generation of Steam and the Thermo-dynamic principles involved. Furnished with such an account, the engineer is able to say, in the language of commerce, I am debtor to the fuel for so many heat units, how, on the credit side of my account, do I discharge that debt? Usefully I have done so much work, converted that much heat into energy. Uselessly I have raised the air needed for combustion from the temperature of the atmosphere to that of the gases escaping by the chimney; and he sets himself to consider whether some portion of the heat cannot be abstracted from these gases and be transmitted to the incoming air. As was first pointed out by Mr. Anderson, he will have to say a portion of the heat has been converted into energy in displacing the atmosphere, and that, so far as the gaseous products of the coal are concerned, must, I fear, be put up with. He will say, I have allowed more air than was needed for combustion to pass through the fuel, and I did it to prevent another source of loss—the waste which occurs when the combustion is imperfect; and he will begin to direct his attention to the use of gaseous or of liquid fuel, or of solid fuel reduced to fine dust, as by Crampton's process, as in these conditions the supply may be made continuous and uniform, and the introduction of air may be easily regulated with the greatest nicety. He will say, I am obliged to put among my credits—loss of heat by convection and radiation, loss by carrying particles of water over with the steam, loss by condensation within the cylinder, loss by strangulation in valves and passages, loss by excessive friction or by leakage; and he will as steadily apply himself to the extinction or the diminution of all such causes of loss, as a prudent Chancellor of the Exchequer would watch and cut down every unproductive and unnecessary expenditure. It is due to the guidance of such considerations as these that the scientific engineer has been enabled to bring down the consumption of fuel in the steam engine, even in marine engines such as those which propelled the ship that brought us here, to less than one-half of that which it was but a few years back. It is true that the daily consumption may not have been reduced, that it may be even greater, but if so it arises from this, that the travelling public will have high speed, and at present the engineer, in his capacity of naval architect, has not seen how—notwithstanding the great improvements that have been made in the forms of vessels—to obtain high speed without a large expenditure of power. I anticipate from the application of thermal science to practical engineering, that great results are before us in those heat motors, such as the gas engine, where the heat is developed in the engine itself. Passing away from heat motors, and considering heat as applied to metallurgy: From the time of the hot blast to the regenerative furnace, it is due to the application of science by the engineer that the economy of the hot blast was originated and that it has been developed by the labours of Lowthian Bell, Cowper, and Cochrane. Equally due to this application are the results obtained in the regenerative furnace, in the dust furnace of Crampton, and in the employment of liquid fuel, and also in operations connected with the rarer metals, the oxygen furnace and the atmospheric gas furnace, and, in its incipient stage, the electrical furnace. To a right knowledge of the laws of heat and to their application by the engineer, must be attributed the success that has attended the air-refrigerating machines, by the aid of which fresh meat is at the end of a long voyage delivered in a perfect condition; and to this application we owe the economic distillation of sea water by repeated ebullitions and condensations at successively decreasing temperatures, thus converting the brine that caused the Ancient Mariner to exclaim, 'Water, water everywhere, nor any drop to drink,' into the purest of potable waters, and thereby rendering the sailor independent of fresh-water storage.

With respect to the application by the engineer of electrical science, it is within the present generation that electricity has passed from the state of a somewhat neglected scientific abstraction into practical use: first, by the establishment of the land telegraph, then by the development into the submarine cable, by means of which any one of us visitors here in Canada may be in instant communication with his own country, and may be so without a selfish exclusive occupation of the cable, for once more the application of science has solved that apparently impossible problem of employing a single wire to be at one and the same time the transmitter of multiple electric messages, and messages in opposite directions. Then, thanks to the application of Faraday's great discovery of induced electricity, there has been, during the last quarter of a century, the progressive development of the dynamo-machine, whereby the energy of ordinary motors, such as steam engines, is converted into electrical energy, competent to deposit metals, to (as has already been said) fuse them, to light not only isolated buildings, but extensive areas of towns and cities, and to transmit power to a distance, whether for manufacturing purposes or for the railway or tramcar; and thus the miracle is performed of converting a waterfall into a source of light, as at Sir William Armstrong's house, or into the origin of power for a railway, as at the Giant's Causeway. To the application of electrical science is due the self-exciting of the dynamos and the construction of secondary batteries, enabling a development of electricity to be continued for many hours. In the United Kingdom, general electric-lighting, that is to say, the lighting of large sections of a town from a central station, has been stopped by the most unwise, because most unjust, conditions imposed by the Government General Electric Lighting Act of 1882. A new and meritorious industry, which should have been granted the same privileges as are accorded to other industrial undertakings needing Parliamentary powers, was subjected to this most unjust condition: that at the end of twenty-one years the public authority of the town or place lighted should have the option of buying the undertaking for the then value of the mere materials, and that if the authority did not choose to purchase (for it was not bound to buy), at every subsequent five-year period this option should re-arise; that is to say, that a new undertaking, which would require years for its general acceptance (for the public is slow to take up a novelty), was, after the experimental and non-paying stage had been passed, to be practically forthwith taken away for a mere fraction of the capital that had been outlaid if the undertaking paid, but was not to be taken away if it did not pay. Such, in spite of the teaching of Section F, is the condition to which our Government has arrived in respect of economic science. The next electrical matter I have to touch upon, that of the telephone and microphone, with which will for ever be associated the names of Graham-Bell, Edison and Hughes, has, as regards the public use of the telephone, been all but similarly treated in the United Kingdom. It has been declared to be within the telegraphic monopoly given by Parliament to the Post Office nine years before the telephone was invented, and the power to use it depends entirely upon the grace and favour of the Post Office, a grace and favour not always accorded; and even when accorded, coupled with limitations as to distance, and coupled with a condition of payment of 10 per cent. of the gross receipts by the companies to the Post Office as a royalty; and all this because Government has become a trader in electrical intelligence, and fears the competition of the telephone with its telegraphs.

No one in the ship-loving countries of England, Canada, and the United States can refrain from feeling the warmest interest in all connected with navigation, and we know how frequently, alas! the prosperous voyage across the wide and fathomless ocean ends in shipwreck and disaster when the wished-for shore is approached, and when the sea is comparatively shallow. Except for the chance of collision, there is in a staunch ship little danger in the open ocean, but on nearing the shore, not only is the liability to collision increased, but shoals and sunken rocks render navigation perilous, and it is on the excellence of the lighthouses and lightships that (coupled with soundings) the sailor relies. These structures and appliances are confided to the engineer, and to be efficient they require him to be able to apply the teachings of Section A in optical science, and in the case of fogs, or as regards buoys at night-time, the science of sound. I parenthetically alluded to soundings as one (indeed a principal one) of the safeguards of ships when approaching shore. It is important in these days of high speeds that these should be made with ease and without the necessity of stopping the ship, or even of diminishing its velocity. Sir William Thomson, by the application of the science of pneumatics, has enabled this to be done. Again, most important is it that the compass, midst all the difficulties attendant upon its being situated on an iron or steel structure, should be trustworthy. And here Sir William has applied the science of magnetism in his improved compass to the practical purposes of navigation.

To go to another important branch of engineering—water supply. The engineer dealing with a district to be fed from the surface will find himself very deficient if he have not the power of applying the science of meteorology to the work that he has in hand; he must know, not the average rainfall, for that is of but little use to him, but the maximum, and most important of all, the minimum rainfall over a consecutive period of years: the maximum so that he may provide sufficient channels and by-washes for floods; the minimum so as to provide sufficient storage. He must know what are the losses by evaporation, what are the chances of frost interfering with his filters and with his distributive plant.

Coming to the mathematical side of Section A—whether we consider the naval architect preparing his design of a vessel to cleave the waves with the least resistance at the highest speed, or whether we consider the unparalleled series of experiments of that most able Associate of Naval Architects, the late William Froude, carried out as they were by means of models which were admirable in their material, their mode of manufacture with absolute accuracy to the desired shape, and their mode of traction and of record, we must see that both architect and experimenter should be able to apply mathematical science to their work, and that it is in the highest degree desirable that they should possess, as Froude did, those most excellent gifts, science and practical knowledge.

Again, the mathematical side of Section A has to be applied by engineers when considering the strength and proportion of boilers, ships, bridges, girders, viaducts, retaining walls, and in short the whole of the work with which an engineer is intrusted. Notable instances of great bridges will occur to all our minds, especially meeting as we are in this Continent of grand streams, Stephenson's Tubular Bridge in this city, Eads' St. Louis Bridge, Roeblings' Niagara Bridge, and his and his sons' East River Bridge, Hannaford and Gzowski's International Bridge, and going back to our own land, Fowler and Baker's Bridge over the Forth.

Passing from Section A to Section B, there is evidently so much overlapping of these sections that a good deal that I have said in reference to Section A might properly have been reserved for Section B. The preparation from the ore of the various metals is in truth a branch of engineering; but to enable this to be accomplished with certainty, with economy, involving the not throwing away of that which is called the waste product, but which is frequently a valuable material, it is essential that the engineer and the chemist should either be combined in one and the same person, or should go hand in hand. In the manufacture of pig iron it is absolutely necessary that the chemical constituents of the ore, the fuel, and the flux should be thoroughly understood, and that the excellence of the process followed should be tested by an analysis of the slag. For want of this chemical knowledge thousands upon thousands of tons of bad pig iron have been made, and thousands upon thousands of tons were formerly left in the issuing slag. Similar remarks apply to the production of lead and of copper from the ores, and still more do they apply to that great metallurgical manufacture of the last few years—'steel.' In the outset steel was distrusted because of the uncertainty of its behaviour, but the application of chemical science now enables the manufacturer to produce with precision the material required to fulfil the physical tests imposed by the engineer.

Reverting to the water engineer, the chemist and the microscopist have their sciences applied to ascertain the purity of the intended source, and, as in the case of Clarke's beautiful process, by the application of chemistry, water, owing its hardness to that common cause, carbonate of lime, is rendered as soft as the water from the mountain lake. Taking that other branch of engineering commonly coupled with water, viz., the supply of gas, the engineer is helpless without the application of chemistry. From the examination of the coal to be used, to the testing of the gas to be supplied, there is not one stage where chemical science is not necessary. The consumer requires gas which shall be as nearly as possible a pure hydrocarbon of high illuminating power, and it might well have been that a person to whom was delivered the crude gas as it issued from the retort would have said, 'Certain things may be separated out more or less, but to practise on a wholesale scale the delicate operations which will be needed to cleanse the illuminating gas from its multifarious accompanying impurities is a hopeless undertaking, and must be so if for no other reason than this—the excessive cost that would be entailed.' But what are the facts? Although I for one do not like to sit in a room where gas is burnt, unless special provision is made for taking away the products of combustion, the engineer of the present day, thanks to the application of chemical science, delivers gas to the consumer in a state of comparative purity (although it may have been made from impure coal) which but a few years ago would have been deemed impossible; and so far is this improvement from being attended with extra cost, that the residual products not now uncommonly all but pay the whole cost of the coal, and in some rare instances even leave a slight profit to go towards the charge for labour. Again, it is by the application of chemical science in the dynamite and the gun-cotton of the present day that the engineer is enabled to prepare submarine foundations, to blast away shoals, and to drive tunnels through rock of a character that cannot be dealt with by mere cutting-machines. Equally to the application of chemistry is it due that there are hopes, by the employment of lime cartridges, of breaking down coal without that risk of igniting fire-damp which is attendant upon the use of gunpowder. I need hardly observe that much more might most pertinently be said on the way in which the engineer applies chemical science. In fact, those ways are so multifarious, that a volume might be written upon them, but I must pass on and ask you to consider how the engineer applies geological science, the science treated by Section C.

I have already spoken of the engineer supplying towns by water collected from the surface; even he, however, must have a knowledge of geology, for without it he will not know what places are apt for the huge reservoirs he constructs, nor where he can in safety make his enormous embankments. In this continent of vast lakes one feels it must excite a sensation of the ridiculous when a 'Welsh lake' is spoken of, but I must ask you to believe you are in Lilliput, and to imagine that the 'Bala Pond' of eleven hundred acres in extent is really 'Bala Lake,' as it is called. Within a few miles of that, our friends at the other end of the Atlantic steam ferry, the inhabitants of Liverpool, are now constructing, under the engineering and advice of Mr. Hawksley, waterworks which will involve the formation, I believe one may safely say the re-formation, of a lake, practically the same area as that of Bala, of some 80 feet in depth, and containing between the overflow and the point of lowest discharge nearly twelve thousand million gallons. This lake will be made by the throwing from side to side of the valley of a solid stone bank, 100 feet above the ground, 146 feet above the deepest part of the foundations, and 113 feet thick at its thickest part. Contrasted with Lake Superior this new lake will be small, a thing even demanding a microscope, but the bursting of the wall would liberate a body of water sufficient to carry death and ruin throughout a considerable district. It is, therefore, in the highest degree important that whether he be constructing the solid stone wall, or the more common earthen embankment with a puddle trench, the engineer should so apply geological science as to ensure the safety of his work. But in those cases where the waterworks engineer has to derive the supply from underground sources, the application of this science is still more necessary; he must know whether he is likely to find a water-bearing stratum at all—if so, where it receives the rain from heaven, and the extent of the area which receives it; in what direction the water travels through it, what is the varying height of water in the different parts of the stratum giving the 'head' to produce that travel; how far this height is likely to be affected by the pumping of the desired quantity; whether, if near the outflow into the sea, the pumping is likely to reverse the direction of the current, and to bring back brackish water, and whether the rocks are of such a character as to be liable to yield a water impregnated with iron or with lime, and whether these water-bearing rocks are accessible from the surface without the execution of costly and laborious work in passing through overlying strata of an unfit or it may be even of a dangerous character. It need hardly be said that the engineer when engaged in metalliferous mining, or in the extraction of coal or of petroleum, unless he applies the science of Section C, is but a haphazard explorer whose work is more likely to end in disaster than in success. Again, the engineer, when laying out a railway, has to consider the geological features of the country in fixing the angles of his cuttings, and in determining where it becomes more economical to tunnel than to cut. Indeed, without the application of that science to engineering there are some enterprises on the feasibility of which the engineer would not be able to pronounce an opinion—a notable instance, the Channel Tunnel. The engineers, of whom I am one, said there is a material, the compact non-water-bearing grey chalk, which we have at a convenient depth on the English side, and is of all materials the most suitable; if that exist the whole way across, success is certain. Then came geological science, and that told the engineer that in France the same material existed; that it existed in the same position in relation to other formations as it existed in England; that the line of outcrop of the gault lying below it had been checked across; and that taken together, these indications enabled a confident opinion to be expressed that it was all but certain this bed of grey chalk did prevail from side to side. The engineers believed it, an intelligent section of the public believed it, and came forward with their money; large sums were expended in England and in France on the faith of the repeated declaration of the English Government (of both sides of politics), that so long as the nation was not called on to contribute towards the cost of the work, it would hail with satisfaction the improved means of communication between England and the Continent; the experimental works were carried on from both sides with the happiest results, and then, when success appeared certain, the whole work was stopped by the incredible suggestion that in the event of a war the soldiers of England, and the science of England, could not defend a couple of rat-holes, holes 14 feet in diameter and 20 miles long, situated far below the surface of the sea, having a rapid dip from the shore to a low point, gradually rising from there to the centre of the length of the tunnel, so that the English end could be flooded with sea-water in twenty-five minutes up to the soffit of the arch at the dip; and in consequence of this incredible and most-to-be-ashamed-of scare a stop has been put not only to one of the finest instances of civil engineering work in connection with the science of geology, but also as I believe to one of the most useful works that has ever been proposed.

To come to Section D, the botanical side of it is interesting to the engineer as instructing him in the locality and quality of the various woods that he occasionally uses in his work. With regard to that most important part of the work of D, which relates to 'germs' and their influence upon health, the engineer deals with it thus far: he bears in mind that the water supply must be pure, and that the building must be ventilated, and that excreta must be removed without causing contamination; thus the waterworks engineer, the warming and ventilating engineer, and the sewage engineer can (and do) all of them profit by the labours of Section D, and can by their works assist in giving practical value to the pure science of that section.

Section E, *Geography*. Probably in these days, when our kingdom at home and the old countries near us are all but full of the works of the engineer, there are few who take a greater interest in geography than he does, and I am quite sure there are none who make a more useful application of geographical knowledge for the benefit of mankind at large than does the engineer. Almost at the outset of this address I claimed to magnify Section G, on the ground that without the aid of its members we should not have had that practical lesson in geography which we have received by our visit here, a lesson that no doubt will be continued and amplified by many of us before we return to our homes. Whether it be by the ocean steamer or by the railway train, the enterprising geographical explorer is carried to or through countries which now, thanks to the engineer, are well known and settled, up to the beginning of the unknown and not settled; and thus his labours are lightened, he consumes his energies only upon his true work, brings back his report, which is, as I have said, studied by the engineer with a view to still further development, and thus turn by turn the geographer and the engineer carry civilisation over the face of the world.

Now to come to Section F, which treats of Economic Science. The matters with which this section deals—birth-rate, death-rate, the increase or the diminution of populations, the development of particular industries in different localities, the varying rates of wages, the extent and nature of taxation, the cost of production, the cost of transport, the statistics of railway and of marine disasters, the consumption of fuel, and many matters which come within the purview of Section F, are of importance to the engineer. Guided by the information given him by the labours of this section, he comes to the conclusion that a work having a particular object in view should or should not be undertaken. With the information derived from the past he judges of the future; he sees what provision should be made for prospective increase of population or of industries; he sees the chances of the commercial success of an undertaking or of its failure, and he advises accordingly.

I do not propose to say anything about Section H, for I have dealt with it as being still included within D.

I trust I have now established the proposition with which I set out, viz., that not only is Section G the section of Mechanical Science, but it is emphatically the section of all others that applies in engineering to the uses of man the several sciences appertaining to the other sections: an application most important in the progress of the world, and an application not to be lightly regarded, even by the strictest votaries of pure science, for it would be vain to hope that pure science would continue to be pursued if from time to time its discoveries were not brought into practical use.

Under ordinary circumstances I should have closed my address at this point, but there is a subject which at this, the first meeting of Section G after the meeting at Southport, must be touched upon. It is one of so sad a character that I have avoided all allusion to it until this the very last moment, but now I am compelled to grapple with it.

In the course of this address I have had occasion to mention several names of eminent men, many of them happily still with us, some of them passed away; but I doubt not you have been struck by the absence of one name, which of all others demands mention when considering physical science, and still more does it come vividly before us when considering the application of science to industrial purposes. I am sure I need not tell you that this name, which I can hardly trust myself to speak, is that of our dear friend William Siemens, whose contributions to science, and whose ability in the application of science, have for years enriched the transactions of this section, and of Sections A and B, for in him were combined the mechanic, the physicist, and the chemist.

But a brief year has elapsed since he quitted the Presidential chair of the Association, and, with us at Southport, was taking his accustomed part in the work of this and of other sections, apparently in good health, and with a reasonable prospect of being further useful to science for many valuable years to come. But it was not to be; he is lost to us, and in losing him we are deprived of a man whose electrical work has been second to none, whose thermic work has been second to none, and whose enlarged views justified him in embarking in scientific speculations of the grandest and most profound character. Whether or not his theory of the conservation of the energy of the sun shall prove to be correct, it cannot be denied that it was a bold and original conception, and one thoroughly well reasoned out from first to last.

I feel that were I to attempt anything like the barest summary of his discoveries and inventions, I should set myself a task which could not have been fulfilled had I devoted the whole of the time I had at my command to the purpose. I had, indeed, thought of making his work the subject of my address, but I felt that his loss was so recent that I could not trust myself to attempt it. There is no need for me to dwell further upon this most painful topic. He was known to you all, he was honoured and loved by you all, and by every member of this Association he had so faithfully served, and over which he had so ably presided; and he enjoyed the respect and esteem of the best intelligence of England, the land of his adoption; of the Continent, his birthplace; and of Canada, and of the United States, whose populations are always ready to appreciate scientific talent and the resulting industrial progress. It is not too much to say that few more gifted men have ever lived, and that with all his ability and talent he combined a simplicity, a modesty, and an affectionate disposition that endeared him to all.

I am sorry to conclude my address to you in this mournful strain. I have endeavoured to confine my allusions to our dear friend within the narrowest limits, but if I have overstepped these I trust you will forgive me, remembering that 'out of the fulness of the heart the mouth speaketh.'

The following Papers were read:—

1. *The Forth Bridge.* *By* BENJAMIN BAKER, *M.Inst.C.E.*

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2. *The Severn Tunnel Railway.* *By* J. CLARKE HAWKSHAW, *M.Inst.C.E.*

This paper described the Severn Tunnel Railway works, begun in 1873, and now approaching completion. The railway is being made to shorten the direct railway route between the South of England and South Wales. It passes under the River Severn about half a mile below the present steam ferry, which connects the South Wales and Bristol and New Passage lines. The river, or estuary, is about $2\frac{1}{4}$ miles wide. The length of the line is $7\frac{1}{2}$ miles, of which $4\frac{1}{3}$ miles is in the tunnel which passes under the Severn. The bed of the river is formed principally of Trias rocks (marls, sandstones, and conglomerates), in nearly horizontal strata. These overlie highly inclined coal measure shales and sandstones, which are also exposed in the river bed. The tunnel is made almost wholly in rocks of the Trias and Coal-measure formation, the exception being a little gravel passed through near the English end.

The lowest part of the line is below the shoots, the deepest part of the river, where there is a depth of 60 feet of water at the time of low water, and 100 feet at the time of high water. Below the shoots the line is level for 13 chains, rising 1 in 100 to the English end, and 1 in 90 to the Welsh end. Below the shoots there is a thickness of 45 feet of rock (Pennant sandstone) over the brickwork of the tunnel. Under the Salmon Pool there is less cover, only 30 feet of Trias marl. Much water has been met with throughout the works, which have been flooded on several occasions. In 1879, the works under the Severn were drowned for some months by the eruption of a large land spring into one of the driftways under land on the Welsh side of the river. On another occasion, a cavity was formed from the driftway under the Salmon Pool to the bed of the river, when a hole, 16 feet by 10 feet, was found in the marl. The works were flooded by the water which found an entry through this hole. It was filled with clay, and the tunnel is now finished beneath it.

The quantity of water now being pumped is about 19,000 gallons per minute. Additional pumps have been erected, as the large land spring, which has been penned back by a brick wall, still remains to be dealt with. When all the pumps are available, the total power will be equal to 41,000 gallons a minute.

The tunnel is for a double line of way, and will be lined throughout with vitrified bricks set in Portland cement mortar.

It is being made by the Great Western Railway Company. Sir John Hawkshaw is engineer in chief; Mr. C. Richardson, engineer; and Mr. T. A. Walker, the contractor.

3. *On Single-Track Railways.* *By* W. K. Muir.

4. *On American Permanent Way.* *By* Joseph Wilson, *A.M., M.Inst.C.E.*—See Reports, p. 593.

5. *On the Canadian Pacific Railway.* *By* Vernon Smith.

The construction of the Canadian Pacific Railway was the outcome of an agreement entered into by the Dominion of Canada with the province of British Columbia, under which on July 20, 1871, the latter became one of the confederated provinces of Canada. By this agreement the Dominion guaranteed the completion within ten years of a trans-continental railway from the Pacific to the Atlantic. No great progress was made, however, in the carrying out of the works until the incorporation of the present Company on February 1, 1881, when it was found necessary to further extend the time for its completion to 1891. When the Company took possession of the road in 1881, only 176 miles of the railway were in a position to hand over to them; but by the end of the year 599 miles were in complete working order, to which 783 miles were added in 1882, and 1,581 in 1883; making a total of 2,963 miles of railway in operation, as the result of three years' work of the Company, a record that so far has not been approached by any existing corporation. The important part of this system, and the section, the rapid construction of which made the whole possible, was the prairie portion between Winnipeg and Calgary at the foot of the Rocky Mountains, 677 miles of which were completed by Messrs. Langdon & Shephard in a little over fifteen months, which included a winter, when nearly all the work was necessarily suspended for over four months. Most of the work was completed at the rate of about three miles per day during the year 1882, and a still greater average was reached in 1883, the maximum daily allowance being six miles. It is believed that this rapidity of construction is unparalleled, and the details of the arrangements by which it was effected possess, therefore, unusual interest.

A comparison of the alignment and geographical and engineering features of the Canadian Pacific Railway as compared with the American trans-continental lines is in every respect in favour of the former, and taking the ocean and railway speeds respectively at 15 knots and 30 miles per hour, the advantage in distance and time by the Canadian route over its rivals amounts, in a journey from England to Japan, to a saving of fully three days. The paper concludes by pointing out the fact that between England and her Pacific antipodes, at either end of the railway and in Australia are immense deposits of coal in the most favourable position for the supply of the steam marine that must eventually work in connection with this line, and that both on the Atlantic and Pacific oceans these vessels may be coaled at the minimum of expense, whilst by the eastern passage from England there is no intermediate supply, excepting from depots furnished at great expense from the English or Australian mines. This Canadian line, therefore, has the great advantage not only of being nearer and quicker than rival routes, but also of being able to offer cheap fuel to the ocean steamers working from either end over the two great oceans between England and the Pacific dependencies of Great Britain.

FRIDAY, AUGUST 29.

The following Papers were read:—

1. *On the Theory of the Steam-Engine.* *By* Professor Robert H. Thurston.—See Reports, p. 569.

2. *Steam-Engine practice in the United States in* 1884. *By* J. C. HOADLEY.

The subject of this paper was not selected by the writer, who is well aware that it is too vast for adequate treatment within admissible limits, but was assigned him by an eminent professor, whose engagements forbade him complying with a request which he had received to prepare a paper on this subject.

It seemed to the writer that the most feasible mode of condensation would be found in a succinct account of a few conspicuous examples of the leading types of each class of steam-engines actually in use, both as to construction and performance. The pumping-engine of the Lowell water-works gave, in July 1873, a duty of 93,002,272 foot-pounds per 100 pounds of coal burned, the contract duty, based on previous experience, being 75,000,000. The mean duty in practice during ten years has been more than 98,000,000.

The Lynn pumping-engine gave, in December 1873, a duty of 103,923,215 foot-pounds per 100 pounds of coal, and for six years, 1877–82, has given, in actual use, a duty of 115,888,996 foot-pounds per 100 pounds of coal burned while pumping. The Lawrence pumping-engine gave, in May 1876, a duty of 98,261,700 foot-pounds; in July 1879, 111,548,925; and during five years, 1879–1883, 102,120,127 foot-pounds, the latter being calculated on all the coal burned except for warming the engine-house when the engine was not running. The pumping-engine at Pawtucket, R.I., gave in August 1878 a duty during the working days of two weeks, based on all the coal burned, of 104,357,654 foot-pounds per 100 pounds of coal and 133,522,060 foot-pounds during 24 hours' continuous run, based on all the coal burned during the test. This is a compound receiver engine, cylinders 15 and 30 inches diameter and 30 inches stroke, 52 revolutions per minuute.

The Pettaconset Station pumping-engine, Providence, gave in May 1882 a duty of 113,271,000 foot-pounds, and during the year 1883, with inferior coal, 106,048,000. With coal equal to that used at the test, the duty during the year would have exceeded 114,000,000.

A Corliss engine at the Hourse Mill, Woonsocket, R.I., of 500 horse-power, running at 400 i.h.p., is warranted to run through the year with not exceeding 1·75 pounds of coal per i.h.p. per hour, and is coming within the guaranty. It uses only 11·5 pounds of visible steam per i.h.p. and per hour, and not more than 16·5 pounds in all, including that returned from the steam-jackets.

Engines of the leading manufacturers are passed in rapid review: The Corliss Steam Engine Company, the Putnam Machine Company, Charles H. Brown & Co., Fitchbung Steam Engine Company, Wm. A. Harris, E. P. Allis & Co., Jerome Wheelock, Buckey Steam Engine Company, and the Hartford Engineering Company, the Atlas Engine Company, the Southwark Foundry and Machine Company (makers of the Porter-Allen engine), Geo. T. McLauthlin & Co. (makers of the Hoadley engine), the Cummer Engine Company, A. L. Ide, B. F. Sturtevant, the Ball Engine Company, the Lambertville Engine Company, the Providence Steam Engine Company (makers of Noble T. Green's engine).

Steam pumps are only mentioned in passing, as are also steamboat engines on western rivers, portable and semi-portable engines, threshing-engines, traction-engines, and ploughing-engines, and marine engines. Herreshoff's launch and torpedo-boat engine is briefly noticed. Curious engines are merely alluded to.

The American locomotive receives more full notice. Gradually developed from the germ during fifty years, this grand machine had assumed a few distinct types which seemed well-nigh incapable of radical improvement, save in the area of fire-grate, which, always too small, had become relatively more inadequate by reason of the rapidly increasing size and weight of engines, while there seemed to be no room for enlarging the fire-grate. The Wootten engine, by placing the grate above the drivers, has removed that difficulty, apparently with good results, so far as the limited number of engines in use—only a few hundred—and the brief experience with the first of them, only seven or eight years, afford the means of judging. This appears to be one of America's most important contributions to the locomotive of the future.

An express passenger locomotive, No. 169, on the Central Railroad of New

Jersey, makes regularly the run between Jersey City and Bound Brook, thirty-two miles, in thirty-seven minutes, at the rate of 52·16 miles per hour, and has made it in 33 minutes, 58·2 miles per hour; and has run three miles of the route in 2 minutes 24·5 seconds—74·74 miles per hour. She has run a single mile in 45 seconds—80 miles per hour. A test of a locomotive by John W. Hill is given in a manner which hardly admits of condensation. The train resistance, on a level, appears to be about 6·7 pounds per ton $\left(\frac{1}{334\cdot9}\right)$. Feed-water evaporated per indicated horse-power, per hour, 32·28, 33·40, and 31·96 pounds—mean, 32·55—which, with the reasonable evaporative duty of nine pounds of water per pound of coal, should have been done with 3·62 pounds of coal per i.h.p. per hour. In fact, the coal was 4·24, 7·03, and 5·36 pounds—mean, 5·54 pounds—per i.h.p. per hour, and the evaporation during the middle run fell as low as 4·51 pounds of water per pound of coal. This shows clearly the deficient fire-grate area already noticed. The water given above includes all that was blown off at the safety-valve, and used at the whistle and gauge-cocks, and in experiments with a calorimeter. Allowing for this, the consumption of water was 30·26 pounds per i.h.p. per hour. The fire-grate-area was but 15·09 square feet, and the rate of combustion was at times as high as 172 pounds per hour on each square foot of grate-area. With a grate four-and-a-half times as large, such as might be obtained in a Wootten engine, this rate would be reduced to 38·2 pounds, and might be still further reduced, by increased economy, to as little as 20 pounds per square foot and per hour.

Some points of locomotive practice are then given. Locomotive No. 137, on the Boston and Albany Railroad, ran 436 days out of 438 (with the loss of only two days by some slight accident), 198·11 miles per day of actual service, 87,190 miles in all, at the rate of 72,192 miles per annum, and was then repaired, including painting and varnishing, in four days, and resumed her regular service.

The locomotive 'Pacific,' built by the shop of which the writer was superintendent, was placed in service on the Boston and Maine Railroad, March 16, 1855, and ran regularly in passenger service to the close of 1883, 28 years 9½ months, and has since run 60 miles per day on gravel trains, making an aggregate mileage of 904,255 miles—an average, for 29½ years, of 30,650 miles per annum. More than one-half of the material originally put into her is in her still, and she is in good working order.

Three engines on the Hudson River Division of the New York Central and Hudson River Railroad, have made a record of which the following table contains the mean results. Mean weight of trains, 294 tons:—

Mean of All. Performance: No. 10, No. 33, & No. 34.	
Mean mileage in 6 years	493,489
Number of days in service	1,777
Number of days idle	399.67
Mean number of months in service	70
Mean number of miles per day	277.63
Mean number of miles per month	7,049
Mean number of miles per annum	82,248.11
Mean number of gallons of oil used	3,667
Mean number of miles per gallon	134.81
Mean total cost of oil	$1,491.67
Mean total cost of waste	286.67

Mean Cost of Repairs. Labour: No. 10, No. 33, and No. 34.		
Items	On Engine	On Tender
	$	$
Machinist	3,614.41	76.92
Blacksmith	483.55	86.47
Boiler-maker	1,260.57	70.86
Coppersmith	65.98	—
Tinsmith	37.45	—
Carpenter	188.95	69.71
Painter	321.35	64.22
	5,972.26	398.18

MEAN COST OF MATERIALS.
No. 10, No. 33, and No. 34.

Items	Engine	Items	Tender
	$		$
Machinery	1,369.60	Iron	102.44
Drivers	33.00	Trucks	733.18
Tire	230.67	Lumber	34.80
Trucks	515.30	Paints	58.33
Boiler and flues	1,182.44		
Lumber	60.30		
Paints	135.88		
Materials	3,527.19	Materials	928.75
Labour brought down	5,972.26	Labour, brought down	398.18
Total, engine	9,499.45	Total, tender	1,326.93
Repairs of engine, brought down			9,499.45
Mean total repairs, engine and tender, in six years			10,826.38
Mean cost of repairs, per annum			1,084.39

MEAN COST PER TRAIN-MILE OF LABOUR AND MATERIALS ON ENGINE AND TENDER ON No. 10, No. 33, AND No. 34, DURING SIX YEARS, IN CENTS AND FRACTIONS OF A CENT.

	No. 10	No. 33	No. 34	Mean
Machinists	.70	.72	.84	.75
Blacksmiths	.11	.13	.12	.12
Boiler-maker	.28	.25	.30	.28
Copper and tinsmith	.02	.02	.02	.02
Carpenter	.05	.05	.06	.05
Painter	.08	.08	.09	.08
Total, labour	1.24	1.25	1.43	1.30
Materials	.84	.93	.95	.90
Total, repairs	2.08	2.18	2.38	2.20
Oil	.28	.30	.32	.30
Waste	.06	.05	.06	.06
Total, cents	2.42	2.53	2.76	2.56

These engines were new at the beginning of the period covered by the record here reproduced, and the cost of repairs must increase with increasing age. The examples presented are, it is admitted, selected examples, and must be above the mean, taking age into consideration if nothing more; but so much has been done, and, accident and misfortune apart, can be done generally with engines of like age.

With compound locomotives little has been done in this country. A few have been constructed, but without any very marked success, so far as the writer has been able to learn. It is certainly very desirable to reduce the consumption of fuel in our locomotives; but if compounding involves of necessity the use of a cranked-axle, as in some examples, it can never be adopted in America, since the well-known evils of that feature must far outweigh all possible gain from compound cylinders. The locomotive engine is, without doubt, the most important application of the non-condensing engine of Oliver Evans and the multi-tubular boiler of Nathan Read, and its development demonstrates that it has not been neglected in the land of its nativity.

With a few words about prices now current, this paper is brought to a close. The weight of our ordinary American locomotive, with cylinder 17 inches diameter, and 24 inches stroke, four driving-wheels connected, 5 feet diameter, is about as follows:—

Loaded: 2 Gauges of Water			Light	
Tons	Pounds		Pounds	Tons
22.991	51,500	On drivers	46,000	20.536
12.589	28,200	On truck	24,000	10.714
35.580	79,700	Total, engine	70,000	31.250
25.446	57,003	Tender, 3,000 gallons capacity .	24,000	10.714
61.026	136,700	Engine and tender	94,000	41.964

Price, with steel boiler, head-light included, $6,500, or say 1,343*l.*; per ton, $154,89, equal to 32*l.*; per pound, 6.91 cents, equal to 3.43 pence.

Engines of various sizes and styles may be bought about at prices subjoined, which, it must be said, are about the actual cost.

Cylinders		Styles	Prices	
Diameter	Length of Stroke		Dollars	Pounds Sterling
16	24	4-wheeled switching . . .	5,500	1,136
15	24	8-wheeled	5,500	1,136
16	24	8-wheeled	6,000	1,240
17	24	8-wheeled	6,500	1,343
18	24	'Mogul,' freight	7,300	1,508
20	24	Consolidation, freight . . .	9,000	1,860

The 'Mogul' engine has six driving-wheels connected, with a single pair of pilot-wheels, swinging-bolster, and radius bar. The 'Consolidation' engine has eight driving-wheels connected, with a single pair of pilot-wheels, swinging-bolster, and radius bar. In both, a part of the weight otherwise carried by the pilot-wheels is transferred to the driving-wheels by equalising levers.

The prices above given are certainly too low, as they afford no satisfactory profit to the manufacturer.

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3. *Pumping Machinery.* *By* E. D. Leavitt, Jun.

The appliances known and used by the ancients for raising water, while possessing great historical interest, cannot for want of space be considered at this time.

It was not until the seventeenth century, when the Marquis of Worcester brought out his fire-engine, to be followed by the inventions of Savery, Newcomen, Papin, and many others, that pumping machinery assumed a decided importance. Its greatest development has occurred during the present century, and must be credited to the improvement in the steam-engine made by James Watts.

The present paper will be mainly devoted to American practice in pumping machinery, it being assumed that the best work of the leading engineers of Great Britain and the Continent (in this special department of mechanical construction) has been previously described in papers read before the Association.

Among the earliest examples of pumping machinery used in the United States were the water-works engines at Philadelphia, which were put in operation between the years 1801 and 1803.

Progress in water-works pumping machinery since the Fairmount works were commenced has been rapid,

Among the cities whose pumping machinery is worthy of mention here, either from peculiarities of construction or its great capacity, may be mentioned Montreal and Toronto, Canada; Boston, Lowell, Lynn, and Lawrence in Massachusetts; Providence and Pawtucket in Rhode Island; Brooklyn, Buffalo, and Saratoga, New York; Jersey City, New Jersey, Philadelphia, and Pittsburgh, Pennsylvania; Cincinnati and Cleveland, Ohio; Louisville, Ky.; St. Louis, Mo.; Chicago, Ill.; and Detroit, Mich.

In the cities above named there will probably be found as great a variety of good, bad, and indifferent pumping machinery as has ever been collected in an equal number of places anywhere in the world. A brief description of the most prominent types and peculiarities was then given; the author dwelling more especially on mine pumping machinery, and direct-acting steam pumps.

4. *The Anthracite Burning Locomotive of America.* *By* J. D. Barnett.

5. *On English Locomotive Engineering.* *By* A. McDonnell *and* J. A. F. Aspinall.

The paper included carefully tabulated statistics of the construction, cost, and performance of the standard types of locomotives running upon the principal English railways.

A special feature in these statistics was the tabulating of the average life in miles of those parts which most frequently require renewal.

The paper was illustrated by outline drawings, giving dimensions of the standard engines of the various railways.

6. *On the Construction of Locomotive Engines for the London, Brighton, and South Coast Railway.* *By* W. Stroudley.

7. *On Valve Gear.* *By* David Joy.

This valve motion was introduced to the public by the author in 1880, in a paper read before the Institute of Mechanical Engineers at their annual summer meeting in Barrow, and at that time was a distinct departure in a new direction, to provide a movement for the valves of steam-engines by the direct movement of the connecting-rod, abandoning the use of excentrics and the time-honoured Lenle motion.

It was first taken up by the London and North-Western Railway Company, and tested by them on an engine built expressly for the purpose, and designed by Mr. Webb, their locomotive engineer-in-chief, for their fast and heavy goods traffic, and this engine has been running ever since.

The essential feature of the gear is that the movement of the valves is accomplished by the combination of two motions at right angles to each other—that is, by employing the direct reciprocating motion of the piston, as imparted to the connecting-rod, with the vibrating movement of the same rod. Thus a movement is imparted to the valve which is susceptible of forward and backward motion for the engine, and for any intermediate degree of expansion. This motion being also almost mathematically correct and giving equal leads, ports, and points, if cut off for both ends of the cylinder, at the same time that it gives a much more rapid action at the moments of admission, cut off, and release than is usual with the back gear; while the machinery for attaining this result is less costly and less complicated than by any of the ordinary methods. This consists of a lever attached at its longer end, through a parallel motion, to the connecting-rod about midway, the fulcrum of that lever sliding in the direction of the vibration of the connecting-rod, in a curved path, which can be angled to either side of its centre line. From the outer and shorter end of this lever a rod is taken direct to the valve-spindle. That part of the movement of the valve due to 'lop' and 'lead' is effected by the action of this lever as a lever, and the movement required for port opening is imparted by the sliding of the fulcrum of the lever in the curved path; and according to the angle given to this path, forward or backward motion, or any degree of expansion, is given.

Since its introduction in 1880 this gear has been applied and tested on almost every kind of steam-engine. For locomotives, especially for express work, it has done good service, many of such engines having already run heavy mileages, while doing very high speeds, and with lighter repairs than the ordinary types of engines.

Also for marine engines, from the smallest launch engine running 600 to 700 revolutions per minute, up to the ponderous engines of war-ships running up to 100 revolutions, and indicating upwards of 5,000 horse-power, it has been applied with success. It is also being built for even larger sizes, where the aggregate indicated horse-power in each ship will be 10,000 horse-power.

The distribution and treatment of the steam in the cylinder, as shown by the indicator cards from such engines, is all that could be expected from the peculiar action imparted to the valves; and the continued endurance and freedom from repairs promise a continued adoption of this new system.

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8. *On Heating Buildings by Steam from a Central Source.* *By* J. H. Bartlett.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Papers were read:—

1. *On the Lighthouse System of Canada.* *By* William Smith.

In Canada, no light dues are exacted from shipping, and the cost of maintaining the lighthouses is a direct charge on the general revenue of the Dominion, and is provided for annually by a vote of Parliament.

During the fiscal year ended June 30, 1884, the total cost of maintaining the 549 light-stations in Canada, with the fog-signals, buoys, and beacons, and four steamers required to attend on the light service, was $541,291.

The system of free lights was adopted by the public men of Canada with the view of reducing the charges on shipping trading to the St. Lawrence, and thereby cheapen freight by this route. By adopting this policy, the shipping and forwarding interests of Canada have secured a fair share of the carrying trade of the West, a large portion of which, however, finds its way by New York and other United States routes.

In the United States no light dues are collected from shipping, but the war tax of 30 cents a ton, payable once a year, on foreign vessels still continues, and last year the amount collected on account of this impost was $1,320,590.

The lighthouse and fog-whistle at Cape Race are maintained by the British Government, and light dues are exacted from passing vessels, for the maintenance of this station; Canada also contributes a share of the cost of its maintenance.

Canada has built, and now maintains, four important light stations, two of them with steam fog-alarms, on the coasts of Newfoundland, which are free to the shipping of all nations.

Sable Island, in the Atlantic Ocean, is the principal light-station maintained by Canada. It is a bank of white sand twenty-two miles long, and has a light-station at each end, one a powerful fixed white dioptric light, and the other a powerful revolving white light. One or two wrecks generally occur on the shores or banks of this island nearly every year. A life-saving station is also maintained here, the staff of which along with the light-keepers numbers twenty persons. The British Government contribute annually the sum of four hundred pounds sterling towards the maintenance of the life-saving station, but nothing for the lights.

The lighthouse service of Canada is managed by the Minister of Marine, who is a political officer and a member of the Cabinet, assisted by the Deputy Minister of Marine, who is a permanent officer, and does not change with the Government. Under these two chief officers is an engineer and a staff of permanent officers and clerks, as also an agent in each of the provinces to attend to the local business.

The necessary funds for the construction of new lights and the maintenance of those already established are voted annually by Parliament on the recommendation of the Minister of Marine.

Since 1867, when the Marine Department was formed, up to December 31 last, 351 new light-stations have been established and thirty-two steam fog-whistles or fog alarms, the cost of which was $1,095,620, or an average of $2,860 for each. All these new lighthouses were built of wood, although many of the lighthouses built previously to 1867 were built of stone or brick, and cost from $30,000 up to $100,000.

The extent of the Canadian sea-coast to be lighted up and buoyed is 3,200 miles, and inland coast 2,600 miles, making altogether 5,800 miles.

To light up this coast we have 308 sea-coast light-stations, 17 light-ships, and 224 inland light-stations. New lighthouses are built by contract, after tenders have been invited publicly, and the lowest tenders have always been accepted.

New light-stations are generally established on the recommendation of practical nautical men, of boards of trade, of steamship owners, and of members of Parliament. The practical officers of the Department are also consulted as to the necessity of any proposed new lighthouse. The steam fog-whistle in use is composed of a multitubular boiler, with a small engine attached for opening the valve and regulating the blasts of steam, at stated intervals, as desired. The whistle is usually 10 inches diameter, and 1 foot 6 inches high, and the cost of the machine without the building is about $2,000. The fog-horn in use is the champion automatic fog-horn, which requires very little fuel and water, and costs about $2,000 exclusive of buildings. The sound is produced by compressed air passing through the horn instead of steam.

This machine has been found to be the most economical and useful.

The Courtenay automatic whistling buoy, of which we have eight, has been found to be most useful at places where there is usually a rolling sea, such as the Atlantic coast. The sound produced is from compressed air, and is very like the sound of the champion fog-horn. The cost of a 10-feet buoy is $1,575 without the moorings.

Two large-sized gas-buoys have been ordered for service in the lower St. Lawrence. They will keep lighted day and night for ninety days. Their cost is $3,750 each in addition to the works to make the gas and the moorings.

The illuminating apparatus in use in Canada is catoptric and dioptric, the former having been made either in Birmingham or Paris, and the latter in Montreal. We have 483 lights on the catoptric principle and 66 dioptric lights.

The illuminant used is petroleum, of Canadian production and manufacture, is double distilled, standard white, extra refined, free from acid or other impurities, weighs, at 62° Fahr., not less than 7·85 lbs. nor more than 8·02 lbs. per gallon, and withstands a flash test of 115° Fahr. by the new standard pyrometer. The quantity used per annum is about 100,000 gallons, and the price is 20 cents per gallon.

The number of light-stations in Canada with fixed lights is 467, and with revolving lights 82, making altogether 549 on December 31, 1883.

The number of persons employed by the Government to attend to these lights is 656, and the salaries paid to them range from $80 to $1,500 per annum. The salaries allowed keepers of sea-coast lights range from $300 to $500, and there are many applicants for these situations. Keepers of lights are usually appointed on the recommendation of the member of the House of Commons representing the district in which the lighthouse is situated, if he is a supporter of the Government.

The expansion of the lighthouse system of Canada during the last seventeen years has been very great. In 1867, when the four provinces were confederated, there were 198 lighthouse stations in the Dominion, and two fog-whistles, and at the close of this season there will be 569 light-stations, 36 fog-alarms, and 10 automatic whistling buoys.

Nearly all the principal lights in the river and Gulf of St. Lawrence have been connected with Quebec and other cities by telegraph, and in the event of a wreck taking place or any other accident, it is immediately made known to the Government and to the boards of trade at Montreal and Quebec. The cost of our telegraph and signal service has been large, but it is a most useful expenditure.

As compared with the United Kingdom, our coast to be lighted is larger, and our lights more numerous although not of so high a class or so expensive. The number of lights managed by the three lighthouse authorities of the United Kingdom, viz., the Trinity House of London, the Commissioners of Northern Lighthouses, and the Commissioners of Irish Lights, is 288, some of these being probably the finest in the world. In addition to these there are about 140 lights, managed by harbour or dock authorities, making altogether about 428. The cost of maintaining the 288 lighthouses managed by the three bodies referred to, including the maintenance of the sailing and steam vessels to attend on them, was 303,830*l.* for the year ended March 31, 1883.

The amount of light dues collected in the United Kingdom during the year 1883-4 was 476*l.* 11*s.* 6*d.* sterling. In Norway there are 132 lights, maintained by the Government, which cost $157,000 last year.

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2. *Improvements in Coast Signals; with supplementary Remarks on the new Eddystone Lighthouse. By* Sir JAMES N. DOUGLASS, *M.Inst.C.E.* —See Reports, p. 584.

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3. *The Watt and Horse-Power. By* W. H. PREECE, *F.R.S.*

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4. *Secondary Batteries. By* W. H. PREECE, *F.R.S.*

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5. *Domestic Electric Lighting. By* W. H. PREECE, *F.R.S.*

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6. *The Portrush Electric Railway. By* Dr. A. TRAILL.

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7. *Electric Tramways. By* HOLROYD SMITH.

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8. *A New Volt-Meter. By* Captain CARDEW.

TUESDAY, SEPTEMBER 2.

The following Reports and Papers were read:—

1. *Report of the Patent Law Committee.*—See Reports, p. 293.

2. *Report of the Screw Gauge Committee.*—See Reports, p. 287.

3. *Report of the Sea Coast Erosion Committee.*—See Reports, p. 238.

4. *Some Points in Dynamo-Electric Machines.*
By Professor S. P. THOMPSON, *D.Sc.*

5. *On the Heating of Conductors by Electric Currents.*
By Professor G. FORBES.

6. *Automatic Sprinklers for Fire Extinction.* *By* C. J. H. WOODBURY.

This paper gave the results of an examination of the various automatic sprinklers which are operated by the melting of an easily fusible solder. These sprinklers are in general use in the eastern portion of the United States, for protecting those portions of textile mills and other industrial establishments where the nature of the product or the processes used introduce extreme hazard of fire. The investigation was undertaken at the instance of the Factory Mutual Insurance Companies of New England, and was directed to an examination of the numerous varieties of automatic sprinklers, in respect to their efficiency for purposes of mill protection, including their methods of distribution and consumption of water under various heads, liability to accident, and deterioration to their sensitiveness, and to all matters pertaining to their practical operation.

The conclusions based upon these tests are:—

1. That the fusible solder which permits the operation of the sprinklers at about 170° Fahrenheit retains its low melting point, no change occurring in sprinklers ten years old.

2. They should be protected against corrosion whenever it might interfere with its prompt action. A heavy mineral oil is suggested for the purpose.

3. The distribution of water upon ceiling and floor was measured upon each square foot of floor, and found to be satisfactory.

4. The concentration of water at the beginning of a fire exceeds that of any other form of inside apparatus.

5. The minimum static head upon the sprinklers should not be less than ten feet.

6. The practical value of automatic sprinkler systems is shown by a list of 131 fires which were extinguished by automatics, either alone or in co-operation with other fire apparatus.

7. Valves should be kept open and secured by a strap. It is important that a constant head of water, ready for immediate use, rests upon the sprinklers.

The sensitiveness of automatic sprinklers was measured by exposing them, while under water-pressure, to a uniform jet of steam, and the sprinklers opened in from 15 to 85 seconds, according to their construction and the fusibility of the solder.

Resistance to internal pressure was measured with a pump constructed for producing the heavy pressures used in graduating the dials of hydraulic gauges.

Those sprinklers designed with reference to elasticity became tight after the bursting pressure had been reduced to a point in equilibrium with the flexure of the yielding portion of the sprinkler.

The temperatures at which a number of specimens of these solders became soft, and afterwards fluid, were measured. In comparison with results of melting the sprinklers in hot water, it was found that an automatic sprinkler opens below the true melting point of the solder, and at the temperature at which this alloy becomes viscous, or, in some instances, granular.

The measurements of the discharge of the sprinklers showed that the discharge conformed to the formula:—

$$Q = 5{\cdot}075aQ\sqrt{P},$$

in which—

Q = Cubic feet of water per minute.

A = Area of orifice in square inches.

Q = Coefficient of efflux, determined by these experiments.

P = Water pressure in pounds per square inch.

The effective head at the sprinkler was found by correcting the measured dynamic head at the gauge by the formula deduced for this purpose, in which the loss of head—

$$L = \frac{{\cdot}0388Q^2}{a^2}.$$

Automatic sprinklers under a head of seven feet will deliver as much water upon each square foot of floor as the system of perforated sprinkler pipes under a head of forty feet.

There seems to be no method of providing against freezing during the winter season, in cold buildings equipped with the pendent form of sprinklers.

With the upright form of sprinklers, it is easy to draw off the water at the point service gate. There seems to be no record of any solution with a lower freezing than any natural temperature, which is also non-corrosive and incombustible.

Experience shows that sheet lead is the only material suited for valve seats of sensitive sprinklers.

Both the results of experience, and the facts proven by this investigation, show that the efficiency of automatic sprinklers is not liable to become impaired by time.

7. *On the Friction of Journals.* *By* Professor Osborne Reynolds, *F.R.S.*

8. *Grain Elevators.* *By* V. C. Van Horn.

9. *On the Flow of Water through Turbines and Screw Propellers.* *By* Arthur Rigg.

10. *On the Ventilation of Ocean Steamships.* *By* A. Lapthorn Smith, *B.A., M.D.*

Provided a passenger can remain on deck, the symptoms of sea-sickness generally pass off after a day or two, although the motion of the ship continues the same, or even increases. Therefore the sea is not alone to blame for the malady. Even a perfectly well person is apt to be attacked with nausea and vomiting, after remaining for a few hours in the steerage of a ship just arriving from sea, although the ship is quite motionless. A passenger steamer is the most difficult of all dwellings to ventilate by natural means, on account of its construction. On the other hand, prisons, asylums, and public buildings, although much better adapted to natural ventilation than ships, have been proved, by experiments, to be incapable of ventilation, except by artificial means. Moreover, the space at the disposal of ocean travellers is exceedingly limited, only 72 cubic feet being allowed per adult. In order to provide the smallest quantity of air consistent with health, the atmosphere would have to be changed 43 times per hour, which is manifestly impossible by natural means. A ship carrying 1,200 passengers requires 3,600,000 cubic feet of air per hour delivered between decks, apart from the requirements of the furnaces. This amount can only be obtained by means of a steam fan. The same fan blower would save its cost in a season or two, by being utilised for *trimming* the cargo of wheat, a hose pipe being attached, and the current of air being directed against the wheat, as it fell from the elevator spout. This would also cool the wheat, a great advantage.

In winter the fresh air could be warmed before being supplied to the passengers, by passing over the boilers or through the condensers; and in summer, in hot latitudes, it could be cooled with ice, or by compression and expansion, as in refrigerators.

To avoid draughts, the air should be distributed by small perforators from a large surface of pipe, which should be introduced into every living apartment of the ship while it was being built.

WEDNESDAY, SEPTEMBER 3.

The following Papers were read:—

1. *The Extent to which a Geological Formation is available as a Gathering-ground for Water Supply. By* W. Whitaker, *B.A., F.G.S.*

The author exhibited a set of maps which he had specially made to show (1) those areas in which rain-water has free, or almost free, access to the Chalk, that rock being either bare, or covered only by deposits of a permeable kind; and (2) those areas over which the infiltration of water to the Chalk is hindered either partially by a protecting mass of beds of a mixed or of a changeable kind (in the former case letting water through to a limited extent, and in the latter allowing it to sink down at one place and not at another), or wholly, by a protecting mass of impermeable beds that absolutely stops infiltration, though sometimes streams flowing over such impermeable beds reach the Chalk, and contribute to its water. It is only those parts of the London Basin for which the Geological Survey has published Drift-maps that can be included in the above scheme, but it is hoped to extend this practical application of geological knowledge as other Drift-maps are issued. Like maps can of course be made for other water-bearing formations where the different divisions of the Drift have been surveyed, and until such maps are made we may have only an approximate idea of the areas of the various water-bearing beds that are available as gathering-grounds.

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2. *On Flood Regulators. By* J. Dillon.

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3. *On Agricultural Implements. By* D. Pidgeon.

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4. *On the Destruction of Town Refuse. By* John Brown, *M.D., B.Sc.*

The used-up material of town life may be classified as sewage and solid material, including night soil, midden and ashpit refuse, street sweepings and gully sludge, market sweepings, garbage and offal.

On the shores of seas, lakes, estuaries, and very large rivers, the sewage may be disposed of by being discharged into these; greatly diluted, it is slowly oxidised into a harmless state.

When possible its great nutritive properties may be utilised on sewage farms or irrigated meadows. Where this cannot be done, the excellent sewage report of this Association shows that the process of intermittent downward filtration is probably the most efficient for the destruction of its hurtful ingredients.

In the case of large towns it is very soon found that the removal of solid used-up materials gives rise to nuisance and entails enormous expense.

The effectual means of dealing with this refuse is to burn it completely, regularly, and speedily. The towns of Derby, Leeds, Bolton, Blackburn, Batley, Leicester, Bradford, Hull, Birkenhead, London, have already adopted this method of dealing with it. In Burnley, Lancashire, the 'Bee Hive' improved refuse destructor, designed by Mr. Stafford, borough engineer, and constructed by Messrs. Thomas Birtwistle & Co., has been in operation for eight months, and has given every satisfaction.

It costs little, about 75*l.* serving for the erection of one which may be attached to any tall factory chimney without in any way interfering with its action. It is small in size, extending below the level of the surface of the ground about four feet, and rising above it as a hemisphere 7 feet in diameter. It will destroy 15 cwt. or 52 cubic feet of rubbish per hour, with a very small consumption of coal, and without the production of any nuisance whatever.

One of these destructors in continuous use will destroy all the solid used material of a population of 20,000, and they can thus be scattered all over the area of a large town. Thus the annoyance of collection and storage is reduced to a minimum, as is also the very important item of cartage.

In cheapness, simplicity, smallness, convenience, and efficacy, it cannot be surpassed, and in the four months during which it has been before the public, orders for its erection have already been received from the towns of Batley, Bradford, Leicester, Birkenhead, and Richmond.

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5. *On the Prevention of Accidents at Sea. By* Admiral J. E. Commerell.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—E. B. TYLOR, D.C.L., LL.D., F.R.S.

[For Dr. Tylor's Address, see next page.]

THURSDAY, AUGUST 28.

The following Papers were read:—

1. *The Range of the Eskimo in Space and Time.* *By* Professor W. BOYD DAWKINS, *F.R.S.*

The Eskimos occupy the coldest parts of the earth in America and Asia, and their civilisation is of a rude and primitive type. To the south of the Eskimos in America is a debatable land, belonging neither to them nor to the Red Indian, between which races a feud exists. In Asia the Eskimos are on better terms with their neighbours. It has been asserted that the Eskimos are related to the Red Indian on the ground of their language being agglutinative, but this is hardly sufficient proof. There are very conflicting opinions as to when they first appeared in America. Mr. Markham considers they were driven from Asia shortly before 1349 by the pressure of Tartar tribes. On the other hand, Dr. Rink considers them the last wave of migration by which the American continent was originally peopled. It is probable that in ancient times they ranged much further south, and have only lately been driven further north. Furthermore, if we trust to the accounts of the Scandinavians who visited America in the eleventh century, they must have had a much lower range, and this is supported by other facts. Thus the Eskimos are a retreating race, the remnant of the ancient possessors of a very wide area, who would have been exterminated but for the inclemency of the north, which has kept back the Red Indian. The Eskimo word 'Kayak,' a 'skin-covered canoe,' meaning probably a 'birch-covered canoe,' is, according to Dr. Isaac Taylor, derived from a primitive word common to the Yakut and Seljuk races in Asia. This agrees very well with the previous results as to the primitive range of the race. As to their range in time, Professor Dawkins connected them with the primitive cave-men, using needles and gloves, three and four, but never five fingered, and implements of stone and bone. They were a race of hunters and fishermen, and were fond of engraving reindeer and now extinct animals upon bones. While hunters, they were hunters of a high type. They were like the Eskimos in their disregard of the rites of burial. Thus, of the cave-men no perfect skeletons are left, probably owing to the prevalence of beasts of prey, and more especially of hyænas. The least that can be said of the cave-men of Europe is, that they were exactly in the same stage of civilisation as the Eskimos. They used the same implements and lived the same life. In the absence of any proof of any two races of diverse origin presenting this identity of implements, weapons, and art, it is very probable that they belong to the same stock as the Eskimos. He therefore felt inclined to extend the range of the Eskimos in the Pleistocene age, as far to the south and the east as the musk sheep (ox), through Northern Asia and middle Europe to the Alps and the Pyrenees.

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2. *Notice of Exploration of a Group of Mounds in Ohio.* *By* F. W. Putnam.

The author gave notice of exploration of a group of mounds in Ohio, containing not only burial mounds but others erected for quite a different purpose. He then described the composition of one elaborate mound and of a group of mounds. The area of the mound is covered with a composition of iron and gravel. The stratification of the interior is not curved, but horizontal, though the exterior of the mound itself is curved. The finds in these mounds were very curious, such as ornaments in mica schists, and in native silver and gold, copper and iron. Images even are found in terra-cotta.

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3. *On the Classification of North American Languages.* *By* Major J. W. Powell.

Four great stocks covered the area of the United States, viz.:—the Algonquian, with about 40 different languages; the Siouan, with about 13; the Shoshonian, with 18; and the Athabascan, very important in the Dominion. Altogether there were 55 stocks represented in the United States. In conclusion, the author added a few words on the affinities of languages: he did not believe in comparing grammatic structure, but rather vocabularies. Institutions as a test of classification were less permanent than languages, but more so than arts. Mythologies probably were only inferior to languages.

The President delivered the following Address:—

Our newly-constituted Section of Anthropology, now promoted from the lower rank of a Department of Biology, holds its first meeting under remarkable circumstances. Here in America one of the great problems of race and civilisation comes into closer view than in Europe. In England anthropologists infer from stone arrow-heads and hatchet-blades, laid up in burial-mounds or scattered over the sites of vanished villages, that Stone Age tribes once dwelt in the land; but what they were like in feature and complexion, what languages they spoke, what social laws and religion they lived under, are questions where speculation has but little guidance from fact. It is very different when under our feet in Montreal are found relics of a people who formerly dwelt here, Stone Age people, as their implements show, though not unskilled in barbaric arts, as is seen by the ornamentation of their earthen pots and tobacco-pipes, made familiar by the publications of Principal Dawson. As we all know, the record of Jacques Cartier, published in the sixteenth century collection of Ramusio, proves by text and drawing that here stood the famous palisaded town of Hochelaga. Its inhabitants, as his vocabulary shows, belonged to the group of tribes whose word for 5 is *wisk*—that is to say, they were of the Iroquois stock. Much as Canada has changed since then, we can still study among the settled Iroquois the type of a race lately in the Stone Age, still trace remnants and records of their peculiar social institutions, and still hear spoken their language of strange vocabulary and unfamiliar structure. Peculiar importance is given to Canadian anthropology by the presence of such local American types of man, representatives of a stage of culture long passed away in Europe. Nor does this by any means oust from the Canadian mind the interest of the ordinary problems of European anthropology. The complex succession of races which make up the pedigree of the modern Englishman and Frenchman, where the descendants perhaps of palæolithic, and certainly of neolithic, man have blended with invading Keltic, Roman, Teutonic-Scandinavian peoples—all this is the inheritance of settlers in America as much as of their kinsfolk who have stayed in Europe. In the present scientific visit of the Old to the New World, I propose to touch on some prominent questions of anthropology with special reference to their American aspects. Inasmuch as in an introductory address the practice of the Association tends to make arguments unanswerable, it will be desirable for me to suggest rather than to dogmatise, leaving the detailed treatment of the topics raised to come in the more specialised papers and discussions which form the current business of the Section.

The term *prehistoric*, invaluable to anthropologists since Professor Daniel Wilson introduced it more than thirty years ago, stretches back from times just outside the range of written history into the remotest ages where human remains or relics, or other more indirect evidence, justifies the opinion that man existed. Far back in these prehistoric periods, the problem of Quaternary man turns on the presence of his rude stone implements in the drift gravels and in caves, associated with the remains of what may be called for shortness the mammoth-fauna. Not to recapitulate details which have been set down in a hundred books, the point to be insisted on is how, in the experience of those who, like myself, have followed them since the time of Boucher de Perthes, the effect of a quarter of a century's research and criticism has been to give Quaternary man a more and more real position. The clumsy flint pick and its contemporary mammoth-tooth have become stock articles in museums, and every year adds new localities where palæolithic implements are found of the types catalogued years ago by Evans, and in beds agreeing with the sections drawn years ago by Prestwich. It is generally admitted that about the close of the Glacial period savage man killed the huge maned elephants, or fled from the great lions and tigers on what was then forest-clad valley-bottom, in ages before the later waterflow had cut out the present wide valleys 50 or 100 feet or more lower, leaving the remains of the ancient drift-beds exposed high on what are now the slopes. To fix our ideas on the picture of an actual locality, we may fancy ourselves standing with Mr. Spurrell on the old sandy beach of the Thames near Crayford, 35 feet above where the river now flows two miles away in the valley. Here we are on the very workshop-floor where palæolithic man sat chipping at the blocks of flint which had fallen out of the chalk cliff above his head. There lie the broken remains of his blocks, the flint chips he knocked off, and which can be fitted back into their places, the striking-stones with which the flaking was done; and with these the splintered bones of mammoth and tichorhine rhinoceros, possibly remains of meals. Moreover, as if to point the contrast between the rude palæolithic man who worked these coarse blocks, and apparently never troubled himself to seek for better material, the modern visitor sees within 50 yards of the spot the bottle-shaped pits dug out in later ages by neolithic man through the soil to a depth in the chalk where a layer of good workable flint supplied him with the material for his neat flakes and trimly-chipped arrow-heads. The evidence of caverns such as those of Devonshire and Perigord, with their revelations of early European life and art, has been supplemented by many new explorations, without shaking the conclusion arrived at as to the age known as the reindeer period of the northern half of Europe, when the mammoth and cave-bear and their contemporary mammals had not yet disappeared, but the close of the Glacial period was merging into the times when in England and France savages hunted the reindeer for food as the Arctic tribes of America do still. Human remains of these early periods are still scarce and unsatisfactory for determining race-types. Among the latest finds is part of a skull from the loess, at Podbaba, near Prague, with prominent brow-ridges, though less remarkable in this way than the celebrated Neanderthal skull. It remains the prevailing opinion of anatomists that these very ancient skulls are not apt to show extreme lowness of type, but to be higher in the scale than, for instance, the Tasmanian. The evidence increases as to the wide range of palæolithic man. He extended far into Asia, where his characteristic rude stone implements are plentifully found in the caves of Syria and the foot-hills of Madras. The question which this Section may have especial means of dealing with is whether man likewise inhabited America with the great extinct animals of the Quaternary period, if not even earlier.

Among the statements brought forward as to this subject, a few are mere fictions, while others, though entirely genuine, are surrounded with doubts, making it difficult to use them for anthropological purposes. We shall not discuss the sandalled human giants, whose footprints, 20 inches long, are declared to have been found with the foot-prints of mammoths, among whom they walked, at Carson, Nevada. There is something picturesque in the idea of a man in a past geological period finding on the Pampas the body of a glyptodon, scooping out its flesh, setting up its carapace on the ground like a monstrous dish-cover, and digging himself a burrow to live in underneath this animal roof; but geologists have not accepted the account. Even in the case of so well-known an explorer as the late Dr. Lund, opinions are still divided as to whether his human skulls from the caves of Brazil are really contemporary with the bones of megatherium and fossil horse. One of the latest judgments has been favourable; Quatrefages not only looks upon the cave-skulls as of high antiquity, but regards their owners as representing the ancestors of the living Indians. The high and narrow dimensions of the ancient and modern skulls are given in the 'Crania Ethnica,' and whatever a similarity of proportions between them may prove, it certainly exists. Dr. Koch's celebrated flint arrow-head, recorded to have been found under the leg-bones of a mastodon in Missouri, is still to be seen, and has all the appearance of a modern Indian weapon, which raises doubt of its being really of the mastodon period. This antecedent improbability of remote geological age is felt still more strongly to attach to the stone pestles and mortars, &c., brought forward by Mr. J. D. Whitney, of the California Geological Survey, as found by miners in the gold-bearing gravels. On the one hand, these elaborate articles of stone-work are the very characteristic objects of the Indian graves of the district, and on the other the theory that the auriferous gravels capped by lava-flows are of tertiary age is absolutely denied by geologists such as M. Jules Marcou in his article on 'The Geology of California' (*Bull. Soc. Géol. de France*, 1883). It is to be hoped that the Section may have the opportunity of discussing Dr. C. C. Abbott's implements from Trenton, New Jersey. The turtle-back celts, as they are called from their flat and convex sides, are rudely chipped from pebbles of the hard argillite out of the boulder-bed, but the question is as to the position of the sand and gravel in which they are found in the bluffs high above the present Delaware River. The first opinion come to, that the makers of the implements inhabited America not merely after but during the great Ice Age, has been modified by further examination, especially by the report of Mr. H. Carvill Lewis, who considers the implement-bearing bed not to have been deposited by a river which flowed over the top of the boulder-bed, but that at a later period than this would involve, the Delaware had cut a channel through the boulder-bed, and that a subsequent glacier-flood threw down sand and gravel in this cutting at a considerable height above the existing river, burying therein the rude stone implements of an Esquimaux race then inhabiting the country. Belt, Wilson, and Putnam have written on this question, which I will not pursue further, except by pointing out that the evidence from the bluffs of the Delaware must not be taken by itself, but in connection with that from the terraces high above the James River, near Richmond, where Mr. C. M. Wallace has likewise reported the finding of rude stone instruments, to which must be added other finds from Guanajuato, Rio Juchipila, and other Mexican localities.

This leads at once into the interesting argument how far any existing people are the descendants and representatives of man of the post-Glacial period. The problem whether the present Esquimaux are such a remnant of an early race is one which Professor Boyd Dawkins has long worked at, and will, I trust, bring forward with full detail in this appropriate place. Since he stated this view in his work on 'Cave-Hunting' it has continually been cited, whether by way of affirmation or denial, but always with that gain to the subject which arises from a theory based on distinct facts. May I take occasion here to mention as preliminary the question, Were the natives met with by the Scandinavian seafarers of the eleventh century Esquimaux, and whereabouts on the coast where they actually found? It may be to Canadians a curious subject of contemplation how about that time of history Scandinavia stretched out its hands at once to their old and their new home. When the race of bold sea-rovers who ruled Normandy and invaded England turned their prows into the northern and western sea, they passed from Iceland to yet more inclement Greenland, and thence, according to Icelandic records, which are too consistent to be refused belief as to main facts, they sailed some way down the American coast. But where are we to look for the most southerly points which the Sagas mention as reached in Vineland? Where was Keel-ness, where Thorvald's ship ran aground, and Cross-ness, where he was buried, when he died by the skräling's arrow? Rafn, in the 'Antiquitates Americanæ,' confidently maps out these places about the promontory of Cape Cod, in Massachusetts, and this has been repeated since from book to book. I must plead guilty to having cited Rafn's map before now, but when with reference to the present meeting I consulted our learned editor of Scandinavian records at Oxford, Mr. Gudbrand Vigfusson, and afterwards went through the original passages in the Sagas with Mr. York Powell, I am bound to say that the voyages of the Northmen ought to be reduced to more moderate limits. It appears that they crossed from Greenland to Labrador (Helluland), and thence sailing more or less south and west, in two stretches of two days each they came to a place near where wild grapes grew, whence they called the country Vine-land. This would, therefore, seem to have been somewhere about the Gulf of St. Lawrence, and it would be an interesting object for a yachting cruise to try down from the east coast of Labrador a fair four days' sail of a viking ship, and identify, if possible, the sound between the island and the ness, the river running out of the lake into the sea, the long stretches of sand, and the other local features mentioned in the Sagas. While this is in the printer's hands, I hear that a paper somewhat to this same effect may come before the Geographical Section, but the matter concerns us here as bearing on the southern limit of the Esquimaux. The *skrälings* who came on the sea in skin canoes (*hudhkeipr*), and hurled their spears with slings (*valslöngva*), seem by these very facts to have been probably Esquimaux, and the mention of their being swarthy, with great eyes and broad cheeks, agrees tolerably with this. The statement usually made that the word *skräling* meant 'dwarf' would, if correct, have settled the question; but, unfortunately, there is no real warrant for this etymology. If we may take it that Esquimaux 800 years ago, before they had ever found their way to Greenland, were hunting seals on the coast of Newfoundland, and cariboo in the forest, their life need not have been very unlike what it is now in their Arctic home. Some day, perhaps, the St. Lawrence and Newfoundland shores will be searched for relics of Esquimaux life, as has been done with such success in the Aleutian Islands by Mr. W. H. Dall, though on this side of the continent we can hardly expect to find, as he does, traces of long residence and rise from a still lower condition.

Surveying now the vast series of so-called native, or indigenous, tribes of North and South America, we may admit that the fundamental notion on which American anthropology has to be treated is its relation to Asiatic. This kind of research is, as we know, quite old, but the recent advances of zoology and geology have given it new breadth as well as facility. The theories which account for the wide-lying American tribes, disconnected by language as they are, as all descended from ancestors who came by sea in boats, or across Behring's Straits on the ice, may be felt somewhat to strain the probabilities of migration, and are likely to be remodelled under the information now supplied by geology as to the distribution of animals. It has become a familiar fact that the Equidæ, or horse-like animals, belong even more remarkably to the New than to the Old World. There was plainly land-connection between America and Asia, for the horses whose remains are fossil in America to have been genetically connected with the horses re-introduced from Europe. The deer may have passed from the Old World into North America in the Pliocene period; and the opinion is strongly held that the camels went the other way, originating in America and spreading thence into Asia and Africa. The mammoth and the reindeer did not cross over a few thousand years ago by Behring's Straits, for they had been since Pleistocene times spread over the north of what was then one continent. To realise this ancient land-junction of Asia and America, this 'Tertiary-bridge,' to use Professor Marsh's expression, it is instructive to look at Mr. Wallace's chart of the present soundings, observing that an elevation of under 200 feet would make Behring's Straits land, while moderately shallow sea extends southward to about the line of the Aleutian Islands, below which comes the plunge into the ocean depths. If, then, we are to consider America as having received its human population by ordinary migration of successive tribes along this highway, the importance is obvious of deciding how old man is in America, and how long the continent remained united with Asia, as well as how these two difficult questions are bound up together in their bearing on anthropology. Leaving them to be settled by more competent judges, I will only point out that the theory of northern migration on dry land is after all only a revival of an old opinion which came naturally to Acosta in the sixteenth century, because Behring's Straits were not yet known, and was held by Buffon in the eighteenth because the zoological conditions compelled him to suppose that Behring's Straits had not always been there. Such a theory, whatever the exact shape it may take, seems wanted for the explanation of that most obvious fact of anthropology, the analogy of the indigenes of America with Asiatics, and more specifically with East and North Asiatics or Mongoloids. This broad race-generalisation has thrust itself on every observer, and each has an instance to mention. My own particular instance is derived from inspection of a party of Botocudo Indians lately exhibited in London, who in proper clothing could have passed without question as Tibetans or Siamese. Now when ethnologists like Dr. Pickering remark on the South Asiatic appearance of Californian tribes, it is open to them to argue that Japanese sailors of junks wrecked on the coast may have founded families there. But the Botocudos are far south and on the other side of the Andes, rude dwellers in the forests of Brazil, and yet they exhibit in an extreme form the Mongoloid character which makes America to the anthropologist part and parcel of Asia. Looked at in this light, there is something suggestive in our still giving to the natives of America the name of Indians; the idea of Columbus that the Caribs were Asiatics was not so absurd after all.

It is perhaps hardly needful now to protest against stretching the generalisation of American uniformity too far, and taking literally Humboldt's saying that he who has seen one American has seen all. The common character of American tribes, from Hudson's Bay to Tierra del Fuego, though more homogeneous than on any other tract of the world of similar extent, admits of wide subvariation. How to distinguish and measure this subvariation is a problem in which anthropology has only reached unsatisfactory results. The broad distinctions which are plainly seen are also those which are readily defined, such as the shape of the nose, curve of the lips, or the projection of the cheek-bones. But all who have compared such American races as Aztecs and Ojibwas must be sensible of extreme difficulty in measuring the proportions of an average facial type. The attempt to give in a single pair of portraits a generalised national type has been tried—for instance, in the St. Petersburg set of models of races at the Exhibition of 1862. But done merely by eye, as they were, they were not so good as well-chosen individual portraits. It would be most desirable that Mr. Francis Galton's method of photographs, superposed so as to combine a group of individuals into one generalised portrait, should have a thorough trial on groups of Iroquois, Aztecs, Caribs, and other tribes who are so far homogeneous in feature as to lend themselves to form an abstract portrait. A set of American races thus 'galtonised' (if I may coin the term) would very likely be so distinctive as to be accepted in anthropology. Craniological measurement has been largely applied in America, but unfortunately it was set wrong for years by the same misleading tendency to find a uniformity not really existent. Those who wish to judge Morton's dictum applied to the Scioto Mound skull, 'the perfect type of Indian conformation, to which the skulls of all the tribes from Cape Horn to Canada more or less approximate,' will find facts to the contrary set forth in chap. 20 of Wilson's 'Prehistoric Man,' and in Quatrefages and Hamy, 'Crania Ethnica.' American crania really differ so much that the hypothesis of successive migrations has been brought into account for the brachycephalic skulls of the mound-builders as compared with living Indians of the district. Among minor race-divisions, as one of the best established may be mentioned that which in this district brings the Algonquin and Iroquois together into the dolichocephalic division; yet even here some divide the Algonquins into two groups by their varying breadth of skull. What may be the interpretation of the cranial evidence as bearing on the American problem it would be premature to say; at present all that can be done is to systematise facts. It is undisputed that the Esquimaux in their complexion, hair, and feature approximate to the Mongoloid type of North Asia; but when it comes to cranial measurement, the Esquimaux with their narrower skulls, whose proportion of breadth to length is only 75 to 80, are far from conforming to the broad-skulled type of North Asiatic Mongoloids, whose average index is toward 85. Of this divergence I have no explanation to offer; it illustrates the difficulties which have to be met by a young and imperfect science.

To clear the obscurity of race-problems, as viewed from the anatomical standing point, we naturally seek the help of language. Of late years the anthropology of the Old World has had ever-increasing help from comparative philology. In such investigations, when the philologist seeks a connection between the languages of distant regions, he endeavours to establish both a common stock of words and a common grammatical structure. For instance, this most perfect proof of connection has been lately adduced by Mr. R. H. Codrington in support of the view that the Melanesians and Polynesians, much as they differ in skin and hair, speak languages which belong to a common stock. A more adventurous theory is that of Lenormant and Sayce, that the old Chaldean language is connected with the Tatar group; yet even here there is an *à priori* case based at once on analogies of dictionary and grammar. The comparative method becomes much weaker when few or no words can be claimed as similar, and the whole burden of proof has to be borne by similar modes of word-formation and syntax, as, for example, in the researches of Aymonier and Keane tending to trace the Malay group of languages into connection with the Khmer or Cambodian. Within America the philologist uses with success the strong method of combined dictionary and grammar in order to define his great language-groups, such as the Algonquin extending from Hudson's Bay to Virginia, the Athapascan from Hudson's Bay to New Mexico, both crossing Canada in their vast range. But attempts to trace analogies between lists of words in Asiatic and American languages, though they may have shown some similarities deserving further inquiry, have hardly proved an amount of correspondence beyond what chance coincidence would be capable of producing. Thus when it comes to judging of affinities between the great American language-families, or of any of them with the Asiatic, there is only the weaker method of structure to fall back on. Here the Esquimaux analogy seems to be with North Asiatic languages. It would be defined as agglutinative-suffixing, or, to put the definition practically, an Esquimaux word of however portentous length is treated by looking out in the dictionary the first syllable or two, which will be the root, the rest being a string of modifying suffixes. The Esquimaux thus presents in an exaggerated form the characteristic structure of the vast Ural-Altaic or Turanian group of Asiatic languages. In studying American languages as a whole, the first step is to discard the generalisation of Duponceau as to the American languages from Greenland to Cape Horn being united together, and distinguished from those of other parts of the world, by a common character of polysynthetism, or combining whole sentences into words. The real divergences of structure in American language-families are brought clearly into view in the two dissertations of Mons. Lucien Adam, which are the most valuable papers of the Congrès International des Americanistes. Making special examination of sixteen languages of North and South America, Adam considers these to belong to a number of independent or irreducible families, as they would have been, he says, 'had there been primitively several human couples.' It may be worth suggesting, however, that the task of the philologer is to exhaust every possibility of discovering connections between languages before falling back on the extreme hypothesis of independent origins. These American language-families have grammatical tendencies in common, which suggest original relationship, and in some of these even correspond with languages of other regions in a way which may indicate connection rather than chance. For instance, the distinction of gender, not by sex as male and female, but by life as animate and inanimate, is familiar in the Algonquin group; in Cree *muskesin* = shoe (mocassin) makes its plural *muskesină*, while *eskwayŭ* = woman (squaw) makes its plural *eskwaywuk*. Now, this kind of gender is not peculiar to America, but appears in South-East Asia, as for instance in the Kol languages of Bengal. In that Asiatic district also appears the habit of infixing, that is, of modifying roots or words by the insertion of a letter or syllable, somewhat as the Dakota language inserts a pronoun within the verb-root itself, or as that remarkable language, the Chocta, alters its verbs by insertions of a still more violent character. Again, the distinction between the inclusive and exclusive pronoun *we*, according as it means 'you and I' or 'they and I,' &c. (the want of which is perhaps a defect in English), is as familiar to the Maori as to the Ojibwa. Whether the languages of the American tribes be regarded as derived from Asia or as separate developments, their long existence on the American continent seems unquestionable. Had they been the tongues of tribes come within a short time by Behring's Straits, we should have expected them to show clear connection with the tongues of their kindred left behind in Asia, just as the Lapp in Europe, whose ancestors have been separated for thousands of years from the ancestors of the Ostyak or the Turk, still shows in his speech the traces of their remote kinship. The problem how tribes so similar in physical type and culture as the Algonquins, Iroquois, Sioux, and Athapascans, should adjoin one another, yet speaking languages so separate, is only soluble by influences which have had a long period of time to work in.

The comparison of peoples according to their social framework of family and tribe has been assuming more and more importance since it was brought forward by Bachofen, McLennan, and Morgan. One of its broadest distinctions comes into view within the Dominion of Canada. The Esquimaux are patriarchal, the father being head of the family, and descent and inheritance following the male line. But the Indian tribes further south are largely matriarchal, reckoning descent not on the father's but the mother's side. In fact, it was through becoming an adopted Iroquois that Morgan became aware of this system, so foreign to European ideas, and which he supposed at first to be an isolated peculiarity. No less a person than Herodotus had fallen into the same mistake over two thousand years ago, when he thought the Lykians, in taking their names from their mothers, were unlike all other men. It is now, however, an accepted matter of anthropology, that in Herodotus' time nations of the civilised world had passed through this matriarchal stage, as appears from the survivals of it retained in the midst of their newer patriarchal institutions. For instance, among the Arabs to this day, strongly patriarchal as their society is in most respects, there survives that most matriarchal idea that one's nearest relative is not one's father but one's maternal uncle; he is bound to his sister's children by a 'closer and holier tie' than paternity, as Tacitus says of the same conception among the ancient Germans. Obviously great interest attaches to any accounts of existing tribes which preserve for us the explanation of such social phenomena. Some of the most instructive of these are too new to have yet found their way into our treatises on early institutions; they are accounts lately published by Dutch officials among the non-Islamised clans of Sumatra and Java. G. A. Wilken, 'Over de Verwantschap en het Huwelijks en Erfrecht bij de Volken van den Indischen Archipel,' summarises the account put on record by Van Hasselt as to the life of the Malays of the Padang Highlands of Mid-Sumatra, who are known to represent an early Malay population. Among these people not only kinship, but habitation follows absolutely the female line, so that the numerous dwellers in one great house are all connected by descent from one mother, one generation above another, children, then mothers and maternal uncles and aunts, then grandmothers and maternal great-uncles and great-aunts, &c. There are in each district several *suku* or mother-clans, between persons born in which marriage is forbidden. Here then appear the two well-known rules of female descent and exogamy, but now we come into view of the remarkable state of society, that though marriage exists, it does not form the household. The woman remains in the maternal house she was born in, and the man remains in his; his position is that of an authorised visitor; if he will, he may come over and help her in the rice-field, but he need not; over the children he has no control whatever, and were he to presume to order or chastise them, their natural guardian, the mother's brother (*mamak*), would resent it as an affront. The law of female descent and its connected rules have as yet been mostly studied among the native Americans and Australians, where they have evidently undergone much modification. Thus 150 years ago Father Lafitau mentions that the husband and wife, while in fact moving into one another's hut, or setting up a new one, still kept up the matriarchal idea by the fiction that neither he nor she quitted their own maternal house. But in the Sumatra district just referred to, the matriarchal system may still be seen in actual existence, in a most extreme and probably early form. If, led by such new evidence, we look at the map of the world from this point of view, there discloses itself a remarkable fact of social geography. It is seen that matriarchal exogamous society, that is, society with female descent and prohibition of marriage within the clan, does not crop up here and there, as if it were an isolated invention, but characterises a whole vast region of the world. If the Malay district be taken as a centre, the system of intermarrying mother-clans may be followed westward into Asia, among the Garos and other hill tribes of India. Eastward from the Indian Archipelago it pervades the Melanesian islands, with remains in Polynesia; it prevails widely in Australia. and stretches north and south in the Americas. This immense district represents an area of lower culture, where matriarchalism has only in places yielded to the patriarchal system, which developes with the idea of property, and which, in the other and more civilised half of the globe, has carried all before it, only showing in isolated spots and by relics of custom the former existence of matriarchal society. Such a geographical view of the matriarchal region makes intelligible facts which while not thus seen together were most puzzling. When years ago Sir George Grey studied the customs of the Australians, it seemed to him a singular coincidence that a man whose maternal family name was Kangaroo might not marry a woman of the same name, just as if he had been a Huron of the Bear or Turtle totem, prohibited accordingly from taking a wife of the same. But when we have the facts more completely before us, Australia and Canada are seen to be only the far ends of a world-district pervaded by these ideas, and the problem becomes such a one as naturalists are quite accustomed to. Though Montreal and Melbourne are far apart, it may be that in prehistoric times they were both connected with Asia by lines of social institution as real as those which in modern times connect them through Europe. Though it is only of late that this problem of ancient society has received the attention it deserves, it is but fair to mention how long ago its scientific study began in the part of the world where we are assembled. Father Lafitau, whose 'Mœurs des Sauvages Amériquains' was published in 1724, carefully describes among the Iroquois and Hurons the system of kinship to which Morgan has since given the name of 'classificatory,' where the mother's sisters are reckoned as mothers, and so on. It is remarkable to find this acute Jesuit missionary already pointing out how the idea of the husband being an intruder in his wife's house bears on the pretence of surreptitiousness in marriage among the Spartans. He even rationally interprets in this way a custom which to us seems fantastic, but which is a most serious observance among rude tribes widely spread over the world. A usual form of this custom is that the husband and his parents-in-law, especially his mother-in-law, consider it shameful to speak to or look at one another, hiding themselves or getting out of the way, at least in pretence, if they meet. The comic absurdity of these scenes, such as Tanner describes among the Assineboins, disappears if they are to be understood as a legal ceremony, implying that the husband has nothing to do with his wife's family. To this part of the world also belongs a word which has been more effective than any treatise in bringing the matriarchal system of society into notice. This is the term *totem*, introduced by Schoolcraft to describe the mother-clans of the Algonquins, named 'Wolf,' 'Bear,' &c. Unluckily the word is wrongly made. Professor Max Müller has lately called attention to the remark of the Canadian philologist Father Cuoq (N. O. Ancien Missionnaire), that the word is properly *ote*, meaning 'family mark,' possessive *otem*, and with the personal pronoun *nind otem*, 'my family mark,' *kit otem*, 'thy family mark.' It may be seen in Schoolcraft's own sketch of Algonquin grammar how he erroneously made from these a word *totem*, and the question ought perhaps to be gone into in this Section, whether the term had best be kept up or amended, or a new term substituted. It is quite worth while to discuss the name, considering what an important question of anthropology is involved in the institution it expresses. In this region there were found Iroquois, Algonquins, Dakotas, separate in language, and yet whose social life was regulated by the matriarchal totem structure. May it not be inferred from such a state of things, that social institutions form a deeper-lying element in man than language or even physical race-type? This is a problem which presents itself for serious discussion when the evidence can be brought more completely together.

It is obvious that in this speculation, as in other problems now presenting themselves in anthropology, the question of the antiquity of man lies at the basis. Of late no great progress has been made toward fixing a scale of calculation of the human period, but the arguments as to time required for alterations in valley-levels, changes of fauna, evolution of races, languages, and culture, seem to converge more conclusively than ever toward a human period short indeed as a fraction of geological time, but long as compared with historical or chronological time. While, however, it is felt that length of time need not debar the anthropologist from hypotheses of development and migration, there is more caution as to assumptions of millions of years where no arithmetical basis exists, and less tendency to treat everything prehistoric as necessarily of extreme antiquity, such as, for instance, the Swiss lake-dwellings and the Central American temples. There are certain problems of American anthropology which are not the less interesting for involving no considerations of high antiquity; indeed, they have the advantage of being within the check of history, though not themselves belonging to it.

Humboldt's argument as to traces of Asiatic influence in Mexico is one of these. The four ages in the Aztec picture-writings, ending with catastrophes of the four elements, earth, fire, air, water, compared by him with the same scheme among the Banyans of Surat, is a strong piece of evidence which would become yet stronger if the Hindu book could be found from which the account is declared to have been taken. Not less cogent is his comparison of the zodiacs or calendar-cycles of Mexico and Central America with those of Eastern Asia, such as that by which the Japanese reckon the Sixty-year cycle by combining the elements seriatim with the twelve animals, Mouse, Bull, Tiger, Hare, &c.; the present year is, I suppose, the second water-ape year, and the time of day is the goat-hour. Humboldt's case may be reinforced by the consideration of the magical employment of these zodiacs in the Old and New World. The description of a Mexican astrologer, sent for to make the arrangements for a marriage by comparing the zodiac animals of the birthdays of bride and bridegroom, might have been written almost exactly of the modern Kalmuks; and in fact it seems connected in origin with similar rules in our own books of astrology. Magic is of great value in thus tracing communication, direct or indirect, between distant nations. The power of lasting and travelling which it possesses may be instanced by the rock-pictures from the sacred Roches Percées of Manitoba, sketched by Dr. Dawson, and published in his father's volume on 'Fossil Man,' with the proper caution that the pictures, or some of them, may be modern. Besides the rude pictures of deer and Indians and their huts, one sees with surprise a pentagram more neatly drawn than that defective one which let Mephistopheles pass Faust's threshold, though it kept the demon in when he had got there. Whether the Indians of Manitoba learnt the magic figure from the white man, or whether the white man did it himself in jest, it proves a line of intercourse stretching back 2,500 years to the time when it was first drawn as a geometrical diagram of the school of Pythagoras. To return to Humboldt's argument, if there was communication from Asia to Mexico before the Spanish Conquest, it ought to have brought other things, and no things travel more easily than games. I noticed some years ago that the Aztecs are described by the old Spanish writers as playing a game called *patolli*, where they moved stones on the squares of a cross-shaped mat, according to the throws of beans marked on one side. The description minutely corresponds with the Hindu game of *pachisi*, played in like manner with cowries instead of beans; this game, which is an early variety of backgammon, is well known in Asia, whence it seems to have found its way into America. From Mexico it passed into Sonora and Zacatecas, much broken down but retaining its name, and it may be traced still further into the game of plumstones among the Iroquois and other tribes. Now, if the probability be granted that these various American notions came from Asia, their importation would not have to do with any remotely ancient connection between the two continents. The Hindu element-catastrophes, the East Asiatic zodiac-calendars, the game of backgammon, seem none of them extremely old, and it may not be a thousand years since they reached America. These are cases in which we may reasonably suppose communication by seafarers, perhaps even in some of those junks which are brought across so often by the ocean-current and wrecked on the Californian coast. In connection with ideas borrowed from Asia there arises the question, How did the Mexicans and Peruvians become possessed of bronze? Seeing how imperfectly it had established itself, not even dispossessing the stone implements, I have long believed it to be an Asiatic importation of no great antiquity, and it is with great satisfaction that I find such an authority on prehistoric archæology as Professor Worsaae comparing the bronze implements in China and Japan with those of Mexico and Peru, and declaring emphatically his opinion that bronze was a modern novelty introduced into America. While these items of Asiatic culture in America are so localised as to agree best with the hypothesis of communication far south across the Pacific, there are others which agree best with the routes far north. A remarkable piece of evidence pointed out by General Pitt-Rivers is the geographical distribution of the Tatar or composite bow, which in construction is unlike the long-bow, being made of several pieces spliced together, and which is bent backwards to string it. This distinctly Asiatic form may be followed across the region of Behring's Straits into America among the Esquimaux and northern Indians, so that it can hardly be doubted that its coming into America was by a northern line of migration. This important movement in culture may have taken place in remotely ancient times.

A brief account may now be given of the present state of information as to movements of civilisation within the double continent of America. Conspicuous among these is what may be called the northward drift of civilisation, which comes well into view in the evidence of botanists as to cultivated plants. Maize, though allied to, and probably genetically connected with an Old World graminaceous family, is distinctly American, and is believed by De Candolle to have been brought into cultivation in Peru, whence it was carried from tribe to tribe up into the North. To see how closely the two continents are connected in civilisation, one need only look at the distribution on both of maize, tobacco, and cacao. It is admitted as probable that from the Mexican and Central American region agriculture travelled northward, and became established among the native tribes. This direction may be clearly traced in a sketch of their agriculture, such as is given in Mr. Lucien Carr's paper on the 'Mounds of the Mississippi Valley.' The same staple cultivation passed on from place to place, maize, haricots, pumpkins, for food, and tobacco for luxury. Agriculture among the Indians of the great lakes is plainly seen to have been an imported craft by the way in which it had spread to some tribes but not to others. The distribution of the potter's art is similarly partial, some tribes making good earthen vessels, while others still boiled meat in its own skin with hot stones, so that it may well be supposed that the arts of growing corn and making the earthen pot to boil the hominy came together from the more civilised nations of the south. With this northward drift of civilisation other facts harmonise. The researches of Buschmann, published by the Berlin Academy, show how Aztec words have become embedded in the languages of Sonora, New Mexico, and up the western side of the continent, which could not have spread there without Mexican intercourse extending far north-west. This indeed has left many traces still discernible in the industrial and decorative arts of the Pueblo Indians. Along the courses of this northward drift of culture remain two remarkable series of structures probably connected with it. The Casas Grandes, the fortified communal barracks (if I may so call them) which provided house-room for hundreds of families, excited the astonishment of the early Spanish explorers, but are only beginning to be thoroughly described now that such districts as the Taos Valley have come within reach by the railroads across to the Pacific. The accounts of these village-forts and their inhabitants, drawn up by Major J. W. Powell, of the Bureau of Ethnology, and Mr. Putnam, of the Peabody Museum, disclose the old communistic society surviving in modern times, in instructive comment on the philosophers who are seeking to return to it. It would be premature in the present state of information to decide whether Mr. J. L. Morgan, in his work on the 'Houses and House-life of the American Aborigines,' has realised the conditions of the problem. It is plausible to suppose with him a connection between the communal dwellings of the American Indians, such as the Iroquois long-house with its many family hearths, with the more solid buildings inhabited on a similar social principle by tribes such as the Zuñis of New Mexico. Morgan was so much a man of genius, that his speculations, even when at variance with the general view of the facts, are always suggestive. This is the case with his attempt to account for the organisation of the Aztec state as a highly-developed Indian tribal community, and even to explain the many-roomed stone palaces, as they are called, of Central America, as being huge communal dwellings like those of the Pueblo Indians. I will not go further into the subject here, hoping that it may be debated in the Section by those far better acquainted with the evidence. I need not, for the same reason, do much more than mention the mound-builders, nor enter largely on the literature which has grown up about them since the publication of the works of Squier and Davis. Now that the idea of their being a separate race of high antiquity has died out, and their earthworks with the implements and ornaments found among them are brought into comparison with those of other tribes of the country, they have settled into representatives of one of the most notable stages of the northward drift of culture among the indigenes of America.

Concluding this long survey, we come to the practical question how the stimulus of the present meeting may be used to promote anthropology in Canada. It is not as if the work were new here, indeed some of its best evidence has been gathered on this ground from the days of the French missionaries of the seventeenth century. Naturally, in this part of the country, the rudimentary stages of thought then to be found among the Indians have mostly disappeared. For instance, in the native conceptions of souls and spirits the crudest animistic ideas were in full force. Dreams were looked on as real events, and the phantom of a living or a dead man seen in a dream was considered to be that man's personality and life, that is, his soul. Beyond this, by logical extension of the same train of thought, every animal or plant or object, inasmuch as its phantom could be seen away from its material body in dreams or visions, was held to have a soul. No one ever found this primitive conception in more perfect form than Father Lallemant, who describes in the 'Rélations des Jesuites' (1626) how, when the Indians buried kettles and furs with the dead, the bodies of these things remained, but the souls of them went to the dead men who used them. So Father Le Jeune describes the souls, not only of men and animals, but of hatchets and kettles, crossing the water to the Great Village out in the sunset. The genuineness of this idea of object-souls is proved by other independent explorers finding them elsewhere in the world. Two of the accounts most closely tallying with the American, come from the Rev. Dr. Mason, in Birma, and the Rev. J. Williams, in Fiji. That is to say, the most characteristic development of early animism belongs to the same region as the most characteristic development of matriarchal society, extending from south-east Asia into Melanesia and Polynesia, and North and South America. Everyone who studies the history of human thought must see the value of such facts as these, and the importance of gathering them up among the rude tribes who preserve them, before they pass into a new stage of culture. All who have read Mr. Hale's studies on the Hiawatha legend and other Indian folklore, must admit that the native traditions, with their fragments of real history, and their incidental touches of native religion, ought never to be left to die out unrecorded. In the Dominion, especially in its outlying districts toward the Arctic region and over the Rocky Mountains, there is an enormous mass of anthropological material of high value to be collected, but this collection must be done within the next generation, or there will be little left to collect. The small group of Canadian anthropologists, able and energetic as they are, can manage and control this work, but cannot do it all themselves. What is wanted is a Canadian

Anthropological Society with a stronger organisation than yet exists, able to arrange explorations in promising districts, to circulate questions and requirements among the proper people in the proper places, and to lay a new burden on the shoulders of the already hard-worked professional men, and other educated settlers through the newly-opened country, by making them investigators of local anthropology. The Canadian Government, which has well deserved the high reputation it holds throughout the world for wisdom and liberality in dealing with the native tribes, may reasonably be asked to support more thorough exploration, and collection and publication of the results, in friendly rivalry with the United States Government, which has in this way fully acknowledged the obligation of making the colonisation of new lands not only promotive of national wealth, but serviceable to science. It is not for me to do more here, and now, than to suggest practical steps toward this end. My laying before the Section so diffusive a sketch of the problems of anthropology as they present themselves in the Dominion, has been with the underlying intention of calling public notice to the important scientific work now standing ready to Canadian hands; the undertaking of which it is to be hoped will be one outcome of this visit of the British Association to Montreal.

FRIDAY, AUGUST 29.

The following Papers and Report were read:—

1. *Instructions Anthropométriques Elémentaires. By* Dr. P. Topinard.

2. *On Myths of the Modoc Indians. By* J. Curtin.

3. *On the Nature and Origin of Wampum. By* Horatio Hale.

It is a notable fact that while the populous and partly-civilised Indian communities of Central and South America, like the ancient Egyptians and Assyrians, carried on their commerce without the aid of money, the more barbarous tribes of the region now composing the United States and Canada had a real monetary currency in common use. This was their wampum, which consisted of shell-beads, in the form of disks or small cylinders, perforated through the centre, and usually strung upon a deer's sinew or some other string. This currency was found by the first white settlers so useful in dealing with the Indians, and so convenient in the absence of silver money, that it was for a time adopted and made a legal currency among the Colonists themselves. These shell-beads were fashioned by the natives from various kinds of sea-shells, including several species of conchs and periwinkles, and also a bivalve common on the Atlantic coast, and known as the *quahang*, or *Venus mercenaria*. The beads were of two colours, white and dark purple, the latter usually styled black, and esteemed, from their rarity, about twice as valuable as the white beads. This money, being a manufactured article, differed from the East Indian cowries, or strung shells, precisely as coined money differs from bullion.

The wampum derived its value partly from the great labour expended in making it, and partly from its prominence in the social usages of the Indians. All important acts of state-policy were authenticated by the exhibition of wampum in the form either of strings or of belts. In the making of treaties several belts were usually exchanged. Each belt had its peculiar device, woven either of white beads on a dark ground, or of dark beads on a white ground. These devices were rude pictorial emblems, resembling the earlier forms of the Chinese characters. The wampum was also largely employed in funeral ceremonies and in sacrifices.

Great quantities of these shells-disks and cylinders were found in the ancient mounds of the Mississippi valley, and there seems no reason to doubt that they were used by the builders of those mounds in the same manner and to the same extent as by the modern Indians.

West of the Rocky Mountains the shell-money was in use among the Indians down almost to our own times. It was made chiefly in the form of disks, which were perforated and strung on strings. In their traffic these were rated sometimes by the number of beads, and sometimes by the length of the string. There was a larger kind, made in oblong strips, with two holes at one end for stringing them. The shell-money was much used by the Californians in their funeral ceremonies and their sacrifices.

Continuing in a westerly course, we come, in the Northern Pacific, to the island groups of Micronesia. In these groups the shell-money is found in use, very much as among the North American Indians. In some islands it is made of disks of sea-shell and cocoanut-shell, strung alternately white and black, and disposed of in lengths. In others it is formed of tortoise-shell disks, strung and used in the same manner.

In the Loo Choo Islands, which are midway between Micronesia and China or Japan, the Chinese money is in use. This consists of small circular copper coins, known to Europeans as 'cash.' They have a hole in the centre, are strung on strings, and usually disposed of in lengths. According to the Chinese authorities, the money anciently used in that empire, before metallic coins were known, was of tortoise-shell. The earliest Chinese copper coins of which specimens are known are of various shapes, probably fashioned after the shapes of this tortoise-shell money. Most of them are round, with a hole in the centre, but some are oblong, and perforated at one end for stringing, like the Californian shell-slips. The Chinese have 'mock-money,' made of tinfoil and paper, which is burnt in their sacrifices. This is regarded as evidence that their current money was originally made of some combustible material.

The natural inference from these facts is that the knowledge and use of the Chinese shell-money were probably carried in early times from Eastern Asia, or from Micronesia, to this continent. The manner in which this may have occurred is shown by the fact that many Japanese junks have been wrecked during the present century on the west coast of North America. The Micronesians also have large and well-rigged vessels, in which they are accustomed to make long voyages, and one of which may easily have drifted to that coast.

The use of this currency as a medium of exchange in the Pacific Islands and in North America, whether it is regarded as of indigenous origin or as introduced from abroad, must in either case be deemed an evidence of good intellectual powers in the people who employ it.

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4. *Marriage Laws of the North American Tribes. By* Major J. W. Powell.

A definition of the term law that will hold good under all circumstances must be divested of the many theories of its origin, the source of its authority, and its ethic characteristics, which are expressed or implied in customary definitions, and laws must be considered as objective facts. The following definition will perhaps do under all circumstances: *A law is a rule of conduct which organised society endeavours to enforce.*

In civilisation law is theoretically founded on justice, but in savagery principles of justice have little consideration. There are two fundamental principles at the basis of primitive law, viz.: first, controversy should be prevented; second, controversy should be terminated. A third is derivative from them, namely: infraction of law should be punished. These principles enter into primitive law in many curious ways.

It was customary among the tribes of North America for individuals to mark their arrows, in order that the stricken game might fall to the man by whose arrow it had been dispatched.

A war party of Sioux surprised a squad of sleeping soldiers, who were all killed at the first volley from the Indians. Their arms, blankets, and other property were untouched, because, the attacking party being large, it could not be decided by whose bullets the soldiers were killed.

It has been widely believed that the practice of placing the property of deceased persons in their graves when they are buried has its origin in religion, and testifies to the universal belief that the dead live again and will need such articles in their new life. But many tribes of North America who have not yet been long in contact with white men avow that, there being no owner for the property, its disposition might lead to controversy, and hence it is destroyed. Many examples of this fact have been collected. Ownership as to the greater part of property in savagery is communal, some classes of property being owned by the clan, others by the tribe; and for such there is no proper inheritance, as the clan and tribe do not die; but purely personal property is inherited by the grave. It seems probable that such is the origin of the custom of burying various articles with the dead. Subsequently it has religious sanctions thrown about it, as have all social customs.

There is a law among the tribes of North America that superior age gives authority. This law is widely spread, and perhaps universal, and exercises a profound influence in tribal society, as the occasions for its application are multifarious. Like many other of the institutions of tribal society, it is woven into the structure of tribal language. Linguists have recorded as a curious fact that in these languages there is no single term for brother, but two terms, one signifying elder brother and the other younger brother. They have also found similar facts relating to the term sister, and to some other kinship words; but, so far as I know, they have failed to observe that the law applies to all consanguineal kinship names. All of these titles express relative age between the person speaking and the person addressed. Among savage tribes the age of an individual is not kept; no man knows his own age; but every man, woman, and child in the tribe knows his relative age to every other person in the tribe—who are older and who are younger than himself; for, in addressing any other person in the tribe, he must necessarily use a term which implies that the person addressed is older or younger than himself, and this is rendered necessary to comply with the general law that authority is inherent in the elder. This is the explanation of another curious custom observed among savage tribes, namely, that it is illegal to address a person by his proper name. Kinship terms are used in direct address, proper names in speaking of a third person. The law that authority is inherent in the elder is a simple and ingenious method of preventing controversy.

An interesting form of outlawry exists among some tribes. When a man has frequently involved his clan in controversy with other clans by reason of quarrels or other outrageous conduct, his own may decide no longer to defend him, and will formally announce in tribal council that such person is no longer under their protection. If the person, thereafter, by his conduct maltreats any member of the tribe, the injured party may do as he will with the offender, and will not be held accountable by the kindred of the outlaw.

The few illustrations here given are sufficient perhaps to make clear what is meant by the statement that a large class of savage laws are designed to prevent controversy. Many other illustrations might be given, for they are found on every hand.

Three especial methods of terminating controversy are widely spread among the tribes of North America.

When controversy arises in relation to ownership, the property is usually destroyed by the clan or tribal authorities. Thus, if two men dispute in bartering their horses, a third steps in and kills both animals. It seems probable that the destruction of property, the ownership of which is in dispute, is common to all tribes.

A second method of ending controversy is by the arbitrament of personal conflict. For example, if two persons disagree and come to blows, unless conflict end in the maiming or killing of one of the parties, it is considered a final settlement, and they cannot thereafter appeal to their clans for justice. By conflict a controversy is outlawed. This law seems to be universal.

The third method of terminating controversy is by the establishment of some day of festival,—sometimes once a month, but usually once a year,—beyond which crimes do not pass. The day of jubilee is a day of forgiveness. The working of this principle might be illustrated in many ways.

It has been thus necessary to briefly set forth certain principles of primitive law, in order that the subject of marriage law in savage society may be clearly understood. Law begins in savagery through the endeavour to secure peace, and developes in the highest civilisation into the endeavour to establish justice.

Society is organised for the regulation of conduct, and conduct is regulated by law in the several stages of human progress in relation to those particulars about which serious disagreement arises. In the early history of mankind it appears from all that we may now know of the matter that the most serious and frequent disagreement arose out of the relations of the sexes. Men disagreed about women, and women about men. Early law therefore deals to a large extent with the relations of the sexes. The savage legislator sought to avoid controversy by regulating marital relations, and this he did by denying to the individual the right of choice, and providing that certain groups of men should take their wives from certain groups of women; and further, that the selection of the woman should not be given to the man, nor the selection of the man to the woman, but that certain officers or elder persons should make the marriage contract. This method of selection will here be called Legal Appointment.

Now, selection by legal appointment exists among all North American tribes, and elsewhere among savages in Australia and other portions of the globe; but it exists in diverse forms, which may not here be recounted for want of space. But the essential principle is this: In order that controversy may be avoided, marriage selection is by legal appointment, and not by personal choice.

But the second fundamental principle of primitive law greatly modifies selection by legal appointment, and gives rise to three forms of marriage, which will be denominated as follows: first, marriage by elopement; second, marriage by capture; third, marriage by duel.

It very often happens in the history of tribes that certain of the kinship groups diminish in number while others increase. A group of men may greatly increase in number while the group of women from whom they are obliged to accept their wives diminishes. At the same time another group of women may be large in proportion to the group of men to whom they are destined. Under these circumstances certain men have a right to many wives while others have a right to but few. It is very natural that young men and young women should sometimes rebel against the law and elope with each other. Now the second fundamental principle of early law, mentioned above, is that controversy must end, and such termination is secured by a curious provision found among many, perhaps all, tribes. A day is established, sometimes once a moon, but usually once a year, at which certain classes of offences are forgiven. If, then, a runaway couple can escape to the forest and live by themselves until the day of forgiveness, they may return to the tribe and live in peace. Marriage by this form exists in many of the tribes of North America.

Again, the group of men whose marriage rights are curtailed by diminution of the stock into which they may marry, sometimes unite to capture a wife for one of their number from some other group. It must be distinctly understood that this capture is not from an alien tribe, but always from a group within the same tribe. The attempt at capture is resisted, and a conflict ensues. If the capture is successful the marriage is thereafter considered legal; if unsuccessful, a second resort to capture in the particular case is not permitted, for controversy must end. When women are taken in war from alien tribes, they must be adopted into some clan within the capturing tribe, in order that they may become wives of the men of the tribe. When this is done, the captured women become by legal appointment the wives of men in the group, having marital rights in the clan which has adopted them.

The third form is marriage by duel. When a young woman comes to a marriageable age it may happen that by legal appointment she is assigned to a man who already has a wife, while there may be some other young man in the tribe who is without a wife because there is none for him in the group within which he may marry. It is then the right of the latter to challenge to combat the man who is entitled to more than one, and if successful he wins the woman; and by savage law controversy must then end. All three of these forms are observed among the tribes of North America, and they are methods by which selection by legal appointment is developed into selection by personal choice. Sometimes these latter forms largely prevail, and they come to be regulated more and more, until at last they become mere forms, and personal choice prevails.

When personal choice thus prevails, the old regulation that a man may not marry within his own group still exists, and selection within that group is incest, which is always punished with great severity. The group of persons within which marriage is incest is always a highly artificial group. Hence, in early society, incest laws do not recognise physiological conditions, but only social conditions.

The above outline will make clear the following statement, that endogamy and exogamy, as originally defined by Maclennan, do not exist. Every savage man is exogamous with relation to the class or clan to which he may belong, and he is to a certain extent endogamous in relation to the tribe to which he belongs; that is, he must marry within that tribe, but in all cases, if his marriage is the result of legal appointment, he is greatly restricted in his marriage rights, and the selection must be made within some limited group. Exogamy and endogamy, as thus defined, are integral parts of the same law, and the tribes of mankind cannot be classed in two great groups, one practising endogamy and the other exogamy.

The law of exogamy is universal. Among all peoples there is a group, larger or smaller, and natural or artificial, within which marriage is prohibited. The terms 'exogamy' and 'endogamy' are misleading, and should be discarded.

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5. *Report of the Committee for defining the Facial Characteristics of the Races and Principal Crosses in the British Isles.*—See Reports, p. 294.

SATURDAY, AUGUST 30.

The Section did not meet.

MONDAY, SEPTEMBER 1.

The following Papers were read:—

1. *Remarks on the Customs and Language of the Iroquois.* *By* Mrs. Erminie A. Smith.

The literal meaning of many Iroquois nouns is extremely interesting. The names of animals in very many cases refer to some peculiarity of the object. The goat and some other animals are named from their odour; birds generally from their note; nearly all trees are named from some quality; tears, translate as eye-juice; sugar, as tree-juice. The feelings and passions are even more strikingly descriptive: a thing that is wonderful is scalp-raising; anything tempting, alluring, or captivating, is said 'to unhook the mind.' The peculiarity of different words requiring unlike pronouns for the same person and number, and the great number of these pronouns have greatly puzzled most students of Indian languages, several of whom have stated that there are but two genders, a noble and an ignoble; Mrs. Smith, however, brings evidence to prove the existence of three genders in these dialects.

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2. *On the Development of Industrial and Ornamental Art among the Zuñis of New Mexico.* *By* F. H. Cushing.

The author brought forward evidence, linguistic and otherwise, to prove the descent of the Zuñis from the Pueblo Indians. The word Pueblo was applied to a nation who lived in communal dwellings. The art of pottery was practised in the Pueblo district to a very great extent, and the author gave an account of the formation of the Zuñi gourds, or water-vessels, showing how they were covered with wicker-work in order to preserve them. The Zuñis regard the bowls they make as possessing something of the nature of life or spirit; they place food and water near the vessel, and as the woman completes it she imagines she has made something like a living being. The different sounds made by the pots when they are struck, or as their contents boil, are believed to be the voices of the beings which are associated with the vessels. Apertures or blank spaces are left for the escape of the spirit. A Zuñi woman, as she closes the apex of a pointed clay vessel, turns her eyes away, and says she is fearful to watch this operation. The Zuñis in representing animals always show a kind of line or passage leading from the throat to the heart. In conclusion the author referred to the probable origin of the shapes used in the pottery of America.

3. *The Huron-Iroquois, a typical race of American Aborigines.* *By* Dr. Daniel Wilson.

4. *Anthropological Discoveries in Canada.* *By* C. A. Hirschfelder.

The ancient remains of Canada have, as yet, been by no means satisfactorily examined, and consequently but superficially described; and although we have no stone ruins, still that does not detract from the interest of the prehistoric works found scattered over various sections of this country, which are well worthy of a thorough scientific examination. The forts, which were built principally of earth, although stone was not unfrequently used to some extent in their construction, are particularly interesting from two points of view—viz., the almost perfect symmetrical shape, and the advantageous positions which were invariably chosen. As to the first-named feature, they bear a striking resemblance to the ancient earthworks of the Western States, by which some writers have endeavoured to prove that the authors of those works must have been advanced in certain sciences. As to the situation of these forts, their ancient builders seem to have carefully studied localities, and to have fully appreciated the advantages to be gained thereby, as the situations chosen were invariably such as to either command a view for a long distance over the country, or, if near the water, to be so constructed that a fleet of canoes could be seen a long distance away, so that sudden attacks by water would be impracticable.

The forts were generally made either circular or oval, although one or two surveyed were crescent or semicircular, the form probably depending upon the lie of the land; and it is very singular that there has not been, to my knowledge, a single fort discovered in Canada which even approaches a square. Entrenchments seem to have been a not uncommon mode of defence, and have every appearance of being anterior to the wall or embankment forts; the largest one surveyed was half a mile in circumference, of a circular form, and, judging by counting the concentric rings of trees growing right in the ditch, which must have grown after the fort was constructed, also by decayed vegetable-matter and other evidences, was computed to be from 800 to 1,000 years old.

Ancient burial-places may be classed under three heads—mounds, ossuaries, and single graves. Mounds are not of frequent occurrence in Canada, and all which have so far been examined have contained human bones, proving they were used as burial repositories. These tumuli (if they may be so termed) are not by any means large; they generally measure about one hundred feet in circumference, and are only about five feet high. The dead seem to have been buried without any regular system, each mound containing from six to twelve bodies.

The ossuaries are probably the most interesting remains we have. They consist of round symmetrical holes dug to the required depth, in which the bodies were promiscuously deposited: some of the larger ones contain the remains of several thousand bodies.

The single graves are the most ordinary remains, and are generally found on high ground, a hill-top being a favourite site. In dwelling on the question of sepulture, the author trusts to be able to show clearly that the burial of articles with the dead was not so much a religious act as a mark of respect to the dead.

The archæological relics of Canada have never been fully described, and are deserving of a higher rank, in a scientific sense, than has as yet been awarded them. We have a grand field to work in, and the articles we find well repay us for the trouble taken. The Aborigines of America are undoubtedly the fathers of smoking, and the elaborate workmanship which was bestowed upon their pipes shows the important place it took in their everyday life. There are no articles found which so well portray the aboriginal ingenuity as the pipes. Animals, birds, reptiles, and the human physiognomy are all carved upon the bowls and stems with lifelike accurateness. Many specimens found would trouble a clever artisan of the present day to copy exactly, allowing him all the modern tools to work with, because stones, tools, ornaments of various kinds, &c., were also manufactured with a precision simply perfect; and, strange to say, it seems to have been a matter of little moment whether they worked the hardest or softest materials.

Pottery, shell, and bone were extensively used in the manufacture of articles for their everyday life, whether for ornaments or necessary utensils; copper was also utilised to some extent, principally for tools, ornaments, and sword-blades; the ore was merely pounded into the required shape.

Shells which must have been brought a distance of nearly two thousand miles are sometimes found in graves, evidencing the extraordinary fact that a trade must have been carried on between the Aborigines of the North and those of the South, which, extending over such a vast distance, and with their primitive mode of travelling, must have made the articles exchanged of great value.

The wampum was probably nearly altogether carved from these foreign shells.

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5. *Observations on the Mexican Zodiac and Astrology. By* HYDE CLARKE.

The author communicated some detailed observations on the Mexican signs, and on the figure of a man to the limbs and organs of which these signs are applied. These he treated in comparison with the Chinese Zodiac, that adopted in Europe, the Phœnician and Hebrew alphabet, and the linguistic relations of the several words. Taurus was correlated with Aleph, א (1); Virgo the Girl with the Chinese Snake; Scorpion (6) with the Mexican Ear; Sagittarius (8) = Tiger, Ocelot, Navel, and 8; Aquarius (10) with the Rat, Water, and the Hair. For the right eye, the Mexican sign is the house. In gesture language and also in speech language the eye = 2. This is also the numerical value of the House ב in the Semitic alphabets. Of purely Mexican signs were illustrated Goat = Foot; Sun = Tongue; and Lizard = Thigh.

Mr. Clarke's conclusion was that at one time there was in the world a common symbolic, linguistic, and numeral connection of the objects, and that Chinese, Egyptian, Mexican, or Aztec and Phœnician are not original types, but simply derivative. The numeral relations are not to be regarded as arithmetical, but serial; and as the order of a series could be changed, the variations in existing types are thus to be accounted for. The originals must have been of most remote antiquity.

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6. *Facts suggestive of Prehistoric Intercourse between East and West. By* Miss A. W. BUCKLAND.

The object of this paper is to point out a few facts which have been somewhat overlooked, but which all tend to show that at some very early period an intercourse must have subsisted between the two hemispheres, by means of which ideas were interchanged, to be worked out differently, although bearing traces of a common origin.

Miss Buckland first points out the similarities between the canoes and rafts of Asia and America, and then proceeds to show the relation between a few peculiar American weapons, which seem to have had a very wide range and also some mystic signification. The first of these is an axe-head of metal, which was used as a symbol on the heads of gods, both in Peru and Mexico, and appears to have adorned Assyrian helmets, and the trappings of horses, both in Assyria and Persia. Then there is the *Maquahuitl*, a Mexican weapon, consisting of blades of obsidian in a wooden handle, which appears also in rock carvings in Peru, and an affinity to which is seen in New Guinea and the Philippines.

The remarkable resemblance existing between the pottery of Hissarlik and Peru is shown to extend to an ornament or symbol found frequently on the vases of Hissarlik, which appears *reversed* on vases in the Mexican paintings; whilst, curiously enough, the *Mexican* form of this symbol appears on the sculptured stones of Scotland in conjunction with the T which forms one of the Maya hieroglyphs.

Another instance of similarity is found in the circle with lines running through it, which in Peru is said to represent a watercourse constructed by one of the Incas. Another suggestive symbol is the protruding tongue, signifying Quetzalcoatl in Mexico, but which is found in statues in various other parts of America, and also in Egypt and Etruria. The winged globe of Egypt, Assyria, and Persia, seems to have its representative, but *reversed*, in Central America, whilst some of the Phœnician letters, also reversed, appear sculptured on the rocks in the Yonan Pass.

The stone circles, cairns, dolmens, and rocking-stones of Europe and Asia, have also their representatives in America, and in the case of the circles are connected with the same legends, that is, that they were men and women turned to stone for dancing instead of listening to a prophet or teacher.

The paper does not deal with similarities in architecture, great tumuli, &c., these having already received considerable attention; but the square apertures in graves in Peru are compared with those in Cyprus and Sardinia, and with similar holes of a round form in various parts of Europe and Asia. These holes are supposed to be made to allow of the free passage of the spirit, a similar idea having originated the curious custom of *trepanning*, which prevailed in Europe in Neolithic times; this is found also in Peru, and is apparently indicated among the mound-builders of Illinois.

Several curious customs alike in the two hemispheres are mentioned, especially that of the distortion of the head.

All these coincidences, and many more which are omitted for want of space, the author believes, can only be accounted for by some very early prehistoric intercommunication, the manner and route of which have yet to be determined, there being many difficulties in either route, whether across the Pacific from Asia, or the Atlantic from Europe, being accepted, because of the absence of intermediate traces, and the fact that in *Peru*, farthest removed from the Atlantic, we find the strongest traces of ancient *European* influence, whilst the *Mexican* civilisation seems to approach nearer to that of *Asia*.

TUESDAY, SEPTEMBER 2.

The following Report and Papers were read :—

1. *Report of the Committee for defraying the expenses of completing the preparation of the final Report of the Anthropometric Committee.*— See Reports, p. 279.

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2. *Notes on the Races of the Jews. By* Dr. A. Neubauer.

In this paper an account is given of the race-elements which at various times have become part of the Jewish nation. The author criticises the popular opinion that the two divisions of Sephardim or Spanish-Portuguese Jews, and Ashkenazim or German-Polish Jews, correspond with the tribal divisions of Judah and Benjamin respectively; this opinion he considers to have no historical foundation.

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3. *On a Skull from the Löss of Podbaba, near Prague, and a Skull found in alluvium at Kankakee, Illinois, along with a Tooth of the Mastodon. By* Dr. Daniel Wilson.

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4. *Recent Excavations in Pen Pits, Somersetshire.* *By the* Rev. H. H. Winwood.

The author described the position of these pits, of which there are a large number, and which cover some 700 acres. Some are oval, some round, and some long, and their depths are various. The question to be decided was whether these pits were ancient dwellings, or merely quarries, and the author described the process of exploration in detail, and brought forward evidence to show that the pits were sunk for the purpose of obtaining stone for building, and for grindstones, a large number of which have from time to time been dug up, and are now to be seen in the neighbourhood.

5. *On some doubtful or intermediate Articulations.* *By* Horatio Hall.

6. *On Food Plants used by the North American Indians.* *By* Professor George Lawson, *Ph.D., LL.D., F.I.C., F.R.S.C.*

A knowledge of the distribution of the spontaneous plants capable of supplying the wants of the aborigines is not unimportant in connection with anthropological research, especially in regard to the range of tribes, whether stationary or migratory, whilst the possession by some of the tribes of cultivated plants foreign to the countries they inhabit affords evidence that may be made available in tracing their origin and migrations, or ascertaining their past relations to other tribes. What little we do know of their primitive modes of cultivation excites a desire to ascertain more of a phase of agriculture which leads us back to its very beginnings. The prevalence of wild fruits over the more or less wooded portions of North America, of which numerous examples were cited, would afford even the improvident tribes a copious supply of healthy summer and autumn food to supplement their fish and flesh diet; their constant recurrence to such sources of supply would lead them to a knowledge of the poisonous properties and powerful physiological action of many native plants.

In the Old World, the *Leguminosæ* are known as economical plants, chiefly on account of their *seeds*; in America the *roots* of several are edible. *Psoralea esculenta* is the *pomme blanche* and *pomme de prairie* of the western voyageurs, who derived their knowledge of its qualities from the Indians. *Amphicarpæa monoica* forms subterranean pods containing a single large seed. *Apios tuberosa* is the wild potato, '*Sgabun*' of the Micmac Indians, the root of which is graphically described by an early writer as like a series of hens' eggs on a string. It appears to have been one of the most important food plants of the Micmacs before the advent of Europeans, and gave its name to the place in Nova Scotia called Shubenacadie (sgabun acadie);[1] but, although at one time abundant, it is not known there now, nor is there any tradition of its ever having been cultivated by the aborigines. One other leguminous plant is well known to have been not only used but also cultivated by the Indians, but chiefly in the south, the kidney bean (*Phasæolus*), of which Columbus found planted fields in Cuba; also 'many things of the country, and calabazas, a glorious sight!' These beans were also found cultivated by the Indians in Florida in 1528, and about the regions now known as New Mexico and Sonora, in 1535. De Soto found fields of maize, beans, and pumpkins near Tampa Bay; and at Caligoa (west of the Mississippi) 'beans and pumpkins were in great plenty.' Cartier (1534) found in the north—Bay of Gaspé—abundance of maize and beans, which must have been carried from the far south and west. Father Sagard (1625) also mentions the cultivation of beans (fezolles) by the Indians in the Huron country; the Hurons used a third or quarter part of these in their 'succotash.' Lescarbot describes the planting of the corn (maize) by the Indians of Maine in hills, 'and between the kernels of corn they plant beans with various colours, which are very delicate; these, because they are not so high as the corn, grow very well among it.' Lawson, in his voyage to Carolina (1700–1708), says the kidney beans were here before the English came,

[1] Sgabun = potato. Acadie = plenty here.

being very plentiful in Indian corn-fields. Hudson saw (on the Hudson river) 'great quantity of maize and beans of the last year's growth' (1625).

Nuttall notices the growth of the Warted Squash on the Upper Missouri, and Gray and Trumbull say it is well nigh certain that the species was cultivated in the Mexican and Texan countries by the aborigines. Pumpkins and other *Cucurbitaceæ* were evidently cultivated over a wide range: Cuba, Mexico, Texas, Virginia, Florida, Appalachian country, Upper Missouri, Canada, St. Lawrence (Cartier), Lake Huron (Sagard).

What is known of the early history and use of the Jerusalem artichoke (*Helianthus tuberosus*) is given by Mr. Trumbull in 'American Journal of Science,' 3rd series, vol. xiii. pp. 349–352, and by Gray and Trumbull, vol. xxv. and xxvi. Grown in the Minnesota and Saskatchewan regions by the Indians, it must have been obtained by them from the valleys of the Ohio and Mississippi. Its near botanical ally, the sunflower (*H. annuus*), was cultivated by the Hurons in their towns near the south-eastern point of Georgian Bay for the oil of the seeds, which they used for greasing their hair, as well as for food (Champlain, Sagard, 1610–1636). Gray and Trumbull believe that this also must have been obtained from beyond the Mississippi, and some degrees farther south.

The hop (*Humulus lupulus*), although undoubtedly indigenous to America, and abundant in our North-West, being a common plant in Manitoba, is not known to have been used for any purpose by the aborigines; neither was the true potato (*Solanum tuberosum*), a native of Chili, cultivated by North American Indians, although its aboriginal cultivation had extended as far north as New Granada. *Passiflora incarnata* was cultivated for its fruit in Virginia.

In a recent endeavour to trace the northern limit of the wild grape vine in British America, no evidence was found of its having been cared for by the aborigines, but rather an indication that before the settlement of the country its range as a spontaneous plant may have been more extensive than now. Dr. E. L. Sturtevant, however, has recently ('Botanical Gazette,' January 1884, vol. ix. p. 8) called attention to the occurrence of *Vitis Californica* in rows near Fort Whipple, in Arizona, as evidence that the ancient Pueblo Indians were in the habit of cultivating it; the great variability of *V. Labrusca*, in the direction of improved varieties, he regards as evidence of the ancient cultivation of this species.

Special reference was made to the papers of Professor Gray and Mr. Trumbull in the 'American Journal of Science,' as sources of information.

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7. *Exhibition of Photographs of Eskimo Relics.* *By* Lieutenant A. W. Greely, *U.S.A.*

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8. *Habits and Customs of the Inu of the Western Shore and Point Barrow.* *By* Lieutenant P. H. Ray, *U.S.A.*

The International Polar Station at Point Barrow, which I had the honour to command, was established nine miles to the south and west of the extreme point, and within one mile of the village of Ooglaamie, which was the native name given to a small cluster of winter huts, whose population numbered about 130 souls all told.

Noowook, or Cape, is the name given to a like village situated at the extreme point, and it has a population of about 150.

These people were first visited by white men in the year 1826, when the launch of H.M.S. 'Blossom,' commanded by Mr. Elsen, succeeded in reaching Point Barrow, and gave it the name it now bears; it was visited by several vessels engaged in the Franklin search from 1850 to 1854, and H.M.S. 'Plover,' Captain Maguire, wintered in Port Moore, two miles to the eastward of the Point, from 1852 to 1854. They have been frequently visited by American whalers since, but no party had ever wintered at the coast north of Behring Straits since the departure of the 'Plover' until the American expedition took up its quarters there. We landed early in September 1881, and the few people we found there gave us valuable assistance in getting our stores up from the beach; and apart from a few cases of petty theft, they showed no disposition to interfere with us, but seemed greatly puzzled to know what we came for. When told that we did not wish to trade, they gravely watched our work of scientific observation, and owing to the fact that they always found a man writing, they called us the Muk-pa-rah, or paper men.

It has been made a matter of considerable discussion as to the probable length of time that this coast has been inhabited by the race of man, and their origin. From their legends, the ancient ruins along the coast, and the great water-courses and traces that I found in excavating, it would appear that they are indigenous to the ice period, that they are contemporary with the polar bear, seal, and fox, that they have followed the ice-cap as it receded to the North, and were never forced to this inhospitable region by the dominant races.

While excavating a shaft for the purpose of taking earth temperatures, we came upon a pair of wooden snow-goggles, of the same pattern as those worn by the people at the present time; showing conclusively that a people dwelt on these shores many centuries ago, under arctic conditions.

That their ancestors did not come to this continent from Asia is not so certain, but many things would go to prove that they did not.

The language spoken by the people along the whole arctic shore from Bhering Straits to Greenland is the same, with the tribal differences that ever occur among a people with an unwritten language. A comparison will show that there is no similarity between the language of the American Inu and the Chukchee of Siberia, but that there is a slight similarity in some words and language of the people living along the shore of the Chukchee peninsula; these people use the dog only, and know nothing about the use of the reindeer, and their language is not that of the Chukchee.

Now, if the migration had been from Asia to America, the people would in all probability have carried with them the most useful and valuable of their domestic animals, the reindeer; but there is not a domestic reindeer among the Inu of North America, but we do find a few of the people who use only dogs inhabiting the shores of Siberia adjacent to Bhering Straits. They are of a similar physical type to the North American Inu, but do not wear the labret, and from their habits it would seem that the migration had been westward instead of eastward.

The Inu of the western shore is superior to the generally accepted type of Eskimo. Of 150 men that we measured and weighed, the tallest was 5 feet 10 inches, the shortest 5 feet 1 inch, and the average weight over 150 lbs.; and we never saw one that could be called fat: their fur-clad bodies and flat, round faces give the casual observer the impression that they are short and fat, but, on the contrary, they are all lithe and slender, with remarkably small hands and feet, and possess great powers of endurance.

There is no form of government known among them—they live in a condition of anarchy. There is no recognised chief and no tribal relations, no punishment for crimes, no ceremony at marriage, and no belief in future existence. The marriage relations are assumed and severed at the will of the parties interested, and often there is an exchange of wives, all parties agreeing. Wife-whipping is rare.

They are kind to their children, and such a thing as striking one is unheard of, and the children in return are obedient, and as they attain maturity show the greatest devotion to their aged parents.

That the race is rapidly becoming extinct is shown by the fact that in the village of Ooglaamie during our stay there occurred eighteen deaths and only two births, and in 1854 Dr. Simpson states that the population of Noowook was nearly 400 and Ooglaamie over 300, while we found the population to be 140 and 130 respectively.

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9. *Customs and Religious Rites of the Blackfeet.* *By* R. G. HALIBURTON.

The author considered the Blackfeet the most remarkable race in America—an odd combination, thorough savages, possessing singularly distinct vestiges of a very high civilisation. They had cycles, or great ages, exactly similar to those of the Mexicans and of the Hindoos. There are four of these, three of which are passed. We are now in the fourth. A great prophet or divine being, called a *Napa,* exists during each of these eras. The Blackfeet have also a zodiac of twenty-four constellations, something that the Aztecs did not approach in their imperfect zodiac. They also have the same names as we have for the Belt of Orion, Sirius, and the Hyades, the latter stars in Taurus being called the Bull of the Hills. They have sacred vestal virgins, a Lent, or sacred period of forty days, the time of the occultation of the Pleiades, and festivals and rites that seem to belong to the civilised nations of the Old World. They have also 'their seven perfect ones,' the Pleiades, which reminds us of the 'seven perfect ones' of the Chinese Buddhists.

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10. *Notes on the Astronomical Customs and Religious Ideas of the Chokitapia or Blackfeet Indians.* *By* JEAN L'HEUREUX, *M.A.*

They observe the Pleiades, and regulate their festivals by them. At the time of the disappearance and reappearance of those stars are two festivals; the first, the solemn planting of the seed, marking the beginning of the agricultural season—the feast of Innissi-man, a festival of the men—and Montoka, the women's festival, when these stars reappear. The first means the grave or burning of the seed, and the other 'the meeting of the absent one.' On the last day of the occultation, there is a women's festival called the *Manistam,* the flag-pole dance. The vestals of the sun take part in this. *Ocan* is the autumn festival, always accompanied by a feast of the dead. They call it *Stapascan,* the dance of the dead. The women swear by the Pleiades, and the men by the sun; the former are called 'the seven ones,' but the word implies perfection, and therefore means 'the seven perfect ones.' The calumet is always presented towards them in all sacred feasts with prayers for life-giving blessings.

These stars were once seven youths guarding by night the sacred seed, and keeping up all night a sacred dance. Epizors, the morning star, pleased with their dance, transported them to the heavens, where they delight the stars by their nightly dance. The sand dance of the Male clan of warriors represents their celestial dance. They are called by the names of different birds.

In the bath for purification of medicine-men, a hole in the form of a triangle is made; seven heated stones are placed in it, and cold water poured over it. When their bathing invocation is made, they pray to the Pleiades for help in curing bodily diseases. They have seven bones, balls, or buttons, as talismen.

The tau cross is the symbol of healing, and their paradise is an island in the Pacific where there are many sand-hills. The dead are spoken of as 'gone to the sand-hills.'

There was a figure found represented on stone—a circle with seven arms extended from it. Also, near tumuli, the figure of a man with his arms extended; from hand to hand is a semi-circle passing over his head. They also believe in the thunder bird, and hold a feast when he returns in the spring.

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11. *Notes on the Kekip Sesoators, or Ancient Sacrificial Stone of the N.W. Territory of Canada.* *By* JEAN L'HEUREUX, *M.A.*

The writer concluded that Hue Hue Tlapalan, or the ancient habitation in the North-west, which Aztec tradition pointed to, was in the Alberta district. He considered that they were the mound-builders, a branch of whom extended up to the Saskatchewan. In the Alberta district are vestiges of this race. The ruins of the Canantzi village, the Omecina pictured rocks, the graded mounds of the third Napa in Bow River, the tumuli of Red River, the walled city of the dead in the Lake of Big Sandy Hill on the south Saskatchewan, and the Sesoators, or sacrificial stones of the country, to describe which is the object of the paper.

The Kamuco of the Quiché mourns over a portion of the race whom they left in northern Tullan. The Papul Vuh, speaking of the cult of the morning star among the Toltecs, states that they drew blood from their own bodies, and offered it to their god Tohil, whose worship they first learned in the north. The Napa traditions say that 'in the third sun (Natose) of the age of the earth, on the day of the Bull of the Hill, the third Napa of Chokitapia, or the plain people (the name of the Blackfeet) when returning from the great river of the south, caused to be erected in the sacred land of the Napas (Alberta district) upon certain high hills of the country, *seven* sesoators, or sacrificial stones, for religious purposes among his people.' The traditions of the Blackfeet have always pointed to a high hill situated on the south-east side of the Red River, opposite to Handhill, two miles east of Brokenknife ridge, as the site of one of their ancient relics.

Elevated 200 feet above the surrounding plain Kekip Sesoators (the hill of the Blood Sacrifice) stands like a huge pyramidal mound, commanding an extensive view of both Deer River and Red River valleys. A natural platform of 100 feet crowns its summit.

At the north end of this platform is the sesoators, a boulder of fine grained quartz ore, hemispheroidal, and hewn horizontally at the bottom, measuring 15 inches in height and 4 feet in circumference. Upon its surface are sculptured, half an inch deep, a crescent moon with a star over it, two small conical basins about 2 inches in diameter, one in the centre of the star-like figure, and the other about 7 inches, in a straight line with it, and around these hieroglyphic signs resembling those of the Davenport stone and the Copan altar. Interwoven all over are numerous small circlets, resembling those on the sacrificial stones in Mexico. At times of great public necessity or trouble, offerings are made, by deputies of the family clan, the tribe, and in certain emergencies, of the whole nation. The warrior, dressed in war costume, ascends the mountain alone, and awaits the rising of the morning star. When it appears he falls prostrate and prays; he then lays a finger of his left hand on the stone and cuts it off. He then presents the finger towards the morning star, saying, 'Hail, O Epizors! Lord of the night, hail! Hear me, regard me from above! To thee I give of my blood, I give of my flesh! Glorious is thy coming, all powerful in battle, Son of the Sun, I worship thee! Hear my prayer, grant me my petition, O Epizors!' He then puts the finger into the basin on the star-like figure, and having dressed the wound in a neighbouring lake, he returns to the village, where he is received with rejoicings. This sacrifice ranks even above wounds in battle in honour, and is with the red man his Cross of the Legion of Honour.

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12. *Race Elements of the Malagasy.* *By* C. STANILAND WAKE, *M.A.I.*

An examination was made of the Rev. L. Dahle's arguments in support of the hypothesis that Madagascar was first occupied by East African tribes, who, after being subjugated by Malayo-Polynesian peoples from the East, became mixed with them, forming the present Malagasy; and that the Hova were later Malay emigrants who took possession of the interior of the island, which had previously been occupied by African tribes. Reasons were given for doubting the African origin of the early inhabitants of Madagascar, particularly the Vazimba, who differed little from some of the other Malagasy, although they may have had a Negrito element. Facts were mentioned to prove that the Vazimba were a numerous people inhabiting the interior of the island, and that the Hova were descended from them, although probably affected by Arab blood. The other Malagasy belong to the same ancient stock as the Melanesians, but with the addition of a strong Mongoloid element.

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13. *Notes on Researches as to American Origins.* *By* HYDE CLARKE.

The author reviewed the papers which he had contributed on American Origins to the British Association and other societies, and stated the result of his investigations in their present development.

Without entering into any defined statement as to the intercourse between the Eastern and Western hemispheres in the earlier epoch of gesture language, he inferred it from various facts. The ideographs were also of the early epoch. The invention of speech, which took place in the Eastern hemisphere, and was transmitted to the Western, created a great psychological and historical revolution. With this latter epoch we can connect the numerous phenomena of language, culture, and mythology, the resemblances of which have been so long noted and by so many authors.

The adaptation of a phonetic system to ideas expressed by gesture, as explained by Mr. Clarke in the 'Transactions' of the Association, depended on the full application by himself of the observations of Mr. Alfred R. Wallace, that in many languages the mouth, tooth, and nose are severally represented by labials, dentals, and nasals. These are applied primarily and secondarily, &c., in series, as from mouth, eye, ear, sun, moon, egg, blood, eat, speak, &c., and with various conventional and symbolic meanings. The resemblances among languages did not depend on descent from one primeval language, but on the propagation of languages based on one phonetic and psychological system. Of such resemblances he instances that of Yahgan of Tierra del Fuego to West Africa (British Association, 1883). He recalled that the ancient geographical nomenclature of America in names of mountains, rivers, lakes, and towns not unfrequently corresponded with that of the Old World. The animal names were of common origin, with the mutation of tapir with elephant, puma with lion and tiger, llama, &c., with horse.

The mythology or fetishism as shown by the Bribri of Central America was in conformity with an identical origin.

A variety of facts of common propagation had to be accounted for, and although intercourse across Behring's Straits and the Pacific would partially explain, there must have been direct and continual intercourse across the Atlantic, assisted by the currents.

He rejected the geological hypothesis of an Atlantis extending across the ocean and now submerged, but considered the traditions in the Dialogue Timæus in Plato to represent broadly the antecedent conditions. America had come under the dominion of an Atlantis or Great King of the West, with territories also in Mauritania, Spain, and the Britains. His defeat in naval contests in the Western Mediterranean by the leading kings of the East was a sufficient cause for the cessation of intercourse with America. The legend of the sinking of Atlantis, and that of the filling up of the ocean with mud so as to make it impassable, were mere excrescences on the legend, but had fascinated most students. If we treated the elephants mentioned in the Timæus as tapirs, and the horses as llamas and beasts of burden, not dealing with the detail of legend too strictly, then the legend itself, freed from impossibilities and inconsistencies, acquired consistency.

Mr. Clarke, in combination with that of the Atlantis, dwelt on the legend of the Four Worlds as showing a former knowledge of the configuration of the Americas in the ancient world.

According to his investigations the languages and culture of America are not of local growth, but imparted by a higher race at the period of the foundation of like institutions in the Eastern world. The differences he assigned to distinct development chiefly consequent on the breaking off of intercourse.

WEDNESDAY, SEPTEMBER 3.

The following Papers were read:—

1. *On the Lapidary Sculptures of the Dolmens of the Morbihan.* *By* Admiral F. H. Tremlett.

The author described in detail a number of the sculptures which were found in the Dolmens of the Morbihan. About eighty of these sculptures had been found, invariably on the interior surfaces of the capstones and their supports. They are circumscribed within an area of about a dozen miles, near to the sea coast, beyond which, although megalithic monuments are very numerous, there is a complete absence of the sculptures. The author considered that the implements used by the carvers were made of stone, and described the manner in which he himself had made experiments with pieces of chert.

2. *An Account of small Flint Instruments found beneath Peat on the Pennine Chain.* By R. Law and James Horsfall.

The authors believed that these were the smallest flint implements ever discovered in England. They were probably carving-implements, some of them being not more than one inch in length and a quarter of an inch in breadth, and bearing a strong resemblance to the graving-tools now used.

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3. *On the Primary Divisions and Geographical Distribution of Mankind.* By James Dallas, *F.L.S.*

The views brought forward in this paper originated in an attempt to appreciate the divisions and distribution of man suggested by Professor Huxley. It is proposed to separate the various races of mankind into three primary groups, the Leucochroi, represented by the white European, &c.; the Mesochroi, represented by the Mongolian and American races, &c.; and the Melanochroi, of which the negroes and negritos are regarded as typical.

With reference to the last, there exist certain facts tending to prove the former presence of negro-like races in north-eastern Africa and in Arabia, and with these it appears probable that the Dekkan tribes of India may be genetically connected. Many of the points of agreement between the Papuans, the Negritos, and the Australians and the African negroes, are very striking, and it might, from the evidence before us, be assumed that these and their allies formed branches of one great family. No very great changes of physical geography would be required to account satisfactorily for the necessary migrations, while to the northward of the assumed region of the Melanochroi the Himalayas and other natural boundaries form a line beyond which the group is not to be met with. The distribution of certain mammals, and particularly of the old-world monkeys, supports the view as to the continuity and isolation of the region assigned to the Melanochroic races, of which the negroes of Africa and the negritos of the Southern Islands probably present two tolerably pure developments, while the Australians appear to have been influenced in language, and to some extent in blood, by contact with the Malays.

To the Leucochroic group may be referred the Aino of Yesso, certain fair races inhabiting the neighbourhood of the Amour in Eastern China, and other Chinese races, as well as the ordinarily accepted Caucasian nations. Perhaps the great central plateau of Asia, so ably described to the Association two years ago by Sir R. Temple, had been the original seat of the Leucochroic peoples, whence they had spread westward as far as the British Isles. Geographical considerations were in favour of this view, while the distribution of existing mammals, and particularly of the true wolves, seems to indicate a natural continuity of the region.

The recognised Mongol, the American Indian, the Eskimo and their allies, are regarded as forming the Mesochroic group, but there appears also to be strong evidence in favour of including the Basks of Western Europe in the group, while a curious and hitherto unexplained affinity has been traced between the Basks and certain mixed races of North Africa. As to the original seat of the Mesochroic group of peoples, it would be difficult to hazard a suggestion, but it may be supposed that at one time or another they occupied the whole of America. In Europe and Asia they appear to have had an extension corresponding to that of the extinct rhinoceros, while the agreements between the Bask and the North American Indian, and the existence of a rhinoceros in America, east of the Rocky Mountains, might be regarded as evidence (though doubtless insufficient evidence) of the former existence of the much-disputed Atlantis.

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4. *Notes on some Tribes of New South Wales.* By A. L. P. Cameron.

APPENDIX I.

ADDRESSES PRESENTED TO THE ASSOCIATION.

FROM THE MAYOR AND ALDERMEN OF MONTREAL.

[Presented August 27.]

To the President and Members of the British Association for the Advancement of Science.

Gentlemen,—It is with no common pleasure that we, the Mayor and Aldermen of Montreal, welcome to this city and to Canada so distinguished a body as the British Association for the Advancement of Science. Already, indeed, not only here, but throughout the length and breadth of the land, that welcome has been pronounced with a heartiness to which we are proud to add the confirmation of formal expression.

During the last two years, and especially since the acceptance of our invitation made it a certainty, your coming amongst us has been looked forward to as an event of deep and manifold importance to the Dominion.

Aware of the devotion with which the Association had, for more than half a century, applied itself to the object indicated in its name, and knowing that its present membership comprised the most eminent of those noble students and investigators who have made the search after truth the aim of their lives, we could not fail to perceive that Canada would gain by the presence of observers and thinkers so exact and so unprejudiced. Nor were we without hope that in the vast and varied expanse of territory which constitutes the Dominion, our learned visitors would meet with features of interest that should be some compensation for so long and wearisome a journey.

Here, in that great stretch of diversified region between the Atlantic and the Pacific, the student of almost every branch of science must find something worth learning; whilst for certain sections of the Association, there are few portions of the world in which the explorer is more likely to be gratified and rewarded.

Throughout this broad domain of ours—rock and herb, forest and prairie, lake and river, air and soil, with whatever life, or whatever relic of life in past ages they may severally contain, afford to the diligent seeker of knowledge various and ample scope for research. Nor to the student of man, as a social and political being, is there less of opportunity for acquiring fresh facts and themes for reflection in a young commonwealth like this.

We flatter ourselves that here you will find a people not unworthy of the great races from which it has sprung, and that on your return to the mother land, you will be able to speak with satisfaction, from your own experience, of our federal system, our resources, our agriculture, our manufactures, our commerce, our institutions of learning, our progress, and our destinies.

You have come, and we place our land, ourselves, and all we are and have at your disposal. We bid you hearty welcome, and, in so honouring ourselves, we only ask you to consider yourselves at home, remembering that you are still on British soil.

In conclusion, Mr. President and Gentlemen, we sincerely hope that your stay in this portion of Her Majesty's Empire may be as happy and as fruitful to the Association as it is grateful, for so many reasons, to the people of Montreal and of the Dominion.

FROM THE ROYAL SOCIETY OF CANADA.

[PRESENTED AUGUST 27.]

To the President and Council of the British Association for the Advancement of Science.

MY LORDS AND GENTLEMEN,—The Royal Society of Canada greets with cordial welcome the members of your Association on the occasion of its first visit to the American Continent, and rejoices to find among those who have accepted the invitation of the citizens of Montreal, so many names renowned as leaders in scientific research.

The Royal Society of Canada, which is a body recently organised, and in the third year of its existence, includes not only students of natural history and natural philosophy, who make up together one-half of its eighty members, but others devoted to the history and the literature of the two great European races, who are to-day engaged in the task of building up in North America a new nation under the shelter of the British Flag.

Recognising the fact that material progress can only be made in conjunction with advancement in literature and in science, we hail your visit as an event destined to give a new impulse to the labours of our own students, believing at the same time that the great problems of material nature, not less than the social and political aspects of this vast realm, will afford you subject for profitable study, and trusting that when your short visit is over, you will return to your native land with kindly memories of Canada, and a confidence that its growth in all that makes a people good and great is secured.

FROM THE MAYOR, CORPORATION, AND CITIZENS OF QUEBEC.

[PRESENTED AUGUST 30.]

To the President and Members of the British Association for the Advancement of Science.

MY LORD AND GENTLEMEN,—It is with the greatest pleasure that I welcome you in the name of the Corporation and Citizens of Quebec to the Capital of our Province. Your Association demands universal respect and esteem, since its object is the promotion of science, which has ever done so much for humanity.

For a lengthened period labour, which is the law of our nature, was chiefly a physical activity, an exertion of the body more than of the mind.

Science has wrought a radical change in this respect. By subjecting the hidden powers of nature to the will of man, it has enabled him to substitute their energies for his own physical strength. The very wheat which enters into the composition of man's daily bread, was for thousands of years crushed with his own hand, and the same primitive process yet prevails in lands where practical science is unknown; for to its teachings and results are we indebted for those gigantic mills, in which a few enlightened minds, having the forces of water and steam under their intelligent command, do better and quicker work than millions of arms in bygone ages.

Thanks to the results of science, the humblest individual of modern times may possess comforts which a few centuries ago were denied to princes. We are indebted to it for those wonderful developments in the arts and manufactures which have placed within the reach of the most limited income products which all the wealth of Crœsus could not have sufficed to give him.

Science, in a word, has raised the standard of living of humanity, and who dare venture to prescribe its future?

But, gentlemen, science has effected something more marvellous yet, and of still greater utility to mankind. It has removed distances, united continents, and brought nations together. Of this no better proof need be asked than your presence here to-day. To whose mind would it have occurred to bring your Association to Canada, when it required five days to travel from London to Liverpool, and several months to cross the ocean? Quebec is nearer London now, than the latter was to Edinburgh a century ago. If the residence of the Queen was to-day at Vancouver, Jeannie Deans could go there to beg her sister's pardon, in less time, and with less fatigue, than when she found it necessary to travel from the heart of Midlothian to Richmond Park.

Who, that has followed the progress of science during the last half century, witnessed the marvels which it has produced, and enjoyed the riches which it has unearthed, would not wish to live for fifty years more, just to see what new victories it will achieve for us during that period?

Nothing, gentlemen, is more conducive to the progress and diffusion of science, than associations like yours, composed of all those who contribute to its progress by their discoveries, or their works, or who manifest an interest in its proceedings by pecuniary encouragement. It spreads its conquests everywhere, and contributes to new discoveries and higher aims, by bringing together from time to time, those who range themselves beneath its banners.

Our country is yet too young to possess an Association like yours. The cares of daily life, and the constant struggles against the obstacles which nature has thrown in our way, engross too much of our attention. We have not that leisure which is necessary for scientific research on a very extended scale. But we appreciate it none the less, and science has amongst us some worthy representatives.

We esteem it a very great honour that you have this year selected our country as the scene of your great scientific assembly. Our only regret is, that our own city was not chosen. But we cherish the hope that this selection has only been postponed for a very few years. And if, in the near future, when the trip from Liverpool to Quebec will be a matter of some five days only, when progress in the art of ship-building, or discoveries of medical science, will have rendered sea-sickness a thing of the past, your Association will think fit to hold its annual meeting on Cape Diamond, you may rest assured that a most hearty welcome will await you.

FROM THE CITIZENS OF OTTAWA.

[PRESENTED AUGUST 30.]

Gentlemen of the British Association for the Advancement of Science.

I have the honour,[1] in the name of the citizens of Ottawa, to offer to you a most hearty welcome to this, the capital city of the Dominion of Canada, and to assure you of the pride and satisfaction with which we seize the opportunity so happily afforded us of extending our hospitality to representatives of perhaps the foremost and most distinguished scientific body in the world.

Our city falls far short in population and resources of some other cities of the Dominion, but we should not willingly yield to any in the honour we pay to the august name and beneficent cause of science.

The Association, gentlemen, of which you are members, represents that cause in all its breadth and universality. It stands for the whole scientific movement of the age. It is committed, therefore, to no narrow views or partial interpretations, but exists as a powerful agency for uniting the forces of science, for checking the

[1] Read by the Chairman of the Reception Committee.

results obtained in one field of labour by those arrived at in another, and so promoting the discovery of truth and the harmonious development of the human mind.

We recognise in science so pursued, and so brought to bear upon the problems of the age, the great friend and ally of the human race, its liberator from error, its guide to higher and nobler conceptions of the constitution and government of the universe, its chief helper in improving, not only the material basis, but the whole structure of our civilisation. Teaching us in the first place what is, it enables us to learn what ought to be, by exhibiting the relations existing between the different objects of its study, the different elements of human life and its environment.

We honour the Association to which you belong for the perfect freedom from all trammels, whether of patronage or of prejudice, with which it pursues its noble ends. Your aim is not to hold truth captive, but to set her free, that her blessings may be poured forth on all mankind.

And while it is true that science, like literature and art, is of no country, and while our homage is due to all who worthily represent it, in whatever nation, or kindred, or tongue, we do not hold it amiss to express towards you, gentlemen, as members of the British Association for the Advancement of Science, those warmer feelings of regard and interest which community of race and flag, which a common loyalty to one Government, should naturally inspire. Your standing as men of science is unaffected by the question of nationality, but to us, as Canadians and subjects of Her Most Gracious Majesty Queen Victoria, there is that in the British name which will always stir the deepest feelings of our hearts.

Allow me further to say that we hail with peculiar satisfaction the holding for the first time of a meeting of your Association in this part of the British dominions, and that we hope the present occasion will not be the last of its kind, but will prove the precursor of other similar visits, and lead to a closer intellectual intercourse than has heretofore prevailed between Canada and the Mother country.

Our city is before you. Whatever it contains of worth or interest, it shall be our pleasure this day to bring under your notice. We regret that your stay among us is to be so brief; but we are confident that, brief as it may be, it will not be without much profit to us; and we can only hope that it will furnish to you hereafter some matter for kindly and pleasant recollection.

FROM THE MAYOR AND CORPORATION OF TORONTO.

[PRESENTED SEPTEMBER 5.]

To the Right Honourable Lord Rayleigh, F.R.S., President of the British Association for the Advancement of Science.

MY LORD,—On behalf of her citizens the Mayor and Corporation beg to tender to the members of the British Association for the Advancement of Science, and to yourself as their distinguished President, a hearty welcome to the City of Toronto.

We have no doubt, that since your arrival in Canada you have already had, in your progress to the West, many evidences brought before you of that sound and flourishing system of trade and commerce; of that enterprising spirit in the promotion of mechanical and useful manufactures; and above all, of those well-developed principles of agricultural industry, which are the groundwork of the material prosperity of every commonwealth.

Referring, therefore, with pleasure to your introduction to these different expositions of Canadian progress and industry, we have a peculiar pride in introducing you to Toronto as the principal seat of learning in this province, and we would fain hope that your visits to the institutions which have been reared in so worthy a cause will tend to show that a good foundation has been laid in our universities, our schools, our institutes, and our public library, as the last addition, for placing the attainment of sound education, useful knowledge, and scientific research within the reach of every class of society, from the lowest to the highest.

We conclude with the hope that your visit to Toronto may prove in every way a pleasurable and agreeable one.

FROM THE PRESIDENT OF THE ST. GEORGE'S SOCIETY (MONTREAL).

[PRESENTED SEPTEMBER 3.]

MR. PRESIDENT AND ASSOCIATES,—It has fallen to my lot, as representing St. George's Society of this city, to tender you a hearty welcome to our shores, and to couple it with the hope that the event which has called you together may be productive of much good to yourselves, and be the means of making the world wiser and better. It may not be out of place to say a few words for your information in reference to the society which I have the honour of representing. It was founded fifty years ago, so that it is one of the oldest (if not the oldest) of our national societies, by a few benevolent and charitably disposed Englishmen, for the purpose of affording material aid and counsel to poor English immigrants in this country; it has existed to the present day, doing its work with varied success, and endeavouring to carry out the intentions of its founders. It knows neither creed, politics, or colour in its work, and the only qualification it is necessary for the needy stranger to have to entitle him to its benefits is, that he be an Englishman. Allow me again to welcome you, and to express the wish that when the purpose of yourself and confrères has been accomplished, you may return in safety to the dear old land, the home of our fathers, with renewed health and strength, so that you may be enabled to carry on to greater perfection the important work you are engaged in.

APPENDIX II.

FOUNDATION OF A MEDAL AT THE McGILL UNIVERSITY, MONTREAL, IN COMMEMORATION OF THE VISIT OF THE BRITISH ASSOCIATION TO CANADA.

During the meeting of the British Association at Montreal, it occurred to some of the members that the foundation of a prize at the McGill University would be a not inappropriate memorial of the visit, and a slight acknowledgment of the generous hospitality with which the Association had been greeted in the Dominion of Canada. The idea, once started, was warmly espoused by the members in Montreal; it was agreed to provide funds for the award of a medal, and of a sum of money as an exhibition, yearly, for proficiency in Applied Science, that subject being without any special prize in the University, and one which seemed cognate to the purposes of the Association. Lord Rayleigh, President of the Association, kindly undertook to act as treasurer, and Messrs. W. Topley and H. T. Wood gave their services as secretaries. The Subscription list, commenced at Montreal, has continued open to the present time, with the result annexed. At the general meeting held in London on November 12, 1884, the Council proposed that the expense of procuring a die for the medal should be provided out of the funds of the Association, and the amount subscribed transmitted to the authorities at Montreal through its officers; this proposal was cordially approved by the General Committee.

It was further decided by the Council, on February 3, that a medal should be offered for competition to the students of the McGill University during the present academical year, the cost of which should be charged to the capital account, and the officers were empowered to take steps to procure a die of appropriate design for the medal.

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Gladstone, Miss Gladstone, Miss E. A.	0	10	0
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Martin, John Biddulph, F.S.S.	10	0	0
Mason, R.	0	10	0
Mello, Rev. J. M., M.A., F.G.S.	1	1	0
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Neild, Theodore	1	1	0
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Reid, Arthur S., B.A., F.G.S.	1	0	0
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Strutt, Hon. Richard	3	3	0
Summers, Alfred	1	0	0
Swales, W.	0	10	6
Swinglehurst, H.	1	1	0
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Taylor, Miss S.	1	0	0
Temple, Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S.	5	0	0
Thomas, T. H.	1	0	0
Thompson, Prof. Silvanus Phillips, B.A., D.Sc., F.R.A.S.	1	1	0
Thomson, James, F.G.S.	1	0	0
Thomson, Prof. Sir William, M.A., LL.D., D.C.L., F.R.S. L. & E., F.R.A.S.	10	0	0
Thomson, William J.	1	0	0
Thurston, Prof. R. H.	2	0	0
Tilden, Prof. William A., D.Sc., F.R.S., F.C.S.	2	0	0
Tillyard, A. I., M.A.	1	0	0
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Williamson, Prof. Benjamin, M.A., F.R.S.	1	0	0
Williamson, Miss E. H.	1	0	0
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„ „ W. Topley	0	18	0
	34	10	5
By Balance available	532	16	7
	£567	7	0

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CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lieut.-Col. Sabine, on some Points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—Dr. J. Percy, Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at 9s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at 10s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s.* 6*d.*

Contents:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s.*

Contents:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

Contents:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—

William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration; —Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface; —W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—

Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s*.

CONTENTS:—A. Cayley, Report on the recent progress of Theoretical Dynamics;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_0^{t} \; {}^{-a} \, \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $a\ (a+1)\ (a+2)$ &c.....$(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—Dr. John P. Hodges, on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Prof. W. A. Miller, on Electro-Chemistry;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Prof. James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive) ;—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s.*

CONTENTS :—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena ;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–1858 ;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs ;—W. Fairbairn, Report of the Committee on the Patent Laws ;—S. Eddy, on the Lead Mining Districts of Yorkshire ;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders ;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland ;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards ;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain ;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857 ;—Report of the Committee on Shipping Statistics ;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results ;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58 ;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District ;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India ;—George C. Hyndman, Report of the Belfast Dredging Committee ;—Appendix to Mr. Vignoles' Paper 'On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains ;'—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories ;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s.*

CONTENTS :—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry ;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester ;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops ;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools ;—On the Upper Silurians of Lesmahagow, Lanarkshire ;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals ;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Brakes for Railway Trains ;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59 ;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59 ;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c. ;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image ; —G. C. Hyndman, Report of the Belfast Dredging Committee for 1859 ;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull ;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals ;—Warren De La Rue, Report on the present state of Celestial Photography in England ;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time ;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S. ;—W. Fairbairn, The

Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s*.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859-60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;

—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders; —Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics; —Prof. G. G. Stokes, Report on Double Refraction;—Fourth Report of the Committee on Steamship Performance;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861;—J. Ball, on Thermometric Observations in the Alps;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland;—Report of the Committee on Technical and Scientific Evidence in Courts of Law;—James Glaisher, Account of Eight Balloon Ascents in 1862;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s*.

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for exploring the Coasts of Shetland by means of the Dredge:—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s*.

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s*.

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science:—A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s.*

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the 'Menevian Group,' and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Ironclad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s.*

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at £1 5s.*

CONTENTS:—Report of the Lunar Committee —Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at £1 2s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Seagoing qualities of Ships;—Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing a 'Close Time' for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures;—Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s*.

CONTENTS :—Report on Steam-boiler Explosions ;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland ;—Report on the Sedimentary Deposits of the River Onny ;—Report on the Chemical Nature of Cast Iron ;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals ;—Report on Standards of Electrical Resistance ;—Sixth Report on Kent's Cavern ;—Third Report on Underground Temperature ;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals ;—Second Report on the Stability, Propulsion, and Seagoing Qualities of Ships ;—Report on Earthquakes in Scotland ;—Report on the Treatment and Utilization of Sewage ;—Report on Observations of Luminous Meteors, 1869-70 ;—Report on Recent Progress in Elliptic and Hyperelliptic Functions ;—Report on Tidal Observations ;—On a new Steam-power Meter ;—Report on the Action of the Methyl and Allied Series ;—Report of the Rainfall Committee ;—Report on the Heat generated in the Blood in the Process of Arterialization ;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s*.

CONTENTS :—Seventh Report on Kent's Cavern ;—Fourth Report on Underground Temperature ;—Report on Observations of Luminous Meteors, 1870–71 ;—Fifth Report on the Structure and Classification of the Fossil Crustacea ;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison ;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers ;—Report of the Committee for discussing Observations of Lunar Objects suspected of change ;—Second Provisional Report on the Thermal Conductivity of Metals ;—Report on the Rainfall of the British Isles ;—Third Report on the British Fossil Corals ;—Report on the Heat generated in the Blood during the Process of Arterialization ;—Report of the Committee appointed to consider the subject of Physiological Experimentation ;—Report on the Physiological Action of Organic Chemical Compounds ;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals ;—Second Report on Steam-Boiler Explosions ;—Report on the Treatment and Utilization of Sewage ;—Report on promoting the Foundation of Zoological Stations in different parts of the World ;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine ;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals ;—Report on Earthquakes in Scotland ;—Report on the best means of providing for a Uniformity of Weights and Measures ;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s*.

CONTENTS :—Report on the Gaussian Constants for the Year 1829 ;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands ;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry ;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures ;—Eighth Report on Kent's Cavern ;—Report on promoting the Foundation of Zoological Stations in different parts of the World ;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871-72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer:—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at* £1 5*s*.

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays; —Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Report on Luminous Meteors; —On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry; —Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at £1 5s.*

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodonts;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface, &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at £1 5s.*

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On the Analytical Forms called Trees;—Report of the Committee on Mathematical Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at* £1 5*s*.

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors, 1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations;—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at* £1 4*s*.

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on some Double Compounds of

Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-EIGHTH MEETING, at Dublin, August 1878, *Published at* £1 4s.

CONTENTS:—Catalogue of the Oscillation-Frequencies of Solar Rays;—Report on Mr. Babbage's Analytical Machine;—Third Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for arranging for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira;—Report on the commencement of Secular Experiments upon the Elasticity of Wires;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine;—Report on the best means for the Development of Light from Coal-Gas;—Fourteenth Report on Kent's Cavern;—Report on the Fossils in the North-west Highlands of Scotland;—Fifth Report on the Thermal Conductivities of certain Rocks;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on Patent Legislation;—Report on the Use of Steel for Structural Purposes;—Report on the Geographical Distribution of the Chiroptera;—Recent Improvements in the Port of Dublin;—Report on Mathematical Tables;—Eleventh Report on Underground Temperature;—Report on the Exploration of the Fermanagh Caves;—Sixth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on the present state of our Knowledge of the Crustacea (Part IV.);—Report on two Caves in the neighbourhood of Tenby;—Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on the Datum-level of the Ordnance Survey of Great Britain;—Report on instruments for measuring the Speed of Ships;—Report of Investigations into a Common Measure of Value in Direct Taxation;—Report on Sunspots and Rainfall;—Report on Observations of Luminous Meteors;—Sixth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Kentish Boring Exploration;—Fourth Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations, with an Appendix on the Filtration of Water through Triassic Sandstone;—Report on the Effect of Propellers on the Steering of Vessels.

Together with the Transactions of the Sections, Mr. Spottiswoode's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-NINTH MEETING, at Sheffield, August 1879, *Published at* £1 4s.

CONTENTS:—Report on the commencement of Secular Experiments upon the Elasticity of Wires;—Fourth Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for endeavouring to procure reports on the Progress of the Chief Branches of Mathematics and Physics;—Twelfth Report on Underground Temperature;—Report on Mathematical Tables;—Sixth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Atmospheric Electricity at Madeira;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on the Calculation of Sun-Heat Coefficients;—Second Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Report on Observations of Luminous Meteors;—Report on the question of Improvements in Astronomical Clocks;—Report of the Committee for improving an Instrument for detecting the presence of Fire-damp in Mines;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Beeberine ;—Seventh Report on the Erratic Blocks of England, Wales, and Ireland ;—Fifteenth Report on Kent's Cavern ;—Report on certain Caves in Borneo ;—Fifth Report on the Circulation of Underground Waters in the Jurassic, Red Sandstone, and Permian Formations of England ;—Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland ;—Report on the possibility of Establishing a 'Close Time' for the Protection of Indigenous Animals ;—Report on the Marine Zoology of Devon and Cornwall ;—Report on the Occupation of a Table at the Zoological Station at Naples ;—Report on Excavations at Portstewart and elsewhere in the North of Ireland ;—Report of the Anthropometric Committee ;—Report on the Investigation of the Natural History of Socotra ;—Report on Instruments for measuring the Speed of Ships ;—Third Report on the Datum-level of the Ordnance Survey of Great Britain ;—Second Report on Patent Legislation ;—On Self-acting Intermittent Siphons and the conditions which determine the commencement of their Action ;—On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-east of England ;—Hydrography, Past and Present.

Together with the Transactions of the Sections, Prof. Allman's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the FIFTIETH MEETING, at Swansea, August and September 1880, *Published at* £1 4*s*.

Contents :—Report on the Measurement of the Lunar Disturbance of Gravity ;—Thirteenth Report on Underground Temperature ;—Report of the Committee for devising and constructing an improved form of High Insulation Key for Electrometer Work ;—Report on Mathematical Tables ;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms ;—Report on Observations of Luminous Meteors ;—Report on the question of Improvements in Astronomical Clocks ;—Report on the commencement of Secular Experiments on the Elasticity of Wires ;—Sixteenth and concluding Report on Kent's Cavern ;—Report on the mode of reproduction of certain species of Ichthyosaurus from the Lias of England and Würtemburg ;—Report on the Carboniferous Polyzoa ;—Report on the 'Geological Record' ;—Sixth Report on the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from these formations ;—Second Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland ;—Eighth Report on the Erratic Blocks of England, Wales, and Ireland ;—Report on an Investigation for the purpose of fixing a Standard of White Light ;—Report of the Anthropometric Committee ;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen ;—Second Report on the Marine Zoology of South Devon ;—Report on the Occupation of a Table at the Zoological Station at Naples; —Report on accessions to our knowledge of the Chiroptera during the past two years (1878–80) ;—Preliminary Report on the accurate measurement of the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures ;—Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg ;—First Report on the Caves of the South of Ireland ;—Report on the Investigation of the Natural History of Socotra ;—Report on the German and other systems of teaching the Deaf to speak ;—Report of the Committee for considering whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters ;—On the Anthracite Coal and Coalfield of South Wales ;—Report on the present state of our knowledge of Crustacea (Part V.) ;—Report on the best means for the Development of Light from Coal-gas of different qualities (Part II.) ;—Report on Palæontological and Zoological Researches in Mexico ;—Report on the possibility of establishing a 'Close Time' for Indigenous Animals ;—Report on the present state of our knowledge of Spectrum Analysis ;—Report on Patent Legislation ;—Preliminary Report on the present Appropriation of Wages, &c. ;—Report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data ;—The French Deep-sea Exploration in the Bay of Biscay ;—Third Report on the Stationary Tides in the English Channel and in the North Sea, &c. ;—List of

Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of 1873):—On the recent Revival in Trade.

Together with the Transactions of the Sections, Dr. A. C. Ramsay's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTY-FIRST MEETING, at York, August and September 1881, *Published at £1 4s.*

CONTENTS:—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Recent Progress in Hydrodynamics (Part I.);—Report on Meteoric Dust;—Second Report on the Calculation of Sun-heat Coefficients;—Fourteenth Report on Underground Temperature;—Report on the Measurement of the Lunar Disturbance of Gravity;—Second Report on an Investigation for the purpose of fixing a Standard of White Light;—Final Report on the Thermal Conductivities of certain Rocks;—Report on the manner in which Rudimentary Science should be taught, and how Examinations should be held therein, in Elementary Schools;—Third Report on the Tertiary Flora of the North of Ireland;—Report on the Method of Determining the Specific Refraction of Solids from their Solutions;—Fourth Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on Fossil Polyzoa;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Migration of Birds;—Report on the Natural History of Socotra;—Report on the Natural History of Timor-laut;—Report on the Marine Fauna of the Southern Coast of Devon and Cornwall;—Report on the Earthquake Phenomena of Japan;—Ninth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Caves of the South of Ireland;—Report on Patent Legislation;—Report of the Anthropometric Committee;—Report on the Appropriation of Wages, &c.;—Report on Observations of Luminous Meteors;—Report on Mathematical Tables;—Seventh Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to Towns and Districts from these Formations;—Report on the present state of our Knowledge of Spectrum Analysis;—Interim Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—On some new Theorems on Curves of Double Curvature;—Observations of Atmospheric Electricity at the Kew Observatory during 1880;—On the Arrestation of Infusorial Life by Solar Light;—On the Effects of Oceanic Currents upon Climates;—On Magnetic Disturbances and Earth Currents;—On some Applications of Electric Energy to Horticultural and Agricultural purposes;—On the Pressure of Wind upon a Fixed Plane Surface;—On the Island of Socotra;—On some of the Developments of Mechanical Engineering during the last Half-Century.

Together with the Transactions of the Sections, Sir John Lubbock's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-SECOND MEETING, at Southampton, August 1882, *Published at £1 4s.*

CONTENTS:—Report on the Calculation of Tables of Fundamental Invariants of Binary Quantics;—Report (provisional) of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report of the Committee appointed for fixing a Standard of White Light;—Report on Recent Progress in Hydrodynamics (Part II.);—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Fifteenth Report on Underground Temperature, with Summary of the Results contained in the Fifteen Reports of the Underground Temperature Committee;—Report on Meteoric Dust;—Second Report on the Measurement of the Lunar Disturbance of Gravity;—Report on the present state of our Knowledge of Spectrum Analysis;—Report on the Investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions;—Report of the Committee for preparing a new Series of Tables of Wave-lengths of the Spectra of the Elements;—Report on the Methods employed in the Calibration of Mercurial Thermometers;—Second Report on the Earthquake Phenomena of Japan;—Eighth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various Towns and Districts from these Formations;—Report on the Conditions under which ordinary Sedimentary Materials may be converted into Metamorphic Rocks;—Report on Explorations in Caves of Carboniferous Limestone in the South of Ireland;—Report on the Preparation of an International Geological Map of Europe;—Tenth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on Fossil Polyzoa (Jurassic Species—British Area only);—Preliminary Report on the Flora of the 'Halifax Hard Bed,' Lower Coal Measures;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report of the Committee appointed for obtaining Photographs of the Typical Races in the British Isles;—Preliminary Report on the Ancient Earthwork in Epping Forest known as the Loughton Camp;—Second Report on the Natural History of Timor-laut;—Report of the Committee for carrying out the recommendations of the Anthropometric Committee of 1880, especially as regards the anthropometry of children and of females, and the more complete discussion of the collected facts;—Report on the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Migration of Birds;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Survey of Eastern Palestine;—Final Report on the Appropriation of Wages, &c.;—Report on the workings of the revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the Committee for determining a Gauge for the manufacture of various small Screws;—Report on the best means of ascertaining the Effective Wind Pressure to which buildings and structures are exposed;—On the Boiling Points and Vapour Tension of Mercury, of Sulphur, and of some Compounds of Carbon, determined by means of the Hydrogen Thermometer;—On the Method of Harmonic Analysis used in deducing the Numerical Values of the Tides of long period, and on a Misprint in the Tidal Report for 1872;—List of Works on the Geology and Palæontology of Oxfordshire, of Berkshire, and of Buckinghamshire;—Notes on the oldest Records of the Sea-Route to China from Western Asia;—The Deserts of Africa and Asia;—State of Crime in England, Scotland, and Ireland in 1880;—On the Treatment of Steel for the Construction of Ordnance, and other purposes;—The Channel Tunnel;—The Forth Bridge.

Together with the Transactions of the Sections, Dr. C. W. Siemens's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-THIRD MEETING, at Southport, September 1883, *Published at £1 4s.*

CONTENTS:—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Sixteenth Report on Underground Temperature;—Report on the best Experimental Methods that can be used in observing Total Solar Eclipses;—Report on the Harmonic Analysis of Tidal Observations;—Report of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report on Mathematical Tables;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Report on Meteoric Dust;—Report of the Committee appointed for fixing a Standard of White Light;—Report on Chemical Nomenclature;—Report on the investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions;—Report on Isomeric Naphthalene Derivatives;—Report on Explorations in Caves in the Carboniferous Limestone in the South of Ireland;—Report on the Exploration of Raygill Fissure, Yorkshire;—Eleventh Report on the Erratic Blocks of England, Wales, and Ireland;—Ninth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various Towns and Districts from these Formations;—Report on the Fossil Plants of Halifax;—Fourth Report on Fossil Polyzoa;—Fourth Report on the Tertiary Flora of the North of Ireland;—Report on the Earthquake Phenomena of Japan;—Report on the Fossil Phyllopoda of the

Palæozoic Rocks;—Third Report on the Natural History of Timor Laut;—Report on the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land;—Report on the Exploration of Kilima-njaro and the adjoining mountains of Eastern Equatorial Africa;—Report on the Migration of Birds;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report on the Ancient Earthwork in Epping Forest, known as the 'Loughton' or 'Cowper's' Camp;—Final Report of the Anthropometric Committee;—Report of the Committee for defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining Illustrative Photographs;—Report on the Survey of Eastern Palestine;—Report on the workings of the proposed revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the Committee for determining a Gauge for the manufacture of various small Screws;—Report of the 'Local Scientific Societies' Committee;—On some results of photographing the Solar Corona without an Eclipse;—On Lamé's Differential Equation;—Recent Changes in the Distribution of Wealth in relation to the Incomes of the Labouring Classes;—On the Mersey Tunnel;—On Manganese Bronze;—Nest Gearing.

Together with the Transactions of the Sections, Professor Cayley's Address, and Recommendations of the Association and its Committees.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

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CORRECTED TO FEBRUARY 3, 1885.

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1884.

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‡ indicates Subscribers not entitled to the Annual Report.
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Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Secretary, 22 Albemarle Street, London, W.

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Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1881. *Abbott, R. T. G. Woodbine House, Trinity-road, Scarborough.
1863. *ABEL, Sir FREDERICK AUGUSTUS, K.C.B., D.C.L., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 39 Welbeck-street, London, W.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1873. ‡Abernethy, James. Ferry-hill, Aberdeen.
1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.
1877. §Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1884. §Achison, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. Oxford.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. School of Gunnery, Shoeburyness.

Year of Election.

1873. *Acland, Rev. H. D., M.A. Nymet St. George, South Molton, Devon.
1873. *ACLAND, Sir HENRY W. D., K.C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 79 Lambeth Palace-road, London, S.E.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
1884. §Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.
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1879. *ADAMS, Rev. THOMAS, M.A. Underhill, Low Fell, Gateshead.
1877. ‡ADAMS, WILLIAM. 3 Sussex-terrace, Plymouth.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.
1873. ‡Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.
1870. ‡Adamson, Robert, M.A., LL.D., Professor of Logic and Political Economy in Owens College, Manchester. 60 Parsonage-road, Withington, Manchester.
1860. *Adie, Patrick. Broadway, Westminster, S.W.
1865. *Adkins, Henry. Northfield, near Birmingham.
1883. §Adshead, Samuel. School of Science, Macclesfield.
1884. §Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
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1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
Ainsworth, Peter. Smithills Hall, Bolton.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
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1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1861. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
1883. §Alexander, George. Kildare-street Club, Dublin.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1883. §Alger, Miss Ethel. Widey Court, near Plymouth.
1883. §Alger, W. H. Widey Court, near Plymouth.
1883. §Alger, Mrs. W. H. Widey Court, near Plymouth.
1867. ‡Alison, George L. C. Dundee.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., M.Inst.C.E. 101 Leadenhall-street, London, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. 1 Surrey-street, Sheffield.
1879. *Allen, Rev. A. J. C. Peterhouse, Cambridge.
1884. §Allen, Rev. George. Shaw Vicarage, Oldham.

Year of Election.

1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. §Ami, Henry. Geological Survey, Ottawa, Canada.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1878. ‡Anderson, Beresford. Saint Ville, Killiney.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1850. ‡*Anderson, John. 31 St. Bernard's-crescent, Edinburgh.*
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1876. ‡Anderson, Matthew. 137 St. Vincent-street, Glasgow.
1859. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1880. §Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1880. *Andrews, Thornton, M.I.C.E. Cefn Eithen, Swansea.
*ANDREWS, THOMAS, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S. Fortwilliam Park, Belfast.
1883. §Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. 81 Ducie-grove, Oxford-street, Manchester.
1859. ‡Angus, John. Town House, Aberdeen.
1878. ‡Anson, Frederick H. 9 Delahay-street, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
APJOHN, JAMES, M.D., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in Trinity College, Dublin. 32 Baggot-street, Dublin.
1868. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1884. §Archbold, George. Oswego, New York, U.S.A.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, Professor THOMAS C., F.R.S.E., Director of the Museum of Science and Art, Edinburgh. St. Margaret's, Greenhill-place, Edinburgh.
1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.
1884. *Archibald, E. Douglas. Grosvenor House, Tunbridge Wells.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyleshire.
1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.
1883. §Armistead, Richard. Wharncliffe House, Beaufort-road, Brooklands, near Manchester.
1883. *Armistead, William. Wharncliffe House, Beaufort-road, Brooklands, near Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.

Year of
Election.

1873. §ARMSTRONG, Professor HENRY E., Ph.D., F.R.S., Sec.C.S. Technical College, Tabernacle-row, London, E.C.
1878. ‡*Armstrong, James. 28A Renfield-street, Glasgow.*
1884. §Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *ARMSTRONG, Sir WILLIAM GEORGE, C.B., LL.D., D.C.L., F.R.S Jesmond Dene, Newcastle-upon-Tyne.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1884. *Asher, Asher, M.D. 18 Endsleigh-street, Tavistock-square, London, W.C.
1873. ‡Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
1875. *Aspland, W. Gaskell. Care of Manager, Union Bank, Chancery-lane, London, W.C.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1872. §Atchison, Arthur T., M.A. 60 Warwick-road, Earl's Court, London, S.W.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. §Atkinson, Edward. Brookline, Mass., Boston, U.S.A.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abingdon-road, Kensington, London, W.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1883. *Atkinson, Miss Maria. The Laurels, Sale, Cheshire.
1881. ‡Atkinson, Robert William. Town Hall-buildings, Newcastle-on-Tyne.
Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. §Auchindors, W. S. Philadelphia, U.S.A.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. ‡AXON, W. E. A. Fern Bank, Higher Broughton, Manchester.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Technical College, Finsbury. 68 Sloane-street, London, S.W.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.

Year of Election.

1884. §Baby, Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1881. ‡Baden-Powell, George S., C.M.G., M.A., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Bagrual, P. H. St. Stephen's Club, Westminster, S.W.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1883. §Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1870. §Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1878. ‡Bailey, John. 3 Blackhall-place, Dublin.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street, Dublin.
1873. ‡Bain, Sir James. 3 Park-terrace, Glasgow.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, Sir EDWARD, J.P. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1882. *Baker, Benjamin, M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡*Baker, James P. Wolverhampton.*
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1865. ‡Baker, Robert L. Barham House, Leamington.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. The Holmes, Stoke Bishop, Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. §Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, D.Sc., M.D., F.R.S. L. & E., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
1835. *BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. ‡BALL, VALENTINE, M.A., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1883. ‡*Balloch, Miss. Glasgow.*
1884. §Ballon, Dr. Naham. Sandwich, Illinois, U.S.A.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.

Year of Election.

1882. §Bance, Major Edward. Limewood, The Avenue, Southampton.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1879. ‡Banham, H. French. Mount View, Glossop-road, Sheffield.
1870. ‡BANISTER, Rev. WILLIAM. B.A. St. James's Mount, Liverpool.
1884. §Bannatyne, Hon. A. G. Winnipeg, Canada.
1883. §Banning, John J. 28 Westcliffe-road, Southport.
1884. §Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. §Barber, Rev. S. F. Little Massingham Rectory, Swaffham, Norfolk.
1861. *Barbour, George. Bankhead, Broxton, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A. Bury Hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1868. *Barclay, W. L. 54 Lombard-street, London; E.C.
1881. §Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. G. Above Bar, Southampton.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Rotherham, Yorkshire.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM. F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.
1873. ‡BARLOW, W. H., F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1884. §Barlowe, Miss Constance. Churton-gardens, Kensington, London, W.
1861. *Barnard, Major R. Cary. F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
Barnes, Thomas Addison. Brampton Collieries, near Chesterfield.
1839. *Barnett, Richard, M.R.C.S. 18 Albany-terrace, Britannia-square, Worcester.
1884. §Barnett, I. D. Port Hope, Ontario.
1881. ‡Barr, Archibald, B.Sc., Professor of Civil and Mechanical Engineering in the Yorkshire College, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1883. §Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.

Year of
Election.

1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., F.C.S., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1874. *BARRINGTON, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1881. §BARRON, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1862. *BARRY, CHARLES. 15 Pembridge-square, London, W.
1883. §Barry, Charles E. 15 Pembridge-square, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1855. ‡*Bartholomew, Hugh. New Gasworks, Glasgow.*
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. §Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T. St. Margaret's House, Victoria-street, London, S.W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1884. §Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, London, N.
1866. ‡*Bassett, Richard. Pelham-street, Nottingham.*
1884. *Bassnett, Thomas. Jacksonville, Florida, U.S.A.
1884. §Bassnett, Mrs. Thomas. Jacksonville, Florida, U.S.A.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.D., M.A., F.R.S., F.L.S., Professor of Pathological Anatomy at University College, London. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1883. ‡Bateman, A. E. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Carpenter-street, above Broad-street, Philadelphia, United States.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1842. *BATEMAN, JOHN FREDERIC LA TROBE, F.R.S., F.G.S., F.R.G.S., M.Inst.C.E. 16 Great George-street, London, S.W.
1864. ‡BATES, HENRY WALTER, F.R.S., F.L.S., Assist.-Sec. R.G.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1884. §Bateson, William, B.A. St. John's College, Cambridge.
1851. ‡BATH AND WELLS, The Right Rev. Lord ARTHUR HERVEY, Lord Bishop of. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur. Red House, Roehampton, Surrey, S.W.
1836. ‡Batten, Edmund Chisholm. 25 Thurloe-square, London, S.W.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, W.
1863. §BAUERMAN, H., F.G.S. 41 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.S., F.R.A.S. 14 Liverpool-road, Birkdale, Southport.

Year of
Election.

1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Thomas Sebastian, M.A. Hatherop Castle, Fairford, Gloucestershire.
1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1882. §*Beamish, Major A. W., R.E. Cranbury-terrace, Southampton.*
1884. §Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
1883. ‡Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Ash Mount, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. 18 Piccadilly, London, W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Lieut.-Colonel George G., F.R.G.S. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 68 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. 155 Shrewsbury-street, Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. Clifton, Bristol.
1858. ‡Bedford, James. Woodhouse Cliff, near Leeds.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S. College of Physical Science, Newcastle-on-Tyne.
1884. §Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, Asahel P. 32 St. Anne's-street, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
1884. §Bell, Charles Napier. Winnipeg, Canada.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1879. ‡*Bell, Henry S. Kenwood Bank, Sharrow, Sheffield.*
1862. *BELL, ISAAC LOWTHIAN, F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, F.R.S., F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. Institution of Engineers, Glasgow.

Year of Election.

1863. *Bell, Thomas. Palazo Vitoria, Bilbao, Spain.
1867. ‡Bell, Thomas. Belmont, Dundee.
1882. §Bell, W. Alexander, B.A. 3 Madeira-terrace, Kemp Town, Brighton.
1875. ‡*Bell, William. Witford House, Briton Ferry, Glamorganshire.*
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1882. §Bellingham, William. 2 Edinburgh Mansions, Victoria-street, London, S.W.
1884. §Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1864. *Bendyshe, T. 3 Sea View-terrace, Margate.
1870. ‡Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1881. §Bennett, John R. Bedminster, Bristol.
1883. *Bennett, Laurence Henry. Trinity College, Oxford.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishophill Junior, York.
1870. *Bennett, William. Heysham Tower, Lancaster.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 5 Tavistock-square, London, W.C.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1884. §Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1842. Bentley, John. 2 Portland-place, London, W.
1863. §Bentley, Robert, F.L.S., Professor of Botany in King's College, London. 38 Penywern-road, Earl's Court, London, S.W.
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡Berkeley, Rev. M. J., M.A., F.R.S., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1881. ‡*Berkley, H. Rorke. Prestwich, Manchester.*
1848. ‡*Berrington, Arthur V. D. Woodlands Castle, near Swansea.*
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *Bessemer, Sir Henry, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. Mount House, Hythe, Southampton.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1883. ‡Betley, Ralph, F.G.S. Mining School, Wigan.
1876. *Bettany, G. T., M.A., B.Sc., Lecturer on Botany at Guy's Hospital, London. 2 Eckington-villas, Ashbourne-grove, East Dulwich, S.E.
1883. †Bettany, Mrs. 2 Eckington-villas, Ashbourne-grove, East Dulwich, S.E.
1880. *Bevan, Rev. James Oliver, M.A. 72 Beaufort-road, Edgbaston, Birmingham.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1884. *Beverley, Michael, M.D. 52 St. Giles'-street, Norwich.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1882. §Biggs, C. H. W., F.C.S. 1 Bloomfield, Bromley, Kent.
1864. ‡Biggs, Robert. 16 Green Park, Bath.

Year of Election.

Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1884. *Bingham, John E. Electric Works, Sheffield.
1881. ‡Binnie, Alexander R., F.G.S. Town Hall, Bradford, Yorkshire.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1879. ‡Binns, E. Knowles, F.R.G.S. 216 Heavygate-road, Sheffield.
Birchall, Edwin, F.L.S. Douglas, Isle of Man.
Birchall, Henry. College House, Bradford.
1880. §Bird, Henry, F.C.S. South Down, near Devonport.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1883. §Bishop, John le Marchant. 100 Mosley-street, Manchester.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. ‡Blachford, The Right Hon. Lord, K.C.M.G. Cornwood, Ivybridge.
1884. §Black, Francis, F.R.G.S. Edinburgh.
1881. §Black, William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. §Blackburn, Robert. New Edinburgh, Ontario, Canada.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. §Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1883. §Blaikie, Adrian. 4 Akenside-terrace, Jesmond, Newcastle-on-Tyne.
1884. §Blaikie, James, M.A. 14 Viewforth-place, Edinburgh.
1878. §Blair, Matthew. Oakshaw, Paisley.
1883. §Blair, Mrs. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. Westminster Hospital School of Medicine, Broad Sanctuary, Westminster, S.W.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *Blake, Rev. J. F., M.A., F.G.S., Professor of Natural Science in University College, Nottingham.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Burledon, Hants.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, B.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., Sec. G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1869. *Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1880. §Bloxam, G. W., M.A., F.L.S. The Hut, Upper Teddington, Surrey.
1883. ‡Blumberg, Dr. 65 Hoghton-street, Southport.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.

Year of Election.

1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. §Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1883. §Bodman, Miss Caroline M. 45 Devonshire-street, Portland-place, London, W.
1884. §Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1881. ‡Bojanowski, Dr. Victor de, Consul-General for Germany. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1866. ‡*Bond, Banks. Low Pavement, Nottingham.*
Bond, Henry John Hayes, M.D. Cambridge.
1884. §Bond, Right Rev. W., LL.D., Bishop of Montreal. Montreal, Canada.
1883. §Bonney, Frederic, F.R.G.S. Oriental Club, Hanover-square, London, W.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., Pres. G.S., Professor of Geology in University College, London. (Secretary.) 22 Albemarle-street, London, W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. ‡Booth, James. Elmfield, Rochdale.
1883. §Booth, James. Hazelhurst House, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. ‡Booth, Rev. William H. Yardley, Birmingham.
1883. §Boothroyd, Benjamin. Rawlinson-road, Southport.
1880. §Boothroyd, Samuel. Warley House, Southport.
1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 6 Anhalt-road, Battersea Park, London, S.W.
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.A.S. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H. Yorkshire College, Leeds.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. *Bottomley, James Thomson, M.A., F.R.S.E., F.C.S. 2 Eton-terrace, Hillhead, Glasgow.
1884. §Bottomley, Mrs. 2 Eton-terrace, Hillhead, Glasgow.
Bottomley, William. Southampton-place, Reading.
1876. ‡Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1883. §Bourdas, Isaiah. 59 Belgrave-road, London, S.W.
1883. ‡Bourne, A. G. University College, London, W.C.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1884. §Bovey, Henry T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill College, Montreal. Ontario-avenue, Montreal, Canada.
1872. ‡*Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.*

Year of Election.

1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1881. *Bower, F. O. Elmscroft, Ripon, Yorkshire.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1884. §Bowley, Edwin. Burnt Ash Hill, Lee, Kent.
1880. ‡Bowly, Christopher. Cirencester.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
BOWMAN, Sir WILLIAM, Bart., LL.D., F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1863. ‡Boyd, Edward Fenwick. Moor House, near Durham.
1884. *Boyd, M. A., M.D. 90 George's-street, Kingstown, Dublin.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1872. *BRABROOK, E. W., F.S.A. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1884. *Brace, W. H., M.D. 7 Queen's-gate-terrace, London, S.W.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1880. ‡Bradford, H. Stretton House, Walters-road, Swansea.
Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., F.R.S., F.L.S., Professor of Natural History in the College of Physical Science, Newcastle-on-Tyne. 22 Fawcett-street, Sunderland.
1862. §BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. 6 Harley-place, Clifton, Bristol.
1880. *Brady, Rev. Nicholas, M.A. Wennington, Essex.
1864. §BRAHAM, PHILIP, F.C.S. 7 Miles's-buildings, Bath.
1870. ‡Braidwood, Dr. Delemere-terrace, Birkenhead.
1879. ‡Bramley, Herbert. Claremont-crescent, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., LL.D., F.R.S., Pres. Inst.C.E. 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 6 King's Bench-walk, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡Briant, T. Hampton Wick, Kingston-on-Thames.
1884. §Bridges, C. J. Winnipeg, Canada.
1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.

Year of Election.

1863. *BRIGHT, Sir CHARLES TILSTON, M.Inst.C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. JOHN, M.P. Rochdale, Lancashire.
1868. ‡Brine, Captain Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. §Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *BRITTAIN, W. H. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, W.C.
1884. *Brittle, John R. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *BRODHURST, BERNARD EDWARD, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. Beverly House, St. Thomas' Hill, Canterbury.
1865. ‡BRODIE, Rev. PETER BELLINGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. §Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1853. ‡*Bromby, J. H., M.A. The Charter House, Hull.*
1878. *Brook, George, F.L.S. Fernbrook, Huddersfield, Yorkshire.
1880. ‡Brook, G. B. Brynsyfi, Swansea.
1881. §Brook, Robert G. Rowen-street, St. Helen's, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1863. ‡Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1883. §Brotherton, E. A. Bolton Bridge-road, Ilkley, Leeds.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. §Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. §Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. §Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. §Brown, Mrs. H. Bientz. 50 Effingham-road, Lee, Kent.
1884. §Brown, Harry. University College, London, W.C.
1883. §Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §BROWN, HORACE T. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. §Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Edenderry House, Belfast.
1881. *Brown, John, M.D. 66 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. Swiss Cottage, Park-valley, Nottingham.
1859. ‡Brown, Rev. John Croumbie, LL.D., F.L.S. Haddington, N.B.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1882. *Brown, Mrs. Mary. Burnley, Lancashire.

Year of Election.

1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡Brown, Robert, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41a New-street, Birmingham.
1884. §Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1879. ‡Browne, J. Crichton, M.D., LL.D., F.R.S. L. & E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. *Browne, William, M.D. Heath Wood, Leighton Buzzard.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. §Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, F.R.S.E., F.G.S., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡Brunton, T. Lauder, M.D., D.Sc., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1877. ‡Bryant, George. 82 Claverton-street, Pimlico, London, S.W.
1875. ‡*Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.*
1875. ‡*Bryant, Miss S. A. The Castle, Denbigh.*
1861. ‡*Bryce, James. York-place, Higher Broughton, Manchester.*
1884. §Bryce, Rev. Professor. The College, Manitoba, Canada.
Bryce, Rev. R. J., LL.D. Fitzroy-avenue, Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1871. §Buchan, Alexander, M.A., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 Barnard-road, Birkenhead, Cheshire.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡Buchanan, John Young. 10 Moray-place, Edinburgh.
1884. §Buchanan, W. Frederick. Winnipeg, Canada.
1883. §Buckland, Miss A. W. 54 Doughty-street, London, W.C.
1864. §Buckle, Rev. George, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1880. §Buckney, Thomas, F.R.A.S. Little Thurlow, Suffolk.
1869. ‡Bucknill, J. C., M.D., F.R.S. E 2 Albany, London, W.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. Science and Art Department, South Kensington, London, S.W.
1851. *Buckton, George Bowdler, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1875. §Budgett, Samuel. Cotham House, Bristol.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1845. *Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.

Year of
Election.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. §Burdett-Coutts, W. L. A. B. 1 Stratton-street, Piccadilly, London, W.
1874. ‡*Burdon, Henry, M.D. Clandeboye, Belfast.*
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1883. *Burne, Colonel Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 57 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877. ‡Burns, David, C.E. Alston, Carlisle.
1884. §Burns, James Austin. Atlantic P.O., Box 456, Georgia, U.S.A.
1883. §Burr, Percy J. 20 Little Britain, London, E.C.
1881. §Burroughs, S. M. 7 Snow-hill, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1877. ‡Burt, J. Kendall. Kendal.
1874. ‡*Burt, Rev. J. T. Broadmoor, Berks.*
1866. *Burton, Frederick M., F.G.S. Highfield, Gainsborough.
1879. ‡*Bury, Percy B. Cambridge.*
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., F.L.S., F.G.S. 32 Harley-street, Cavendish-square, London, W.
1878. ‡Butcher, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. §Butler, Matthew I. Napanee, Ontario, Canada.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Ph.D. 298 Regent-street, London, W.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 7 Grosvenor-crescent, London, S.W.
1883. ‡Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡Byerley, Isaac, F.L.S. Seacombe, Cheshire.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. §Byrom, John R. Royal Mills, Droylesden.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1877. ‡Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.

Year of Election.

1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1854. ‡Calver, Captain E. K., R.N., F.R.S. 23 Park-place, East Sunderland, Durham.
1884. §Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, CHARLES A., M.D. 15 Pembroke-road, Dublin.
1884. §Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1881. ‡Cameron, Major-General, C.B. 3 Driffield-terrace, York.
1884. §Campbell, Archibald H. Toronto, Canada.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S., F.S.S. 17 Southwell-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
1883. ‡Campbell, H. J. 81 Kirkstall-road, Talfourd Park, Streatham Hill, S.W.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London ,W.; and Marchmont House, near Dunse, Berwickshire.
1872. ‡*Campbell, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.*
1876. ‡Campbell, James A. 3 Claremont-terrace, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1859. ‡Campbell, William. Dunmore, Argyllshire.
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1876. §Campion, Frank, F.G.S., F.R.G.S. The Mount, Duffield-road, Derby.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1880. ‡Capper, Robert. Westbrook, Swansea.
1883. §Capper, Mrs. R. Westbrook, Swansea.
1873. *Carbutt, Edward Hamer, M.P., C.E. 19 Hyde Park-gardens, London, W.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1883. §Carey-Hobson, Mrs. 54 Doughty-street, London, W.C.
1877. ‡Carkeet, John, C.E. 3 St. Andrew's-place, Plymouth.
1876. ‡Carlile, Thomas. 5 St. James's-terrace, Glasgow.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡*Carlton, James. Mosley-street, Manchester.*
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1884. §Carnegie, John. Peterborough, Ontario, Canada.
1884. §Carpenter, Louis G. Agricultural College, Lansing, Michigan, U.S.A.
1871. *CARPENTER, P. HERBERT, D.Sc. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. 36 Craven-park, Harlesden, London, N.W.
1884. *Carpmael, Charles. Toronto, Canada.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1883. §Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.

Year of
Election.

1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, E. Henry. Magherafelt Manor, Co. Derry.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.
1884. §Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1883. §Carver, James. Garfield House, Elm-avenue, Nottingham.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1878. ‡Casey, John, LL.D., F.R.S., M.R.I.A., Professor of Higher Mathematics in the Catholic University of Ireland. 2 Iona-terrace, South Circular-road, Dublin.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1884. *Cave, Herbert. Christ Church, Oxford.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1879. §Chadburn, Alfred. Brincliffe Rise, Sheffield.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Park Cottage, East Sheen, Middlesex, S.W.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1883. §Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. §Chamberlain, Montague. St. John's, New Brunswick, Canada.
1883. ‡Chambers, Benjamin. Hawkshead-street South, Southport.
1883. ‡CHAMBERS, CHARLES, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun. The College, Cooper's Hill, Staines.
1842. Chambers, George. High Green, Sheffield.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
1877. *CHAMPERNOWNE, ARTHUR, M.A., F.G.S. Dartington Hall, Totnes, Devon.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.

Year of Election.

1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1884. §Chapman, Professor. University College, Toronto, Canada.
1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.
1866. ‡*Chapman, William. The Park, Nottingham.*
1871. ‡Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
1883. ‡Chater, Rev. John. Part-street, Southport.
1884. *Chatterton, George, 42 Queen Anne's-gate, London, S.W.
1867. *Chatwood, Samuel, F.R.G.S. Irwell House, Drinkwater Park, Prestwich.
1884. §CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. §Chawner, W., M.A. Emanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. §Cherriman, Professor, J. B. Ottawa, Canada.
1879. *Chesterman, W. Broomsgrove-road, Sheffield.
1879. ‡*Cheyne, Commander J. P., R.N. 1 Westgate-terrace, West Brompton, London, S.W.*
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. §Chinery, Edward F. Monmouth House, Lymington.
1884. §Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1882. §Chorley, George. Midhurst, Sussex.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1884. *Christie, William. 13 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.
1876. *CHRYSTAL, G., M.A., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1881. ‡Churchill, Lord Alfred Spencer. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1869. *Clapp, Frederick. Roseneath, St. James's-road, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square Dublin.

Year of Election.

1859. ‡Clark, David. Coupar Angus, Fifeshire.
1876. ‡Clark, David R., M.A. 31 Waterloo-street, Glasgow.
1877. *Clark, F. J. Street, Somerset.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1877. Clark, G. T. 44 Berkeley-square, London, W.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 20 Bootham, York.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. 45 Nelson-street, Chorlton-on-Medlock, Manchester.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. §Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡Cleghorn, Hugh, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1873. §Cliff, John, F.G.S. Linnburn, Ilkley, near Leeds.
1883. ‡Clift, Frederic, LL.D. Norwood, Surrey.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1883. *Clowes, Frank, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. University College, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
Cobb, Edward. 6 Lansdowne-place East, Bath.
1884. §Cobb, John. Lenzie, near Glasgow.
1864. ‡Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Professor of Botany and Helminthology in the Royal Veterinary College, London. 74 Portsdown-road, Maida Hill, London, W.
1864. *Cochrane, James Henry. Elm Lodge, Prestbury, Cheltenham.
1884. *Cockburn-Hood, J. J. Walton Hall, Kelso, N.B.
1883. §Cockshott, J. J. 74 Belmont-street, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.

Year of Election.

1881. §Coffin, Walter Harris, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1884. *Cohen, B. L. 30 Hyde Park-gardens, London, W.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1876. ‡Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 14 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 2 Gipsy Hill-villas, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. New Athenæum Club, 3 Pall Mall East, London, S.W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡Collins, J. H., F.G.S. 64 Bickerton-road, London, N.
1876. ‡Collins, William. 3 Park-terrace East, Glasgow.
1884. §Collins, William J., M.D., B.Sc. Albert-terrace, Regent's Park, London, N.W.
1883. ‡Collis, W. Elliott. 3 Lincoln's-Inn-fields, London, W.C.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. §Colmer, Joseph G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.
1884. §Colomb, Capt. J. C. R., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
1884. §Common, A. A. 63 Eaton-rise, Ealing, Middlesex, W.
1870. *Compton, The Very Rev. Lord Alwyne, D.D., Dean of Worcester. The Deanery, Worcester.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1884. §Conklin, Dr. William A. Central Park, New York, U.S.A.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Notting Hill House, Belfast.
1881. ‡Conroy, Sir John, Bart. Arborfield, Reading, Berks.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡Cooke, Major-General A. C., R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Southampton.
1876. *Cooke, Conrad W. 2 Victoria-mansions, Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishophill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. §Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishophill, York.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. §Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. §Cooke-Taylor, Mrs. Frenchwood House, Preston.

Year of Election.

1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1863. ‡*Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.*
1869. §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1883. ‡*Coomer, John. 53 Albert-road, Southport.*
1884. §Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1884. §Cooper, Mrs. M. A. West Tower, Marple, Cheshire.
1879. §Cooper, Thomas. Rose Hill, Rotherham, Yorkshire.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1884. §Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S. Dun Echt, Aberdeen.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Ravenoak, Cheadle Hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology in Queen's College, Cork.
1881. §Cordeaux, John. Great Cotes, Ulceby, Lincolnshire.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
1883. §Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazenose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, D.D., Bishop of Edinburgh. Edinburgh.
1874. *COTTERILL, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. ‡Cowan, J. B., M.D. Helensburgh, N.B.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.G.S. Comptons Lea, Horsham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.Inst.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.

Year of Election.

1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 85 Rann-street, Birmingham.
1883. §Crabtree, William, C.E. Manchester-road, Southport.
1884. §Craigie, Major P. E., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡*Crampton, Rev. Josiah. Nettlebeds, near Oxford.*
1879. §Crampton, Thomas Russell, M.Inst.C.E. 19 Ashley-place, London, S.W.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. §Crathern, James. Sherbrooke-street, Montreal, Canada.
1876. ‡Crawford, Chalmond. Ridemon, Crosscar.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, LL.D., F.R.S., F.R.A.S. The Observatory, Dun Echt, Aberdeen.
1871. ‡*Crawshaw, Edward. Burnley, Lancashire.*
1883. *Crawshaw, Edward. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1879. ‡Creswick, Nathaniel. Handsworth Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1878. ‡Croke, John O'Byrne, M.A. The French College, Blackrock, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §Crookes, William, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1883. ‡Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §Crosskey, Rev. H. W., LL.D., F.G.S. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1883. §Crowder, Robert. Stannix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1861. §Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1883. §Crowther, Elon. Cambridge-road, Huddersfield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.

Year of Election.

1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. §Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *Cunningham, Major Allan, R.E., A.I.C.E. 9 Campden Hill-road, Kensington, London, W.
1877. ‡Cunningham, D. J., M.D., Professor of Anatomy in Trinity College, Dublin.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. William, B.D., D.Sc. Trinity College, Cambridge.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1881. ‡Curley, T., C.E., F.G.S. Hereford.
1884. §Currier, John McNab. Castleton, Vermont, U.S.A.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, ARTHUR HILL, LL.D. 1 Hume-street, Dublin.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. §Cushing, Frank Hamilton. Washington, U.S.A.
1883. §Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1863. ‡*Daglish, John. Hetton, Durham.*
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Wesley College, Glossop-road, Sheffield.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡*Dalrymple, Colonel. Troup, Scotland.*
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
1862. ‡DANBY, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1883. ‡Darbishire, S. D., M.D. 60 High-street, Oxford.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
1884. §Darling, Thomas. 99 Drummond-street, Montreal, Canada.
1882. ‡DARWIN, FRANCIS, M.A., F.R.S., F.L.S. Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Trinity College, Cambridge.
1878. *Darwin, Horace. 66 Hills-road, Cambridge.
1882. §Darwin, W. E., F.G.S. Bassett, Southampton.

Year of Election.

1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1878. ‡D'Aulmay, G. 22 Upper Leeson-street, Dublin.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. §Davey, Henry, M.Inst.C.E. Rupert Lodge, Grove-road, Headingley, Leeds.
1884. §David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1871. ‡*Davidson, James. Newbattle, Dalkeith, N.B.*
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, LL.D., F.R.S., F.G.S. 9 Salisbury-road West, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. 88 Seel-street, Liverpool.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1873. *Davis, Alfred. Parliament Mansions, London, S.W.
1870. *Davis, A. S. 6 Paragon-buildings, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1881. †Davis, George E. The Willows, Fallowfield, Manchester.
1882. §Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1873. *DAVIS, JAMES W., F.G.S., F.S.A. Chevinedge, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1883. ‡Davis, Joseph, J.P. Park-road, Southport.
1883. §Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1882. ‡Davis, W. H. Gloucester Lodge, Portswood, Southampton.
1873. ‡*Davis, William Samuel. 1 Cambridge-villas, Derby.*
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Blaen-y-Roe, St. Asaph, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
Dawson, John. Barley House, Exeter.
1884. §Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. ‡DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1879. ‡Day, Francis. Kenilworth House, Cheltenham.
1871. ‡DAY, ST. JOHN VINCENT, M.Inst.C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. *DEACON, G. F., M.Inst.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1884. *Debenham, Frank, F.S.S. 26 Upper Hamilton-terrace, London, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1884. §Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1882. *DE CHAUMONT, FRANÇOIS, M.D., F.R.S., Professor of Hygiène in the Royal Victoria Hospital, Netley.

Year of Election.

1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *De La Rue, Warren, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1884. *De Laune, C. DeL. F. Sharsted Court, Sittingbourne.
1870. ‡De Meschin, Thomas, M.A., LL.D. 8 New-square, Lincoln's Inn, London, W.C.
Denchar, John. Morningside, Edinburgh.
1873. ‡Denham, Thomas. Huddersfield.
1884. §Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.
1875. ‡Denny, William. Seven Ship-yard, Dumbarton.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §De Rance, Charles E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *Derby, The Right Hon. the Earl of, K.G., M.A., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*Devonshire, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James, M.A., F.R.S. L. & E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. 19 Brookside, Cambridge.
1881. ‡Dewar, Mrs. 19 Brookside, Cambridge.
1883. §Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William. Park House, Barnsley.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 2 Southwick-place, Hyde Park, London, W.
1884. §De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *Dew-Smith, A. G., M.A. 7a Eaton-square, London, S.W.
1883. §Dickinson, A. P. Fair Elms, Blackburn.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1867. ‡Dickson, Alexander, M.D., Professor of Botany in the University of Edinburgh. 11 Royal-circus, Edinburgh.
1884. §Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.
1872. ‡Dines, George. Woodside, Hersham, Walton-on-Thames.

Year of Election.

1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1868. ‡Dittmar, William, F.R.S. L. & E., F.C.S., Professor of Chemistry in Anderson's College, Glasgow.
1884. §Dix, John William H. Bristol.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1883. §Dixon, Miss E. 2 Cliff-terrace, Kendal.
1853. ‡Dixon, Edward. Wilton House, Southampton.
1879. *Dixon, Harold B., M.A., F.C.S. Trinity College, Oxford.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡*Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.*
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *Dobson, G. E., M.A., M.B., F.R.S., F.L.S. Royal Victoria Hospital, Netley, Southampton.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.
1870. *Dodd, John. 53 Cable-street, Liverpool.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1882. §Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Colonel, R.E. South Kensington Museum, London, W.
1881. §Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. *Douglas, Rev. G. C. M. 18 Royal-crescent West, Glasgow.
1877. *Douglass, Sir James N., C.E. Trinity House, London, E.C.
1878. ‡Douglass, William. 104 Baggot-street, Dublin.
1884. §Douglass, William Alexander. A. H. Union House of Commons, Ontario, Canada.
1883. §Dove, Arthur. Crown Cottage, York.
1884. §Dove, Miss J. F. St. Andrews, N.B.
1884. §Dove, P. Edward, Sec.R.Hist.Soc. 9 Argyll-street, Regent-street, London, W.
1884. §Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1870. ‡Dowie, J. Muir. Achanacreagh, Morvern, N.B.
1876. ‡Dowie, Mrs. Muir. Achanacreagh, Morvern, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1878. ‡Dowling, Thomas. Claireville House, Terenure, Dublin.
1882. §Downes, Rev. W. Kentisbeare, Collumpton, Devon.
1857. ‡Downing, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1878. ‡Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1865. *Dowson, E. Theodore, F.M.S. Geldeston, near Beccles, Suffolk.
1881. §Dowson, Joseph Emerson, C.E. 3 Great Queen-street, London, S.W.
1883. §Draper, William. De Grey House, St. Leonard's, York.
1868. ‡Dresser, Henry E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §Drew, Frederic, F.G.S., F.R.G.S. Eton College, Windsor.
1879. ‡*Drew, Joseph, M.B. Foxgrove-road, Beckenham, Kent.*

Year of Election.

1879. ‡Drew, Samuel, M.D., D.Sc., F.R.S.E. 10 Laura-place, Bath.
1872. **Druce, Frederick.* 27 *Oriental-place, Brighton.*
1874. ‡*Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.*
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1884. §Du Bois, Henri. 39 Bentick-street, Glasgow.
1856. *Ducie, The Right. Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1883. ‡*Duck, A. E. Southport.*
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holme House, Columbia-road, Oxton, Birkenhead.
1867. *Duff, The Right Hon. Mountstuart Elphinstone Grant-, F.R.S., F.R.G.S., Governor of Madras. Care of W. Hunter, Esq., 14 Adelphi-court, Union-street, Aberdeen.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., G.C.B., LL.D., F.R.S., F.R.G.S., Governor-General of India. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1884. §Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡*Duncan Charles.* 52 *Union-place, Aberdeen.*
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1867. ‡Duncan, Peter Martin, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 4 St. George's-terrace, Regent's Park-road, London, N.W.
1880. ‡Duncan, William S. 22 Delamere-terrace, Bayswater, London, W.
1881. §Duncombe, The Hon. Cecil. Nawton Grange, York.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1882. §Dunn, J. T., M.Sc. High School for Boys, Gateshead-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University of Virginia, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodberry Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1884. §Dyck, Professor Walter. The University, Munich.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1883. ‡Eagar, Rev. Thomas. The Rectory, Ashton-under-Lyne.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1833. *Earnshaw, Rev. Samuel, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.

Year of Election.

1833. ‡*Eastham, Silas. 50 Leyland-road, Southport.*
1871. *EASTON, EDWARD, M.Inst.C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. §Eastwood, Miss. Littleover Grange, Derby.
1870. ‡Eaton, Richard. 1 Stafford-street, Derby.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1884. §Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Syward Lodge, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, R. Arnold, B.A., F.C.S. Ashburnham House, Little Dean's-yard, Westminster, S.W.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1884. *Edmunds, James, M.D. 8 Grafton-street, Piccadilly, London, W.
1883. ‡Edmunds, L. H., D.Sc. 8 Grafton-street, Piccadilly, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1884. §Edwards, W. F. Niles, Michigan, U.S.A.
1873. ‡*Elcock, Charles. 30 Lyme-street, Shakspere-street, Ardwick, Manchester.*
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1883. §Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1880. *Elliot, Colonel Charles, C.B. Hazelbank, Murrayfield, Midlothian, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., LL.D., F.R.S., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, U.S.A.
1883. *ELLIOTT, EDWIN BAILEY, M.A. Queen's College, Oxford.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1879. §Elliott, Joseph W. Post Office, Bury, Lancashire.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 67 Ladbroke Grove-road, Notting Hill, London, W.
1883. ‡Ellis, John. 17 Church-street, Southport.
1880. *ELLIS, JOHN HENRY. New Close, Cambridge-road, Southport.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
**Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.*
1884. §Ellis, W. Hodgson. Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.

Year of Election.

1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. §Elwes, George Robert. Bossington, Bournemouth.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1884. §Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1884. §England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Wayfield House, Stratford-on-Avon.
ENNISKILLEN, The Right Hon. WILLIAM WILLOUGHBY, Earl of, LL.D., D.C.L., F.R.S., F.G.S., M.R.I.A. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1883. §Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, F.R.S., F.R.C.S., Professor of Clinical Surgery in University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S. L. & E., F.G.S., Assistant Keeper (Geological and Palæontological Department) Natural History Museum (British Museum). 14 Carlyle-square, London, S.W.
1883. §Eunson, Henry J. 20 St. Giles-street, Northampton.
1881. ‡Evans, Alfred. Exeter College, Oxford.
1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempstead.
1865. *EVANS, Rev. CHARLES, M.A. The Rectory, Solihull, Birmingham.
1876. ‡EVANS, Captain Sir FREDERICK J. O., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S. 21 Dawson-place, Bayswater, London, W.
1884. §Evans, Horace L. Moreton House, Tyndall Park, Bristol.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, Surrey.
1861. *EVANS, JOHN, D.C.L., LL.D., Treas.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.
1883. §Evans, J. C. Nevill-street, Southport.
1883. §Evans, Mrs. J. C. Nevill-street, Southport.
1881. §Evans, Lewis. Picton Villa, Carmarthen.
1876. ‡Evans, Mortimer, M.Inst.C.E. 97 West Regent-street, Glasgow.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Heathfield, Alleyne Park, Lower Norwood, Surrey, S.E.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. The Spring, Kenilworth.
1871. §Eve, H. Weston, M.A. University College, London, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. Lennox-vale, Belfast.
1880. ‡Everingham, Edward. St. Helen's-road, Swansea.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.

Year of Election.

1883. §Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, William, M.P. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, B.Sc., F.R.S.E., Professor of Engineering in University College, Dundee.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1884. §Fairbairn, Dr. A. M. Airedale College, Bradford, Yorkshire.
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1876. ‡Fairlie, James M. Charing Cross Corner, Glasgow.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1878. *Fairlie, Robert F. Palace-chambers, Victoria-street, Westminster, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1883. §Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §Faraday, F. J., F.L.S., F.S.S. College Chambers, 17 Brazenose-street, Manchester.
1879. *Farnworth, Ernest. Swindon, near Dudley.
1883. §Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. §Farnworth, William. 86 Preston New-road, Blackburn.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1866. *Farrar, Ven. Frederick William, M.A., D.D., F.R.S., Archdeacon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Ebor Villa, Godwin-road, Clive-vale, Hastings.
1883. §Faulding, Mrs. Ebor Villa, Godwin-road, Clive-vale, Hastings.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *Fellows, Frank P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. §Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Sir Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.

Year of Election.

1883. §Fernald, H. P. Alma House, Cheltenham.
1863. **Fernie, John.* 113 *South 40th Street, Philadelphia, U.S.A.*
1862. ‡Ferrers, Rev. Norman MacLeod, D.D., F.R.S., Vice-Chancellor of the University of Cambridge. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 16 Upper Berkeley-street, London, W.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *Field, Rogers, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1882. §Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 10 Lyndhurst-road, Hampstead, London, N.W.
1883. ‡Finch, Mrs. Gerard. 10 Lyndhurst-road, Hampstead, London, N.W.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1878. *Findlater, William, M.P. 22 Fitzwilliam-square, Dublin.
1884. §Finlay, Samuel. Montreal, Canada.
1883. §Finney, John Douglass. 27 Porchester-terrace, London, W.
1883. §Finney, Mrs. J. D. 27 Porchester-terrace, London, W.
1883. §Finney, Miss. 27 Porchester-terrace, London, W.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *Fischer, William L. F., M.A., LL.D., F.R.S., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1858. ‡Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., M.A., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡Fitch, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. §Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis, M.A., F.R.S., Professor of Natural and Experimental Philosophy. Trinity College, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1881. ‡Fitzsimmons, Henry, M.D. Minster-yard, York.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
1881. ‡Fleming, Rev. Canon James, B.D. The Residence, York.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E. 5 Edge-lane, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1869. ‡Fletcher, Lavington E., M.Inst.C.E. Alderley Edge, Cheshire.

Year of Election.

Fletcher, T. B. E., M.D. *7 Waterloo-street, Birmingham.*
1862. ‡Flower, William Henry, LL.D., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Department, British Museum, South Kensington, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Cairo.
1881. ‡Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1879. ‡Foote, Harry D'Oyley, M.D. Rotherham, Yorkshire.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *Forbes, George, M.A., F.R.S.E. 34 Great George-street, London, S.W.
1883. §Forbes, Henry O., F.Z.S. Rubislaw Den, Aberdeen.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *Fordham, H. George, F.G.S. Odsey Grange, Royston, Cambridgeshire.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
1883. §Formby, R. Formby, near Liverpool.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *Forster, The Right Hon. William Edward, M.P., F.R.S. 80 Eccleston-square, London, S.W.; and Wharfeside, Burley-in-Wharfedale, Leeds.
1883. ‡Forsyth, A. R. University College, Liverpool.
1884. §Fort, George H. Lakefield, Ontario, Canada.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 3 Burr-street, London, E.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.G.S. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *Foster, George Carey, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
1881. ‡Foster, J. L. Ogleforth, York.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *Foster, Michael, M.A., M.D., Sec. R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Trinity College, and Great Shelford, near Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Glasgow.
1882. ‡Fowler, John, M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 50 Cornhill, London, E.C.
1884. §Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. 25 St. George's-road, Tufnell Park, London, N.
1883. §Fox, Charles Douglas, M.Inst.C.E. 5 Delahay-street, Westminster, S.W.
1860. *Fox, Rev. Edward, M.A. Upper Heyford, Banbury.

Year of
Election.

1883. §Fox, Howard, United States Consul. Falmouth.
1876. *Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1876. ‡Fox, St. G. Lane. 9 Sussex-place, London, S.W.
1881. *FOXWELL, HERBERT S., M.A., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
1884. §Francis, James B. Lowell, Massachusetts, U.S.A.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. The Yews, Reigate Hill, Surrey.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1882. §Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E. 37 Melville-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc., Professor of Chemistry in the Franklin Institute of Pennsylvania. 917 Clinton-street, Philadelphia, U.S.A.
1884. *Fream, W., B.Sc., Professor of Natural History in the College of Agriculture, Downton, Salisbury.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester.
1877. §Freeman, Francis Ford. 8 Leigham-terrace, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1880. ‡Freeman, Thomas. Brynhyfryd, Swansea.
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
1884. *Fremantle, Hon. C. W., C.B. Royal Mint, London, E.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summerhill, Dublin.
1883. ‡Froane, William. Beech House, Birkdale, Southport.
1869. ‡*Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.*
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. §Frost, Captain H., J.P. West Wratting, Cambridgeshire.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse Hill, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, GEORGE, M.Inst.C.E., Professor of Engineering in Queen's College, Belfast. 14 College-gardens, Belfast.
1884 §Fuller, William. Oswestry.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

Year of Election.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire
*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Aswardby Hall, Spilsby.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. §GALLOWAY, W. Cardiff.
1860. *GALTON, Captain DOUGLAS, C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. Capetown. (Care of Messrs. Ollivier and Brown, 37 Sackville-street, Piccadilly, London, W.)
1877. ‡Gamble, William. St. Helen's, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E., Professor of Physiology in Owens College, Manchester. Fairview, Prince's-road, Fallowfield, Manchester.
1883. ‡Gant, Major John Castle. St. Leonard's.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡Gardner, John Starkie, F.G.S. 7 Damer-terrace, Chelsea, London, S.W.
1884. §Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1862. ‡GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. ‡Garner, Mrs. Robert. Stoke-upon-Trent.
1882. ‡Garnett, William, M.A., Principal of the College of Physical Science, Newcastle-on-Tyne.
1873. ‡*Garnham, John.* 123 *Bunhill-row, London, E.C.*
1883. §Garson, J. G., M.D. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. §Geddes, John. 33 Portland-street, Southport.
1859. ‡Geddes, William D., M.A., Professor of Greek in King's College, Old Aberdeen.

Year of Election.

1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. ‡GEIKIE, ARCHIBALD, LL.D., F.R.S. L. & E., F.G.S., Director-General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡Geikie, James, LL.D., F.R.S. L. & E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 10 Bright's-crescent, Mayfield, Edinburgh.
1883. ‡Gell, Mrs. Seedley Lodge, Pendleton, Manchester.
1882. §Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1884. §*German, John.*
1884. *Gerrans, Henry T., B.A. Worcester College, Oxford.
1870. ‡Gerstl, R., F.C.S. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1884. §Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1884. §Gibbs, Professor Wolcott. Cambridge, Massachusetts, U.S.A.
1874. ‡Gibson, The Right Hon. Edward, Q.C., M.P. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., F.G.S. 1 Randolph Cliff, Edinburgh.
*Gibson, George Stacey. Saffron Walden, Essex.
1884. §Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1870. ‡*Gibson, Thomas. 51 Oxford-street, Liverpool.*
1870. ‡*Gibson, Thomas, jun. 10 Parkfield-road, Prince's Park, Liverpool.*
1884. §Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. §Gilbert, Mrs. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 245 St. Antoine-street, Montreal, Canada.
1883. ‡Gilbert, Thomas. Derby-road, Southport.
1859. *GILCHRIST, JAMES, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.I.C.E. Cosford, Godalming.
1878. ‡Giles, Oliver. Park Side, Cromwell-road, St. Andrew's, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *GILL, DAVID, LL.D., F.R.S. Royal Observatory, Cape Town.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1884. §Gillman, Henry. 79 East Columbia-street, Detroit, Michigan, U.S.A.
1861. *Gilroy, George. Woodlands, Parbold, near Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. ‡Gimingham, Charles H., F.C.S. 45 St. Augustine's-road, Camden-square, London, N.W.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. §Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1884. §Gisborne, Frederick Newton. Ottawa, Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.

Year of Election.

1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Brighton.
1883. *Gladstone, Miss Isabella M. 17 Pembridge-square, London, W.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. Trinity College, Cambridge.
1881. §Gleadow, Frederic. Brunswick House, Beverley-road, Hull.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
1874. ‡*Glover, Thomas. 77 Claverton-street, London, S.W.*
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
1883. §Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. Nore, Bramley, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. ‡*Goff, James. 11 Northumberland-road, Dublin.*
1881. ‡Goldschmidt, Edward. Nottingham.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1884. §Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1878. ‡Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1884. §Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville, M.A. Peterhouse, Cambridge.
1884. §Goodridge, Richard E. W. Hudson's Bay Co., Canada.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1884. §Goodwin, Professor W. L. Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. 6 Church-walk, Worthing, Sussex.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1875. *Gotch, Francis, B.A., B.Sc. Holywell Cottage, Oxford.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.

Year of Election.

1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, CYRIL, C.M.G., F.L.S., F.R.G.S. Travellers' Club, Pall Mall, London, S.W.
1875. ‡GRAHAME, JAMES. Auldhouse, Pollokshaws, near Glasgow.
1852. *GRAINGER, Rev. Canon JOHN, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1870. ‡GRANT, Colonel JAMES A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *GRANT, ROBERT, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., M.Inst.C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1881. ‡Graves, E. 22 Trebovir-road, Earl's Court-road, London, S.W.
1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1870. ‡*Gray, C. B. 5 Rumford-place, Liverpool.*
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1864. ‡*Gray, Jonathan. Summerhill House, Bath.*
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. ‡*Gray, J. Macfarlane. 127 Queen's-road, Peckham, London, S.E.*
1878. ‡*Gray, Matthew Hamilton. 14 St. John's Park, Blackheath, London, S.E.*
1878. ‡*Gray, Robert Kaye. 14 St. John's Park, Blackheath, London, S.E.*
1881. ‡Gray, Thomas. 21 Haybrom-crescent, Glasgow.
1883. ‡Gray, Thomas. Spittal Hill, Morpeth.
1873. ‡Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1883. §Greathead, J. H. 8 Victoria-chambers, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879. ‡Green, A. F. 15 Ashwood-villas, Headingley, Leeds.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. §GREENHILL, A. G., M.A., Professor of Mathematics at the Royal Artillery Institution, Woolwich. Emmanuel College, Cambridge.

Year of
Election.

1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. §Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. §Greenshields, E. B. Montreal, Canada.
1884. §Greenshields, Samuel. Montreal, Canada.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. ‡Greenwood, J. G., LL.D., Vice-Chancellor of Victoria University. Owens College, Manchester.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.M.G. 2 Delahay-street, Westminster, S.W.
1883. ‡Gregson, Edward. Ribble View, Preston.
1883. §Gregson, G. E. Ribble View, Preston.
1861. *Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1881. §Gregson, William. Baldersby, Thirsk.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
1875. ‡Grey, Mrs. Maria G. 18 Cadogan-place, London, S.W.
1871. *Grierson, Samuel, Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1875. ‡Grieve, David, F.R.S.E., F.G.S. 2 Victoria-terrace, Portobello, Edinburgh.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1859. *Griffith, George, M.A., F.C.S. Harrow.
1870. ‡Griffith, Rev. Henry, F.G.S. Barnet, Herts.
1884. §Griffiths, E. H. 12 Park-side, Cambridge.
1884. §Griffiths, Mrs. 12 Park-side, Cambridge.
Griffiths, Rev. John, M.A. Wadham College, Oxford.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.
1879. §Griffiths, Thomas, F.C.S., F.S.S. Heidelberg House, King's-road, Clapham Park, London, S.W.
1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1884. §Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Nottingham.
1864. ‡Groom-Napier, Charles Ottley. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 42 Ovington-square, London, S.W.
Grove, The Hon. Sir William Robert, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡Grubb, Howard, F.R.S., F.R.A.S. 141 Leinster-road, Rathmines, Dublin.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *Guise, Lieut.-Colonel Sir William Vernon, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.

Year of Election.

1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. ‡Gunn, William, F.G.S. 20 Cumberland-street, Edinburgh.
1866. ‡Günther, Albert C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, S.W.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1868. *Gurney, John. Sprouston Hall, Norwich.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡Guthrie, Frederick, B.A., F.R.S. L. & E., F.G.S., Professor of Physics in the Royal School of Mines. Science Schools, South Kensington, London, S.W.
1883. §Guthrie, Malcolm. 2 Parkfield-road, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F., M.A. Owens College, Manchester.

1884. §Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1884. §Hadden, Captain C. F., R.A. Woolwich.
1881. *Haddon, Alfred Cort, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1879. ‡Hake, H. Wilson, Ph.D., F.C.S. Queenwood College, Hants.
1869. ‡*Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.*
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡*Halhead, W. B. 7 Parkfield-road, Liverpool.*
1883. §Haliburton, Robert Grant. National Club, Whitehall, London, S.W.
Halifax, The Right Hon. Viscount, G.C.B., F.R.G.S. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡*Hall, Dr. Alfred. 30 Old Steine, Brighton.*
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. **Hall, Miss Emily. Bowdon, Cheshire.*
1881. §Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *Hall, Hugh Fergie, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡*Hall, John Frederic. Ellerker House, Richmond, Surrey.*
1872. *Hall, Captain Marshall. 7 St. Margaret's-terrace, Ilkley, near Leeds.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1884. §Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *Hall, Townshend M., F.G.S. Pilton, Barnstaple.
1860. ‡Hall, Walter. 11 Pier-road, Erith.
1883. *Hall, Miss Wilhelmina. The Gore, Eastbourne.
1873. *Hallett, T. G. P., M.A. Claverton Lodge, Bath.
1868. *Hallett, William Henry, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Bole Hall, Tamworth.

Year of Election.

1869. §Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. 110 Cannon-street, London, E.C.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 6 Sea Bank-avenue, Egremont, Cheshire.
1875. ‡*Hancock, C. F., M.A. 36 Blandford-square, London, N.W.*
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡*Hands, M. Coventry.*
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. C. 1591 Catherine-street, Montreal, Canada.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡*Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.*
*HARCOURT, A. G. VERNON, M.A., LL.D., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1884. *Hardcastle, Norman C., M.A., LL.M. Downing College, Cambridge.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
1880. §Hardy, John. 118 Embden-street, Manchester.
*HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. §Hargreaves, Miss H. M. Oakhurst, West Haughton, near Bolton.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.
1878. *Harkness, H. W. Sacramento, California.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. Stanbridge, Staplefield, Crawley, Sussex.
1883. ‡Harland, Miss S. 25 Acomb-street, Greenheys, Manchester.
1883. *Harley, Miss Clara. College-place, Huddersfield.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. College-place, Huddersfield.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. College-place, Huddersfield.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. §Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill College, Montreal. Wallbrac-place, Montreal, Canada.

Year of Election.

1872. *Harris, Alfred. Lunefield, Kirkby-Lonsdale, Westmoreland.
1883. §Harris, Charles, F.R.G.S. Derwent Villa, Whalley Range, Manchester.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1842. *Harris, G. W., M.Inst.C.E. Mount Gambier, South Australia.
1884. §Harris, Miss Katherine E. 75 Linden-gardens, Bayswater, London, W.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1860. ‡*Harrison, Rev. Francis, M.A. Oriel College, Oxford.*
1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. ‡Harrison, George, Ph.D., F.L.S., F.C.S. 96 Northgate, Huddersfield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. 22 Connaught-street, Hyde Park, London, W.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1883. ‡Harrison, Thomas. 34 Ash-street, Southport.
1854. ‡Harrowby, The Right Hon. the Earl of. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1876. *Hart, Thomas. Brooklands, Blackburn.
1881. §Hart, Thomas, F.G.S. Yewbarrow, Grange-over-Sands, Carnforth.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡HARTLEY, WALTER NOEL, F.R.S. L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1854. §HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1884. §Haslam, George E., B.A. Trinity College, Toronto, Canada.
1882. §Haslam, George James, M.D. Owens College, Manchester.
1875. ‡HASTINGS, G. W., M.P. Barnard's Green House, Malvern.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §HAWKSLEY, THOMAS, M.Inst.C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. ‡Hay, Arthur J. Lerwick, Shetland.

Year of
Election.

1861. *HAY, Rear-Admiral the Right Hon. Sir JOHN C. D., Bart., C.B., M.P., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. The Park, Harrow.
1879. *Hazlehurst, George S. The Elms, Runcorn.
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. ‡Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 2 Lulworth-road, Birkdale, Southport.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1883. ‡Heape, Charles. 14 Hawkshead-street, Southport.
1883. ‡Heape, Joseph R. 96 Mereland-terrace, Rochdale.
1882. *Heape, Walter. New Museums, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1865. ‡Hearder, William. Rocombe, Torquay.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1884. §Heath, Thomas. Royal Observatory, Calton Hill, Edinburgh.
1861. §HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 12 Alexandra-villas, Brighton; and Arthur's Club, St. James's, London, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1884. §Heaviside, Rev. George, F.R.G.S. The Hollies, Stoke Green, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡HECTOR, JAMES, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡*Henderson, Andrew.* 120 *Gloucester-place, Portman-square, London, W.*
1873. *Henderson, A. L. 49 King William-street, London, E.C.
1883. §Henderson, Mrs. A. L. 49 King William-street, London, E.C.
1880. *Henderson, Commander W. H., R.N. H.M.S. *Nelson*, Australia.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. Brookvale, Donnybrook, Co. Dublin.
1857. ‡Hennessy, Sir John Pope, K.C.M.G., Governor and Commander-in-Chief of Mauritius.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Meldorf Cottage, Kemplay-road, Hampstead, London, N.W.
Henry, Franklin. Portland-street, Manchester.

Year of Election.

1873. Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
1874. ‡*Henry, Rev. P. Shuldam, D.D., M.R.I.A. Belfast.*
*HENRY, WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1884. §Henshaw, George H. 43 Victoria-street, Montreal, Canada.
1870. ‡Henty, William. 12 Medina-villas, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Baldwyns, Bexley, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, W.
1856. ‡*Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.*
1882. §Herbert, The Hon. Auberon. Ashley, Arnewood Farm, Lymington.
1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.
1871. *HERSCHEL, Professor ALEXANDER S., M.A., F.R.S., F.R.A.S. College of Science, Newcastle-on-Tyne.
1883. §Herschel, Miss F. Collingwood, Hawkhurst, Kent.
1874. §HERSCHEL, Lieut.-Colonel JOHN, R.E., F.R.S., F.R.A.S. Collingwood, Hawkhurst, Kent.
1883. ‡Hesketh, Colonel E. Fleetwood. Meol's Hall, Southport.
1865. ‡Heslop, Dr. Birmingham.
1884. §Hewett, George Edwin. The Leasowe, Cheltenham.
1883. §Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.
1882. §Heycock, Charles T., B.A. King's College, Cambridge.
1883. §Heyes, John Frederick, M.A., F.C.S. 5 Rufford-road, Fairfield, Liverpool.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861. *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1881. §Hick, Thomas, B.A., B.Sc. 2 George's-terrace, Harrogate.
1875. ‡HICKS, HENRY, M.D., F.G.S. Hendon Grove, Hendon, Middlesex, N.W.
1877. §HICKS, W. M., M.A. Endcliff-crescent, Sheffield.
1884. §Hickson, Joseph. Montreal, Canada.
1864. *HIERN, W. P., M.A. Castle House, Barnstaple.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
1870. ‡Higginson, Alfred. 135 Tulse Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1880. ‡Hill, Benjamin. Cwmdwr, near Clydach, Swansea.
1883. §Hill, Berkeley, M.B., Professor of Clinical Medicine in University College, London. 55 Wimpole-street, London, W.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
1881. §HILL, Rev. EDWIN, M.A., F.G.S. St. John's College, Cambridge.

Year of Election.

1884. §Hill, Rev. James Edgar, M.A., B.D. 1516 St. Catherine-street, Montreal, Canada.
1857. §Hill, John, C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1872. *Hill, Rev. Canon, M.A., F.G.S. Sheering Rectory, Harlow.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 225 Oxford-street, London, W.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J., Ph.D., F.G.S. 11 Glebe-villas, Mitcham, Surrey.
1883. *Hindle, James Henry. 67 Avenue-parade, Accrington.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. †Hinds, William, M.D. Parade, Birmingham.
1881. §Hingston, J. T. Clifton, York.
1884. §Hingston, William Hales, M.D., D.C.L. 37 Union Avenue, Montreal, Canada.
1884. §Hirschfilder, C. A. Toronto, Canada.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S., F.R.A.S. 7 Oxford and Cambridge Mansions, Marylebone-road, London, N.W.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
1884. §Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. The Dockyard, Chatham.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1879. §Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1879. §Hobson, John. Tapton Elms, Sheffield.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. §Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1880. §Hodgkinson, W. R. Eaton, Ph.D. Science Schools, South Kensington Museum, London, S.W.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1884. §Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1865. *Hofmann, August Wilhelm, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. §Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.

Year of Election

1879. ‡Holland, Calvert Bernard. Ashdell, Broomhill, Sheffield.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring-grove, Isleworth, Middlesex.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1876. ‡*Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.*
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. 39 Lorrimore-square, London, S.E.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1884. *Hopkins, Edward M. 3 Upper Berkeley-street, Portman-square, London, W.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *Hopkinson, Charles. 29 Princess-street, Manchester.
1882. *Hopkinson, Edward, D.Sc. Grove House, Oxford-road, Manchester.
1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. 3 Holland Villas-road, Kensington, London, W.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S. 95 New Bond-street, London, W.; and Wansford House, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.
1884. *Horsfall, Richard. Post Office-buildings, George-street, Halifax.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1884. *Hotblach, G. S. Prince of Wales-road, Norwich.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
HOUGHTON, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. Travellers' Club, London, S.W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
1884. §Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. 60 Belsize Park, London, N.W.
1883. §Howard, James Fielden, M.D., M.R.C.S. Randycroft, Shaw.
1882. ‡Howard, William Frederick, Assoc. Memb. Inst. C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1883. ‡Howarth, Richard. York-road, Birkdale, Southport.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1884. §Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. §Howland, Oliver Aiken. Toronto, Canada.

Year of
Election.

1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, H. H. Derby House, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1883. ‡Hoyle, James. Blackburn.
1883. ‡Hoyle, William. Claremont, Bury, Lancashire.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *HUDSON, HENRY, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1879. ‡Hudson, Robert S., M.D. Redruth, Cornwall.
1883. ‡Hudson, Rev. W. C. 58 Belmont-street, Southport.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 14 Geraldine-road, Wandsworth, London, S.W.
1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡Hulke, John Whitaker, F.R.C.S., F.R.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1884. *Humphreys, A. W. 42 Pine-street, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1884. §HUNT, T. STERRY, M.A., D.Sc., LL.D., F.R.S. 105 Union-avenue, Montreal, Canada.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1881. ‡Hunter, F. W. 4 Westmoreland-road, Newcastle-on-Tyne.
1881. ‡Hunter, Rev. John. 38 The Mount, York.
1884. *Hunter, Michael, jun. Greystones, Sheffield.
1869. *Hunter, Rev. Robert, LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. §HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.

Year of Election.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. §Hurst, Walter, B.Sc. 94 Lloyd-street, Greenheys, Manchester.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. May Bank, Bournemouth.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡Hutton, Henry D. 17 Palmerston-road, Dublin.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡Huxley, Thomas Henry, Ph.D., LL.D., Pres.R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1879. ‡Ibbotson, H. J. 26 Collegiate-crescent, Sheffield.
Ihne, William, Ph.D. Heidelberg.
1873. ‡Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, The Ven. Archdeacon, M.A. The Close, Lichfield.
1884. §Iles, George. Windsor Hotel, Montreal, Canada.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1876. ‡Inglis, Anthony. Broomhill, Partick, Glasgow.
1871. ‡Inglis, The Right Hon. John, D.C.L., LL.D., Lord Justice-General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1883. ‡Ingram, Rev. D. C. Church-street, Southport.
1852. ‡Ingram, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1882. ‡Irving, Rev. A., B.A., B.Sc., F.G.S. Wellington College, Wokingham, Berks.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.

1865. ‡*Jabet, George. Wellington-road, Handsworth, Birmingham.*
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. §Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. §Jackson, A. H. New Bridge-street, Strangeways, Manchester.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. ‡Jackson, Mrs. Esther. 16 East Park-terrace, Southampton.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. Brooklands, Alderley Edge, Manchester.
1883. ‡Jackson, Mrs. F. J. Brooklands, Alderley Edge, Manchester.
1874. **Jackson, Frederick Arthur. Cheadle, Cheshire.*
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.

Year of Election.

1869. §Jackson, Moses. The Vale, Ramsgate.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, Surrey.
1874. *Jaffe, John. Edenvale, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney-hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1863. *James, Sir Walter, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1884. §James, W. Culver, M.D. 11 Marloes-road, London, W.
1858. ‡James, William C. Woodside, Plymouth.
1884. §Jameson, W. C. 48 Baker-street, Portman-square, London, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1862. ‡*Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, London, W.*
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1856. §Jeffery, Henry M., M.A., F.R.S. 9 Dunstanville-terrace, Falmouth.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.
1883. ‡Jeffreys, Miss Gwyn. 1 The Terrace, Kensington, London, W.
1852. ‡Jellett, Rev. John H., D.D., M.R.I.A., Provost of Trinity College, Dublin.
1881. §Jellicoe, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1862. §Jenkin, H. C. Fleeming, F.R.S., M.Inst.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1873. §Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.
1880. *Jenkins, Sir John Jones, M.P. The Grange, Swansea.
Jennette, Matthew. 102a Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. 13 Victoria-street, London, S.W.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
*Jerram, Rev. S. John, M.A. 2 Kent-avenue, Castle Hill, Ealing, Middlesex, W.
1872. ‡*Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.*
Jessop, William, jun. Butterley Hall, Derbyshire.
1884. §Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1884. §Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill College, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. §Johnson, Miss Alice. Llandaff House, Cambridge.
1883. §Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 52 Fitzjohn's-avenue, South Hampstead, London, N.W.

Year of Election.

1881. ‡Johnson, Captain Edmond Cecil. Junior United Service Club, Charles-street, London, S.W.
1883. §Johnson, Edmund Litler. 73 Albert-road, Southport.
Johnson, Edward. 22 Talbot-street, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1866. ‡*Johnson, John G.* 18A *Basinghall-street, London, E.C.*
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. ‡Johnson, Richard C., F.R.A.S. 19 Catherine-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Samuel George. Municipal Offices, Nottingham.
1883. §Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
1884. §Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. §Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. §Johnston, Walter R. Fort Qu'Appele, N.W. Territory, Canada.
1884. *Johnston, W. H. 11 Chapel-street, Preston.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.
1881. ‡Jones, Alfred Orlando, M.D. Belton House, Harrogate.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1883. §Jones, George Oliver, M.A. 11 Cambridge-road, Waterloo, Liverpool.
1884. §Jones, Rev. Harry, M.A. Bartonmere, Bury St. Edmunds; and Savile Club, Piccadilly, London, W.
1877. ‡Jones, Henry C., F.C.S. Normal School of Science, South Kensington, S.W.
1883. ‡Jones, Rev. Canon Herbert. Waterloo, Liverpool.
1881. §Jones, J. Viriamu, M.A., B.Sc., Principal of the University College of South Wales and Monmouthshire. Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1875. *Jose, J. E. 3 Queen-square, Bristol.
1884. §Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1875. *Joule, Benjamin St. John B., J.P. 12 Wardle-road, Sale, near Manchester.
1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.
1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1879. †Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.

Year of Election.

1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.

1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.

Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.

1883. §Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.

1848. *Jubb, Abraham. Halifax.

1870. ‡JUDD, JOHN WESLEY, F.R.S., Sec. G.S., Professor of Geology in the Royal School of Mines. Hurstleigh, Kew.

1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 47 Finsbury-circus, London, E.C.

KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S. Fortland, Killiney, Co. Dublin.

1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.

1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.

Kay, John Cunliff. Fairfield Hall, near Skipton.

1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.

1872. ‡*Keames, William M. 5 Lower Rock-gardens, Brighton.*

1883. ‡Kearne, John H. Westcliffe-road, Birkdale, Southport.

1884. §Keefer, Samuel. Brockville, Ontario, Canada

1884. §Keefer, Thomas Alexander. Port Arthur, Ontario, Canada.

1875. ‡Keeling, George William. Tuthill, Lydney.

1881. ‡Keeping, Walter, M.A., F.G.S. The Museum, York.

1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.

1884. §Kellogg, J. H. Battle Creek, Michigan, U.S.A.

1876. ‡Kelly, Andrew G. The Manse, Alloa, N.B.

1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.

1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.

1884. §Kemper, Andrew C. 101 Broadway, Cincinnati, U.S.A.

1875. ‡KENNEDY, ALEXANDER B. W., M.Inst.C.E., Professor of Engineering in University College, London.

1884. §Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.

1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.

1884. §Kennedy, John. 113 University-street, Montreal, Canada.

1884. §Kennedy, William. Hamilton, Ontario, Canada.

Kent, J. C. Levant Lodge, Earl's Croome, Worcester.

1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1855. *Ker, Robert. Dougalston, Milngavie, N.B.

1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.

1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.

1884. §Kerr, James, M.D. Winnipeg, Canada.

1883. §Kerr, Dr. John. Garscadden House, near Kilpatrick, Glasgow.

1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.

1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.

1861. *Keymer, John. Parker-street, Manchester.

1883. *Keynes, J. N., M.A., B.Sc., F.S.S. Harvey-road, Cambridge.

1876. ‡Kidston, J. B. West Regent-street, Glasgow.

1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.

1865. *Kinahan, Edward Hudson, M.R.I.A. 11 Merrion-square North Dublin.

Year of Election.

1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1884. §Kinahan, Gerrard, A. 24 Waterloo-road, Dublin.
1875. *KINCH, EDWARD, F.C.S. Agricultural College, Cirencester.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1883. *King, Francis. Rose Bank, Penrith.
1871. *King, Rev. Herbert Poole. Royal Thames Yacht Club, 7 Albemarle-street, London, W.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Welford House, Greenhill, Hampstead, London, N.W.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. Welford House, Greenhill, Hampstead, London, N.W.
1864. §KING, KELBURNE, M.D. 6 Albion-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1883. ‡Kingston, Mrs. Sarah B. Boscastle House, Grove-road, Highgate-road, London, N.W.
1876. §Kingston, Thomas. Boscastle House, Grove-road, Highgate-road, London, N.W.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. Trevena, Amhurst Park, London, N.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *KINNAIRD, The Right Hon. Lord. 2 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 7 Melville-terrace, Stirling, N.B.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1883. ‡Kirsop, Mrs. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1881. ‡Kitching, Langley. 50 Caledonian-road, Leeds.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. ‡*Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.*
1883. §Knight, J. R. 32 Lincoln's Inn-fields, London, W.C.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1870. ‡Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.

Year of Election.

1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 29 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P. Staveley Rectory, Leeds.
1883. §Knubley, Mrs. Staveley Rectory, Leeds.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.
1882. ‡Kyshe, John B. 19 Royal-avenue, Sloane-square, London, S.W.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. ‡Ladd, William, F.R.A.S. Trewinian, Burnt Ash Hill, Lee, Kent.
1884. §Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1882. ‡Lake, G. A. K., M.D. East Park-terrace, Southampton.
1880. ‡Lake, Samuel. Milford Docks, Milford Haven.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1883. §Lamb, W. J. 15 Weld-road, Birkdale, Southport.
1883. §LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, Kent, S.E.
1884. §Lamborn, Robert H. Montreal, Canada.
1884. §Lancaster, Alfred. Manchester-road, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 8 The Circus, Greenwich, London, S.E.
1883. §Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1864. ‡*Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.*
1882. ‡Langstaff, Dr. Bassett, Southampton.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 11 Wellington Mansions, North Bank, London, N.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Eyre Cottage, The Grove, Blackheath, London, S.E.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1884. §Lanza, Professor G. Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1881. ‡Larmor, Joseph, M.A., Professor of Natural Philosophy in Queen's College, Galway.
1883. §Lascelles, B. P. Dynevor Castle, Llandilo, South Wales.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡LAUGHTON, JOHN KNOX, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Greenwich, S.E.
1883. §Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Sydney Villa, 36 Outram-road, Addiscombe, Croydon.

Year of Election.

1878. ‡Law, Henry, C.E. 5 Queen Anne's-gate, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. Hollingsworth, Walsden, near Todmorden.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. §Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S. Botanic Gardens, Oxford.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1883. *Leach, Charles Catterall. Bedlington Collieries, Bedlington.
1883. §Leach, John. Haverhill House, Bolton.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. §Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1844. *Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 604 Main-street, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. §Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1883. §Lee, Daniel W. Halton Bank, Pendleton, near Manchester.
1861. ‡Lee, Henry, M.P. Sedgeley Park, Manchester.
1883. ‡Lee, J. H. Warburton. Rossall, Fleetwood.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1884. *Leech, Bosdin T. Oak Mount, Temperley, Cheshire.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. §Lees, William, M.A. St. Leonard's, Morningside-place, Edinburgh.
1883. *Leese, Miss H. K. Hazeldene, Fallowfield, Manchester.
*Leese, Joseph. Hazeldene, Fallowfield, Manchester.
1883. ‡Leese, Mrs. Hazeldene, Fallowfield, Manchester.
1881. §LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, M.P., F.R.G.S. 18 Bryanston-square, London, W.
*LEFROY, Lieut.-General Sir JOHN HENRY, K.C.M.G., C.B., R.A., LL.D., F.R.S., F.R.G.S. 82 Queen's-gate, London, S.W.
*Legh, Lieutenant-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1880. ‡Leighton, William Henry, F.G.S. 2 Merton-place, Chiswick.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.

Year of
Election.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E. 11 The Avenue, Southampton.
1863. *LENDY, Major AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1861. ‡*Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.*
Lentaigne, Sir John, C.B., M.D. Tallaght House, Co. Dublin; and 1 Great Denmark-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. ‡LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. St. David's, Malahide-road, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1884. §Lesage, Louis. City Hall, Montreal, Canada.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 35 Colebrooke-row, Islington, London, N.
1884. *Lewis, W. T. The Mardy, Aberdare.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, D.D., F.R.S., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
1883. ‡*Lincoln, Frank. 111 Marylebone-road, London, N.W.*
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, C.E., F.G.S. 10 Kidbrooke-terrace, Blackheath, London, S.E.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1870. ‡Lindsay, Thomas, F.C.S. Maryfield College, Maryhill, by Glasgow.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
1883. §Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, B.A. Hawridge Rectory, Berkhampstead.
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1881. §Littlewood, Rev. B. C., M.A. Holmdale, Cheltenham.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N. S.W. (Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.)
1864. §Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.

Year of Election.

1880. ‡Llewelyn, John T. D. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
Lloyd, George, M.D., F.G.S. Acock's-green, near Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. **Lloyd, Sampson Samuel. Moor Hall, Sutton Coldfield.*
1865. *Lloyd, Wilson, F.R.G.S. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.; and New Athenæum Club, S.W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. Science Schools, South Kensington, London, S.W.
1875. *LODGE, OLIVER J., D.Sc., Professor of Physics in University College, Liverpool. 26 Waverley-road, Sefton Park, Liverpool.
1883. ‡Lofthouse, John. West Bank, Rochdale.
1883. ‡London, Rev. H. High Lee, Knutsford.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. §Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.
1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S., F.S.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Butterknowle, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. §Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1883. *Louis, D. A., F.C.S. Harpenden.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 2 Queensland-terrace, Oval-road, Croydon.
1883. §Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse. 17 Firs Hill-road, Pitsmoor, Sheffield.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton, near Chepstow.
1884. §Lowe, F. J. Elm-court, Temple, London, E.C.
1870. ‡*Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.*
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.

Year of Election.

1853. *LUBBOCK, Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. 34 Queen Anne's-gate, London, S.W.; and High Elms, Hayes, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1884. §*Lumsden, Miss L. J.*
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Teviot Bank, Newport Road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Instructor in Coal Mining in Yorkshire College. 4 Albion-place, Leeds.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *LUPTON, SYDNEY, M.A. The Harehills, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Leonard, F.G.S. 92 Onslow-gardens, London, S.W.
1884. §Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. §Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1884. §Lyman, Roswell C. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. ‡Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.
1862. *LYTE, F. MAXWELL, F.C.S. Cotford, Oakhill-road, Putney, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Strathmore House, Harvey-road, Cambridge.
1878. §MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, M.P., F.R.G.S. Raleigh Hall, Brixton Rise, London, S.W.
1884. §Macarthur, Alexander, Winnipeg, Canada.
1884. §Macarthur, D. Winnipeg, Canada.
1840. MACAULAY, JAMES, A.M., M.D. 25 Carlton-road, Maida Vale, London, N.W.
1871. *MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1884. §McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1866. ‡M'CALLAN, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. The Lawn, Lower Norwood, Surrey, S.E.

Year of Election.

1884. *McCarthy, J. J., M.D. Junior Army and Navy Club, London, S.W.
1884. §McCausland, Orr. Belfast.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'Clintock, Admiral Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H., F.R.G.S. 5 Park-row, Albert-gate, London, S.W.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1859. *M'Connell, David C., F.G.S. Care of Mr. H. K. Lewis, 136 Gower-street, London, W.C.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1883. ‡McCrossan, James. 29 Albert-road, Southport.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1884. §Macdonald, The Right Hon. Sir John Alexander, G.C.B., D.C.L., LL.D. Ottawa, Canada.
1884. §MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1871. ‡*M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)*
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Maplewell, Loughborough.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1878. ‡McDonnell, Robert, M.D., F.R.S., M.R.I.A. 89 Merrion-square West, Dublin.
1884. §Macdougall, Alan. Toronto, Canada.
1884. §McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1878. *M'Ewan, John. 4 Douglas-terrace, Stirling, N.B.
1881. ‡Macfarlane, A., D.Sc., F.R.S.E. The University, Edinburgh.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1879. ‡Macfarlane, Walter, jun. 22 Park-circus, Glasgow.
1884. §Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.
1884. §MacGillivray, James. 42 Cathcurt-street, Montreal, Canada.
1884. §MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1884. *McGregor, James Gordon. Dalhousie College, Halifax, Nova Scotia, Canada.
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1874. ‡MacIlwaine, Rev. Canon, D.D., M.R.I.A. Ulsterville, Belfast.
1884. §McIntyre, John, M.D. Odiham, Hants.
1859. ‡*Macintosh, John. Middlefield House, Woodside, Aberdeen.*
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S. L. & E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1871. ‡*Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.*

Year of Election.

1884. §Mackay, Alexander Howard. The Academy, Picton, Nova Scotia, Canada.
1873. ‡McKendrick, John G., M.D., F.R.S. L. & E., Professor of the Institutes of Medicine in the University of Glasgow. The University, Glasgow.
1883. §McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1884. §McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.
1884. §McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. §Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, London, W.
1884. §McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 32 Glover-street, Birkenhead.
1884. §Mackintosh, James B. New York, U.S.A.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. ‡MacLaren, Duncan. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.
1884. §McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. §McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. §McLennan, John. Lancaster, Ontario, Canada.
1868. §M'Leod, Herbert, F.R.S., F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William, F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Colonel C. A. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1883. ‡MacMahon, Captain P. A., R.A., Instructor in Mathematics at the Royal Military Academy, Woolwich.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1884. *Macmillan, A., M.D. Hull.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. §McMurrick, Playfair. Ontario Agricultural College, Guelph, Ontario, Canada.
1871. ‡M'Nab, William Ramsay, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1883. §Macpherson, J. 44 Frederick-street, Edinburgh.

Year of Election.

*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1883. ‡McWhirter, William. 24 Bute-terrace, Strathbungo, Glasgow.
1883. §Madden, W. H. Marlborough College, Wilts.
1883. §Maggs, Thomas Charles, F.G.S. Yeovil.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.
1883. §Maitland, P. C. 233 East India-road, London, E.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡*Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.*
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1884. *Mann, F. S. W. Linton Park, Maidstone.
1866. §Mann, Robert James, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1866. ‡*Manning, John. Waverley-street, Nottingham.*
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1881. *Marr, John Edward, B.A., F.G.S. St. John's College, Cambridge.
1871. ‡Marreco, A. Friere-. College of Physical Science, Newcastle-on-Tyne.
1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1883. *Marsh, Henry. Cressy House, Woodsley-road, Leeds.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1882. *Marshall, A. Milnes, M.A., M.D., D.Sc., Professor of Zoology in Owens College, Manchester.
1881. ‡Marshall, D. H. Greenhill Cottage, Rothesay.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1881. §Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P., M.Inst.C.E. 15 Augustus-road, Birmingham.
1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.
1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡Martin, Professor H. Newell. John Hopkins University, Baltimore, U.S.A.
1871. ‡*Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.*

Year of Election.

1883. *Martin, John Biddulph, F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 29 Mosley-street, Newcastle-on-Tyne.
1836. Martin, Studley. Liverpool.
Martindale, Nicholas. Queen's Park, Chester.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1883. §Marwick, James. Killermont, Maryhill, Glasgow.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., M.P., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. 39 Cornwall-gardens, London, W.
1861. *Mason, Hugh, M.P. Groby Hall, Ashton-under-Lyne.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. §Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. ‡Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. 4 Moray-place, Edinburgh.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1863. ‡Mease, George D. Lydney, Gloucestershire.
1884. §Mecham, Arthur. 11 Newton-terrace, Glasgow.
1883. §Medd, John Charles, M.A. 99 Park-street, Grosvenor-square, London, W.
1881. ‡Meek, Sir James. Middlethorpe, York.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 16 Notting Hill-square, London, W.
1881. *MELDOLA, RAPHAEL, F.R.A.S., F.C.S., F.I.C. 21 John-street, Bedford-row, London, W.C.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.

Year of Election.

1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡Mello, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1883. §Mello, Mrs. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1881. ‡Melrose, James. Clifton, York.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count, LL.D. 14 Rue de l'Elysée, Paris.
1862. ‡Mennell, Henry J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. ‡Merivale, John Herman, Professor of Mining in the College of Science, Newcastle-on-Tyne.
1879. ‡Merivale, Walter. Engineers' Office, North-Eastern Railway, Newcastle-on-Tyne.
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1884. §Merritt, William Hamilton. 34 George-street, Toronto, Canada.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡Miall, Louis C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1883. §Middleton, Henry. St. John's College, Cambridge.
1881. §Middleton, R. Morton, F.L.S., F.Z.S. Hudworth Cottage, Castle Eden, Co. Durham.
1876. *Middleton, Robert T., M.P. 197 West George-street, Glasgow.
1881. §Miles, Morris. Barron Villa, Hill, Southampton.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Hightield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1882. §Miller, A. J. High-street, Southampton.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1884. §Miller, Mrs. Hugh. 51 Lauriston-place, Edinburgh.
1861. *Miller, Robert. Cranage Hall, Holmes Chapel, Cheshire.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1884. *Miller, Robert Kalley, M.A., Professor of Mathematics in the Royal Naval College, Greenwich, London, S.E.
1884. §Miller, T. F., B.Ap.Sc. Nápanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. 60 John-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
1880. ‡Mills, Mansfeldt H. Tapton-grove, Chesterfield.
Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.
1882. *Milne, John, F.G.S., Professor of Geology in the Imperial College of Engineering, Tokio, Japan. Runnymede, Bexhill-on-Sea, Sussex.

Year of Election.

1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1882. §Milnes, Alfred, M.A., F.S.S. 30 Almeric-road, London, S.W.
1880. §Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. §Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870. ‡Mitchell, John. Clough Bank, Clitheroe, Lancashire.
1868. ‡Mitchell, John, jun. Pole Park House, Dundee.
1862. **Mitchell, W. Stephen, M.A., LL.B. Caius College, Cambridge.*
1879. ‡MIVART, ST. GEORGE, M.D., F.R.S., F.L.S., F.Z.S., Professor of Biology in University College, Kensington. 71 Seymour-street, London, W.
1884. §Moat, Robert. Montreal.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1861. ‡MOLESWORTH, Rev. W. NASSAU, M.A. Spotland, Rochdale.
1883. ‡Mollison, W. L. Clare College, Cambridge.
1878. §Molloy, Constantine. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. §Monaghan, Patrick. Halifax (Box 379), Nova Scotia, Canada.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1882. *Montagu, Samuel. 12 Kensington Palace-gardens, London, S.W.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. §Moore, George Frederick. 36 Newsham-drive, Liverpool.
1881. §Moore, Henry. 4 Sheffield-terrace, Kensington, London, W.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1877. ‡Moore, W. F. The Friary, Plymouth.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1881. ‡*Morgan, Alfred. 3 Aughton-road, Birkdale, Lancashire.*
1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1882. §Morgan, Thomas. Cross House, Southampton.
1878. ‡MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.
1867. ‡Morison, William R. Dundee.
1883. §Morley, Henry Forster, M.A., B.Sc., F.C.S. University Hall, Gordon-square, London, W.C.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1881. ‡Morrell, W. W. York City and County Bank, York.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.

Year of Election.

1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. §Morris, C. S. Millbrook Iron Works, Landore, South Wales.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1883. §Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. ‡Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1881. ‡Morris, John, M.A., F.G.S., Emeritus Professor of Geology in University College, London. 4 Vinery-villas, Park-road, London, N.W.
1880. ‡Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1879. ‡*Morrison, Dr. R. Milner.* 20 *Pentland-terrace, Edinburgh.*
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 122 London-road, Liverpool.
1858. *Morton, Henry Joseph. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1868. ‡Moseley, H. N., M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 14 St. Giles's, Oxford.
1883. §Moseley, Mrs. 14 St. Giles's, Oxford.
1857. ‡*Moses, Marcus.* 4 *Westmoreland-street, Dublin.*
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1878. *Moss, John Francis, F.R.G.S. Ranmoor, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, Richard Jackson, F.C.S., M.R.I.A. 66 Kenilworth-square, Rathgar, Dublin.
1873. *Mosse, George Staley. 13 Scarsdale-villas, Kensington, London, W.
1874. *Mosse, J. R. Conservative Club, London, S.W.
1873. ‡Mossman, William. Woodhall, Calverley, Leeds.
1869. §Mott, Albert J., F.G.S. Crickley Hill, Gloucester.
1865. ‡Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. Birstall Hill, Leicester.
1862. *Mouat, Frederick John, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., F.R.S. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1882. ‡Mount-Temple, The Right Hon. Lord. Broadlands, Romsey, Hants.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.

Year of Election.

1884. §Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. §Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. F.R.S.E. Caius College, Cambridge.
1876. §Muir, Thomas. High School, Glasgow.
1884. *Muir, William Ker. Detroit, Michigan, U.S.A.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 3 Elm-court, Temple, London, E.C.
1871. *MUIRHEAD, HENRY, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. *Muirhead, Robert Franklin, B.Sc. Meikle Cloak, Lochwinnoch, Renfrewshire.
1884. §Muirhead-Paterson, Miss Mary. Laurieville, Carshill, Glasgow.
1883. §MULHALL, MICHAEL G. 19 Albion-street, Hyde-park, London, W.
1883. §Mulhall, Mrs. Marion. 19 Albion-street, Hyde-park, London, W.
1884. *Müller, Hugo, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. §Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. The Park, Nottingham.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1883. *Munro, Robert. Braehead House, Kilmarnock, N.B.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡MURCH, JEROM. Cranwells, Bath.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1876. ‡*Murdoch, James. Altony Albany, Girvan, N.B.*
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1884. §Murphy, Patrick. Newry, Ireland.
1869. ‡Murray, Adam. Westbourne Sussex-gardens, Hyde-park, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, M.Inst.C.E. Downlands, Sutton, Surrey.
1884. §Murray, John. *Challenger* Expedition Office, Edinburgh.
1884. §Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill College, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 7 Whitehall-place, London, S.W.

1842. Nadin, Joseph. Manchester.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡*Napier, John. Saughfield House, Hillhead, Glasgow.*

Year of Election.

1876. *Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1872. ‡Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1883. *Neild, Theodore. Dalton Hall, Manchester.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
Neilson, Robert, J.P., D.L. Halewood, Liverpool.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡Nelson, D. M. 48 Gordon-street, Glasgow.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡NEVILLE, PARKE, M.Inst.C.E., M.R.I.A. 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1879. ‡Newbould, John. Sharrow Bank, Sheffield.
1866. *Newdigate, Albert L. 25 Craven-street, Charing Cross, London, W.C.
1876. ‡*Newhaus, Albert. 1 Prince's-terrace, Glasgow.*
1883. ‡Newman, Albert Robert. 33 Lisson-grove, Marylebone-road, London, N.W.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1883. ‡Newton, A. W. 7A Westcliffe-road, Birkdale, Southport.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡*Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.*
1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Ashleigh, Ventnor, Isle of Wight.
1871. §Nicholson, E. Chambers. Herne Hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1884. §Nicholson, Joseph S., M.A., Professor of Political Economy in the University of Edinburgh. 15 Jordan-lane, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1881. §Nicholson, William R. Clifton, York.
1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. Aberdeen.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1884. §Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *NOBLE, Captain ANDREW, C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.

Year of Election.

1880. ‡Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. §Norfolk, F. Montrose Villa, Cromwell-road, Southampton.
1859. ‡Norfolk, Richard. Ladygate, Beverley.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A., D.C.L., F.L.S. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. ‡North, William, B.A., F.C.S. 28 Regent's Park-road, London, N.W.
1869. ‡Northcote, The Right Hon. Sir Stafford H., Bart., G.C.B., M.P., F.R.S. Pynes, Exeter.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
Norton, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1878. ‡Nugent, Edward. Seel's-buildings, Liverpool.
1883. ‡Nunnerley, John. 46 Alexandra-road, Southport.
1883. ‡Nutt, Alfred. Rosendale Hall, West Dulwich, London, S.E.
1883. §Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.
1883. §Nutt, Miss Mabel. Rosendale Hall, West Dulwich, London, S.E.

1882. ‡Obach, Eugene, Ph.D. 17 Charlton-villas, Old Charlton, Kent.
1878. ‡O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Carroll, Joseph F. 78 Rathgar-road, Dublin.
1878. ‡O'Conor Don, The, M.P. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
Odgers, Rev. William James. Savile House, Fitzjohn's-avenue, Hampstead, London, N.W.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. §Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. §Ogden, Joseph. 21 Station-road, South Norwood, London, S.E.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1874. ‡Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
*Ogilvie-Forbes, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldovan House, Dundee.
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.

Year of Election.

1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.
1884. §O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, 15 Strand, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1853. §OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1863. ‡Oliver, Daniel, F.R.S., F.L.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1883. §Oliver, J. A. Westwood. Braehead House, Lochwinnoch, Scotland.
1883. §Oliver, Samuel A. Springfield, Wigan, Lancashire.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 3 St. Andrew's-terrace, Grimsby.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1880. *Ommanney, Rev. E. A. 123 Vassal-road, Brixton, London, S.W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. §Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. §Ord, Miss Sarah. Fern Lea, Park-crescent, Southport.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Woodway, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1883. §Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Captain R. T., R.E. 58 Stephen's-green, Dublin.
1884. *Orpen, Rev. T. H., M.A. Plas Dinas, Newnham, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E.
1884. §Osler, William, M.D., Professor of the Institutes of Medicine in McGill College, Montreal, Canada.
1884. §O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. New Place House, Southampton.
1881. *Ottewell, Alfred D. 83 Siddals-road, Derby.
1854. ‡Outram, Thomas. Greetland, near Halifax.
1882. ‡*Owen, Rev. C. M., M.A. Woolston Vicarage, Southampton.*
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡*Owen, James H. Park House, Sandymount, Co. Dublin.*
OWEN, Sir RICHARD, K.C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. Sheen Lodge, Mortlake, Surrey, S.W.
1884. §*Owen, Richard, M.D.*
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1884. §Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.

Year of Election.

1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. Lyons Mills, Straffan Station, Dublin.
1866. §Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Notts.
1872. **Palmer, W. R. Hawthorne, Rivercourt-road, Hammersmith, W.*
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1883. §Pant, F. J. van der. Clifton Lodge, Kingston-on-Thames.
1884. §Panton, Dr. J. Hoyes. Winnipeg, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. Barrow-in-Furness, Lancashire.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.
1865. **Parker, Walter Mantel. High-street, Alton, Hants.*
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling, F.L.S. 6 St. Mary's-row, Birmingham.
1864. ‡Parkes, William. 23 Abingdon-street, Westminster, S.W.
1879. §Parkin, William, F.S.S. The Mount, Sheffield.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1883. §Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. ‡Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.
1883. ‡Part, C. T. 5 King's Bench-walk, Temple, London, E.C.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1884. *Paton, David. Johnstone, Scotland.
1883. §Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 992 Sherbrooke-street, Montreal, Canada.
1883. ‡Paton, Rev. William. Mossfield House, New Ferry, Chester.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. §Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1879. *Patzer, F. R. Stoke-on-Trent.

Year of Election.

1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1883. §Paul, G., F.G.S. Moortown, Leeds.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-on-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Western Bank, Sheffield.
1847. ‡PEACH, CHARLES W., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *PEARCE, HORACE, F.L.S., F.G.S. The Limes, Stourbridge.
1882. §Pearce, Walter, B.Sc., F.C.S. Craufurd, Ray Mead, Maidenhead.
1884. §Pearce, William. Winnipeg, Canada.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
Pearsall, Thomas John. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1881. ‡Pearse, Richard Seward. Southampton.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1883. §Pearson, Miss Helen, E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. §Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Fern Lodge, Lenton-road, The Park, Nottingham.
1881. ‡Pearson, Richard. 23 Bootham, York.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1883. *Pearson, Thomas H. Golborne Park, near Newton-le-Willows, Lancashire.
1863. ‡Pease, H. F. Brinkburn, Darlington.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1884. §Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, C. E. Conservative Club, London, S.W.
1878. **Peek, William.* 54 *Woodstock-road, Bedford Park, Chiswick, London, W.*
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1884. §Pegler, Alfred. Maybush Lodge, Old Shirley, Southampton.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. †*Pendergast, Thomas. Lancefield, Cheltenham.*

Year of
Election.

1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Percival, Rev. John, M.A., LL.D., President of Trinity College, Oxford.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., Pres. C.S. The Chestnuts, Sudbury, Harrow.
1884. §Perkin, William Henry, jun., Ph.D. The Chestnuts, Sudbury, Harrow, Middlesex.
1877. ‡Perkins, Loftus. Seaford-street, Regent-square, London, W.C.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. ‡Perry, James. Roscommon.
1874. *PERRY, JOHN, Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 10 Penywern-road, South Kensington, London, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.R.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1883. §Petrie, Miss Anne S. Stone Hill, Rochdale.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonard's-on-Sea.
1882. ‡Pfoundes, Charles, F.R.G.S. Spring Gardens, London, S.W.
1867. ‡PHAYRE, Lieut.-General Sir ARTHUR, K.C.S.I., C.B. Athenæum Club, Pall Mall, London, S.W.
1884. §Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. §Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
Philips, Robert N., M.P. The Park, Manchester.
1877. §Philips, T. Wishart. 53 Tredegar-square, Bow, London, E.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1883. §Phillips, Arthur G. 20 Canning-street, Liverpool.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1872. ‡PHILLIPS, J. ARTHUR, F.R.S., F.G.S., F.C.S., M.Inst.C.E. 18 Fopstone-road, Earl's Court-road, London, S.W.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1883. ‡Phillips, Mrs. Leah R. 1 East Park-terrace, Southampton.
1883. ‡Phillips, S. Rees. Wanford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Oak Bank, Lancaster.

Year of
Election.

1864. ‡Pickering, William. Oak View, Clevedon.
1884. §Pickett, Thomas E., M.D. Mayville, Kentucky, U.S.A.
1870. ‡Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1884. §Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., LL.D., Q.C. 45 Upper Mount-street, Dublin.
1883. §Pilling, R. C. The Robin's Nest, Blackburn.
1863. *PIM, Captain BEDFORD C. T., R.N., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1884. §Pinart, A. G. N. L. 74 Market-street, San Francisco, U.S.A.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1884. §Pirz, Anthony. Long Island, New York, U.S.A.
1866. ‡*Pitcairn, David. Dudhope House, Dundee.*
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. §Pitt, George Newton, M.A., M.D. Sutton, Surrey.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. §Pitt, Sydney. Sutton, Surrey.
1868. ‡PITT-RIVERS, Major-General A. H. L., F.R.S., F.G.S., F.R.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1842. PLAYFAIR, The Right Hon. Sir LYON, K.C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. (PRESIDENT ELECT.) 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Kensington House, Southport.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D., President of Queen's College, Belfast.
1866. §Porter, Robert. Montpelier Cottage, Beeston, Nottingham.
1883. §Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.

Year of Election.

1883. ‡Potter, M. C., B.A. St. Peter's College, Cambridge.
Potter, Richard, M.A. 10 Brookside, Cambridge.
1883. §Potts, John. 33 Chester-road, Macclesfield.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1883. §Powell, John. Wannarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡Poynting, J. H. Brentwood, Hagley-road, Edgbaston, Birmingham.
1884. §Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., M.A., B.C.L., Law Lecturer in the University of Oxford. Trinity College, Oxford.
1869. *PREECE, WILLIAM HENRY, F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1881. §Preston, Rev. Thomas Arthur, M.A. The Green, Marlborough.
*PRESTWICH, JOSEPH, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 35 St. Giles's, Oxford; and Shoreham, near Sevenoaks.
1884. *Prevost, Major. 11 Rosslyn-terrace, Kelvinside, Glasgow.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford, 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
1882. ‡Price, John E., F.S.A. 60 Albion-road, Stoke Newington, London, N.
Price, J. T. Neath Abbey, Glamorganshire.
1881. §Price, Peter. Crockherbtown, Cardiff.
1875. *Price, Rees. 1 Montague-place, Glasgow.
1870. *Price, Major W. E., F.G.S. Hillfield, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. §Prince, Thomas. Horsham-road, Dorking.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1863. **Prosser, Thomas. 25 Harrison-place, Newcastle-on-Tyne.*
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1884. *Proudfoot, Alexander. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. 4 Cambridge-villas, Richmond Park-road, Kingston-on-Thames.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.

Year of Election.

1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. §Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. §PYE-SMITH, P. H., M.D. 54 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §Pye-Smith, R. J. 6 Surrey-street, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, Lord. 70 Portland-place, London, W.
1878. ‡Rae, John, M.D., LL.D., F.R.S., F.R.G.S. 2 Addison-gardens, South Kensington, London, W.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1845. ‡RAMSAY, Sir ANDREW CROMBIE, LL.D., F.R.S., F.G.S. 15 Cromwell-crescent, South Kensington, London, S.W.
1884. §Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. §Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.
1883. §Ramsay, Mrs. 10 Osborne-road, Clifton, Bristol.
1884. §RAMSAY, R. A. 1134 Sherbrooke-street, Montreal, Canada.
1867. *Ramsay, W. F., M.D. 39 Hammersmith-road, West Kensington, London, W.
1876. ‡RAMSAY, WILLIAM, Ph.D., Professor of Chemistry in University College, Bristol.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry. St. Andrew's-street, Cambridge.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.

Year of Election.

1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1858. *Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. 26 Lancaster-gate, Hyde Park, London, S.W.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 29 Lambert-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhall, Liverpool.
1866. *Rawlinson, Rev. Canon George, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1883. §Ray, Miss Catherine. Mount Cottage, Flask-walk, Hampstead, London, N.W.
1868. *Rayleigh, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (President.) Terling Place, Witham, Essex.
1883. ‡Rayne, Charles A., M.B., B.Sc., M.R.C.S. 3 Queen-street, Lancaster.
1865. ‡Read, William. Albion House, Epworth, Rawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas Mellard, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., F.R.S.E. 9 Moray-place, Edinburgh.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 5 Crowhurst-road, Brixton, London, S.W.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡*Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.*
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡Reed, Sir Edward J., K.C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1878. §Reichel, The Very Rev. Dean, D.D. St. Patrick's, Trim, Ireland.
1881. §Reid, Arthur S., B.A., F.G.S. 12 Bridge-street, Canterbury.
1883. *Reid, Clement, F.G.S. 28 Jermyn-street, London, S.W.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. §Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1881. ‡Reid, William. 19½ Blake-street, York.

Year of
Election.

1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §RENALS, E. 'Nottingham Express' Office, Nottingham.
1863. ‡*Rendel, G. Benwell, Newcastle-on-Tyne.*
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1884. §Retallack, Captain Francis. 6 Beauchamp-avenue, Leamington.
1883. *Reynolds, A. H. 12 Leicester-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., F.R.S., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1884. §Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1884. *Richardson, George Straker. Heathfield House, Swansea.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1870. ‡Richardson, Ralph, F.R.S.E. 19 Castle-street, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1881. ‡Richardson, W. B. Elm Bank, York.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1863. ‡*Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow.*
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helen's, Lancashire.
1883. *Rideal, Samuel. Mayow-road, Forest-hill, Kent, S.E.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1884. §Ridout, Thomas. Ottawa, Canada.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 71 Warrington-crescent, London, W.
1883. ‡Rigg, Edward, M.A. Royal Mint, London, E.
1883. ‡Rigg, F. F., M.A. 32 Queen's-road, Southport.
1883. ‡Rigge, Samuel Taylor. Halifax.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.

Year of Election.

1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, F.G.S. Kennessee, Maghull, Lancashire.
1881. §Roberts, R. D., M.A., D.Sc., F.G.S. Clare College, Cambridge.
1883. §ROBERTS, RALPH A. 23 Clyde-road, Dublin.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. ‡Roberts, William, M.D. 89 Moseley-street, Manchester.
1868. ‡ROBERTS, W. CHANDLER, F.R.S., F.G.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal School of Mines. Royal Mint, London, E.
1883. §Robertson, Alexander. Montreal, Canada.
1884. *Robertson, Andrew. Elmbank, Dorchester-street, Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. §Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1883. §Robertson, George H. The Nook, Gateacre, near Liverpool.
1883. §Robertson, Mrs. George H. The Nook, Gateacre, near Liverpool.
1870. *Robertson, John. 4 Albert-road, Southport.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1866. ‡*Robertson, William Tindal, M.D. Nottingham.*
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
**Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.*
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1861. ‡ROBINSON, JOHN, M.Inst.C.E. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1881. §Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
1884. §Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1882. §Robinson, W. Braham. Rosenheim, The Avenue, Southampton.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1855. ‡Robson, Neil. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1872. ‡RODWELL, GEORGE F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1860. ‡ROGERS, JAMES E. THOROLD, M.P., Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 16 Strand, Exmouth, Devon.
1883. §Rogers, Major R. Alma House, Cheltenham.

Year of Election.

1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1883. ‡Rogers, Thomas Stanley, LL.B. 77 Albert-road, Southport.
1884. *Rogers, Walter M. Lamowa, Falmouth.
1876. §ROLLIT, A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1866. ‡*Rolph, G. F.*
1876. ‡Romanes, George John, M.A., LL.D., F.R.S., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. ‡Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Southfield, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1883. *Rose, J. Holland, M.A. Ventnor College, Ventnor, Isle of Wight.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1880. §Ross, Captain G. E. A., F.R.G.S. Forfar House, Cromwell-road, London, S.W.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. ‡Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.
1880. ‡Ross, Colonel William Alexander. Acton House, Acton, London, W.
1869. *ROSSE, The Right Hon. the Earl of, B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 147 John-street. Toronto, Canada.
1861. ‡Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1881. ‡Routh, Rev. William, M.A. Clifton Green, York.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1877. §ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salthill, Galway.
1881. *Rowntree, Joseph. 24 St. Mary's, York.
1881. *ROWNTREE, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡Roy, Charles S., M.D., F.R.S. Brown Institution, Wandsworth-road, London, S.W.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875. ‡RÜCKER, A. W., M.A., F.R.S., Professor of Mathematics and Physics in the Yorkshire College, Leeds.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.

Year of Election.

1884. §Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.
1873. ‡*Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.*
1847. ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Brantwood, Coniston, Ambleside.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1884. §Russell, George. Hoe Park House, Plymouth.
1883. *Russell, J. W. Merton College, Oxford.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
Russell, John. 39 Mountjoy-square, Dublin.
1876. §Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1862. §RUSSELL, W. H. L., B.A., F.R.S. 5 Ridgmount-terrace, Highgate, London, N.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Professor of Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1883. *Ruston, Joseph, M.P. Monk's Manor, Lincoln.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1881. ‡Rutson, Albert. Newby Wiske, Thirsk.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Rear-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1874. ‡Rye, E. C., F.Z.S., Librarian R.G.S. Royal Geographical Society, 1 Savile-row, London, W.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. *Sabine, Robert. 3 Great Winchester-street-buildings, London, E.C.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1880. ‡*Sakurai, J. 96 Camden-street, London, N.W.*
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1883. ‡Salmond, Robert G. The Nook, Kingswood-road, Upper-Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1883. §Salt, Shirley H., M.A. 73 Queensborough-terrace, London, W.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Garry Cottage, Perth.
1876. ‡Sandeman, David. Woodlands, Lenzie, Glasgow.
1883. ‡Sandeman, E. 53 Newton-street, Greenock.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. §Sanders, Charles J. B. Pennsylvania, Exeter.
1884. §Sanders, Henry. 185 James-street, Montreal, Canada.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.

Year of Election.

1883. §Sanderson, Surgeon Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. ‡SANDERSON, J. S. BURDON, M.D., LL.D., F.R.S., Professor of Physiology in the University of Oxford. 50 Banbury-road, Oxford.
1883. §Sanderson, Mrs. Burdon. 50 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1881. §SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. §Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1884. §Saunders, William. London, Ontario, Canada.
1884. §Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1871. §Savage, W. D. Ellerslie House, Brighton.
1883. §Savage, W. W. 109 St. James's-street, Brighton.
1883. §Savery, G. M., M.A. Cotlake House, Taunton.
1872. *Sawyer, George David, F.R.M.S. 55 Buckingham-place, Brighton.
1868. ‡*Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.*
1884. §Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1883. ‡Scarisbrick, Charles. 5 Palace-gate, Kensington, London, W.
1884. §*Scarth, William Bain.*
1868. §Schacht, G. F. 1 Windsor-terrace, Clifton, Bristol.
1879. *SCHÄFER, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. Boreham Wood, Elstree, Herts.
1883. §Schäfer, Mrs. Boreham Wood, Elstree, Herts.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
1876. ‡Schuman, Sigismond. 7 Royal Bank-place, Glasgow.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Applied Mathematics in Owens College, Manchester.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, London, W.
1883. *Sclater, William Lutley. Keble College, Oxford.
1882. *SCLATER-BOOTH, The Right Hon. G., M.P., F.R.S. 74 St. George's-square, London, S.W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., B.Sc. Trinity College, Cambridge.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. ‡Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angus. Girton College, Cambridge.
1876. ‡Scott, Mr. Bailie. Glasgow.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.R.M.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.

Year of Election.

1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1884. *Scott, Sydney C. 39 King-street, Cheapside, London, E.C.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1881. *Scrivener, A. P. Weston Turvill, Tring.
1883. §Scrivener, Mrs. Weston Turvill, Tring.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡Sedgwick, Adam, M.A. Trinity College, Cambridge.
1880. ‡Seebohm, Henry, F.L.S., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. The Vine, Sevenoaks.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. 80 Sackville-street, Barnsley.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1883. §Seville, Miss M. A. Blythe House, Southport.
1875. §Seville, Thomas. Blythe House, Southport.
1873. ‡*Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds.*
1868. ‡Sewell, Philip E. Catton, Norwich.
1883. §Shadwell, John Lancelot. 21 Nottingham-place, London, W.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡SHARP, DAVID, M.B. Bleckley, Shirley Warren, Southampton.
Sharp, Rev. John, B.A. Horbury, Wakefield.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1881. *SHAW, H. S. HELE, Professor of Engineering in University College, Bristol.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1883. *Shaw, W. N., M.A. Emmanuel College, Cambridge.
1884. §*Sheafer, Peter W.*
1883. ‡Sheard, J. 42 Hoghton-street, Southport.
1883. §Shearer, Miss A. M. Bushy Hill, Cambuslang, Lanark.
1883. ‡*Shield, Robert. Wing House, near Oldham.*
1884. §Sheldon, Professor J. P. Downton College, near Salisbury.
1878. ‡Shelford, W., C.E. 35A Great George-street, Westminster, S.W.
1881. ‡Shenstone, W. A. Clifton College, Bristol.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1883. ‡Shepherd, James. Birkdale, Southport.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.

Year of Election.

Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1883. §Sherlock, David. Lower Leeson-street, Dublin.
1883. §Sherlock, Mrs. David. Lower Leeson-street, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1880. ‡*Shida, R. 1 St. James's-place, Hillhead, Glasgow.*
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. 4 Varden's-road, Clapham Junction, Surrey, S.W.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, JAMES N., M.Inst.C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. ‡Shore, Thomas W., F.C.S., F.G.S. Hartley Institution, Southampton.
1882. ‡Shore, T. W., jun., B.Sc. Uplands, Woolston, Southampton.
1881. ‡Shuter, James L. 9 Steele's-road, Haverstock Hill, London, N.W.
1883. §Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Erlesdene, Bowdon, Cheshire.
1861. *Sidebotham, Joseph. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Erlesdene, Bowdon, Cheshire.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. ‡*Simkiss, T. M. Wolverhampton.*
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1847. ‡Simon, John, C.B., D.C.L., F.R.S., F.R.C.S., Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. §Simpson, Byron R. 7 York-road, Birkdale, Southport.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1884. *Simpson, W. J. R., M.D. Town House, Aberdeen.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Mahendra Lal, M.D. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.

Year of Election.

1883. §Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. Orsett House, Ewell, Surrey.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1873. ‡*Slater, W. B. 42 Clifton Park-avenue, Belfast.*
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1884. §Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.R.M.S. Clifton, Bristol.
1884. §Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. ‡Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1867. ‡Small, David. Gray House, Dundee.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡*Smith, George. Glasgow.*
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1871. *Smith, John Alexander, M.D., F.R.S.E., F.S.A.Scot. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
1874. ‡Smith, John Haigh. 77 Southbank-road, Southport.
Smith, John Peter George. Netherall, Largs, Ayrshire.
1871. ‡Smith, J. William Robertson, M.A., Lord Almoner's Professor of Arabic in the University of Cambridge.
1883. ‡Smith, M. Holroyd. Fern Hill, Halifax.
*Smith, Philip, B.A. The Bays, Parkfields, Putney, S.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1840. *Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1884. §Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.

Year of Election.

1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡Smithells, Arthur, B.Sc. Owens College, Manchester.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *Smyth, Charles Piazzi, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1883. §Smyth, Rev. Christopher. Woodford Rectory, Thrapston.
1874. ‡Smyth, Henry. Downpatrick, Ireland.
1870. ‡*Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.*
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *Smyth, John, jun., M.A., F.R.M.S. Milltown, Banbridge, Ireland.
1864. ‡Smyth, Warington W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1883. ‡Snape, Joseph. 13 Scarisbrick-street, Southport.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1879. *Sollas, W. J., M.A., D.Sc., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
*Solly, Edward, F.R.S., F.S.A. Camden House, Sutton, Surrey.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *Sorby, H. Clifton, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1883. §Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1879. ‡*Spence, David. Brookfield House, Freyinghall, Yorkshire.*
1869. *Spence, J. Berger. Erlington House, Manchester.
1881. ‡Spencer, Herbert E. Lord Mayor's Walk, York.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1884. *Spice, Robert Paulson, M.Inst.C.E. 21 Parliament-street, Westminster, S.W.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond, M.A., F.R.S.E. 29 Buckingham-terrace, Edinburgh.

Year of Election.

1883. §Spratling, W. J., B.Sc., F.G.S. Maythorpe, 72 Wickham-road, Brockley, S.E.
1853. ‡Spratt, Joseph James. West Parade, Hull.
1884. *Spruce, Samuel. Beech House, Tamworth.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 9 Osman-road, Hammersmith, London, W.
1879. ‡Stacye, Rev. John. Shrewsbury Hospital, Sheffield.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1884. §Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1883. *Stanford, Edward, jun., F.R.G.S. 17 Spring-gardens, London, S.W.
1865. ‡STANFORD, EDWARD C. C. Glenwood, Dalmuir, N.B.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. §Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1881. §Stead, W. H. Hexham House, Southport, Lancashire.
1881. ‡Stead, Mrs. W. H. Hexham House, Southport, Lancashire.
1870. ‡*Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.*
1884. §Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. †Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
1884. §Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. §Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, HENRY, J.P. Endcliffe Vale, Sheffield.
1881. ‡Stephenson, J. F. 3 Mount-parade, York.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. 13 Elm-place, Bath.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1880. *Stevens, J. Edward. 6 Carlton-terrace, Swansea.
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1878. ‡Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1882. ‡Steward, Rev. C. E., M.A. The Polygon, Southampton.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1875. *Stewart, James, B.A., M.R.C.P.Ed. Dunmurry, Sneyd Park, Clifton, Gloucestershire.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡Stirling, William, M.D., D.Sc., F.R.S.E., Professor of Physiology in the University of Aberdeen.
1867. *Stirrup, Mark, F.G.S. Richmond Hill, Bowdon, Cheshire.

Year of Election.

1865. *Stock, Joseph S. St. Mildred's, Walmer.
1883. *Stocker, W. R. Cooper's Hill, Staines.
1864. ‡Stoddart, William Walter, F.G.S., F.C.S. Grafton Lodge, Sneyd Park, Bristol.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *Stokes, George Gabriel, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1862. ‡Stone, Edward James, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1874. ‡Stone, J. Harris, B.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1883. §Stone, Thomas William. 17 Davisville-road, Shepherd's Bush, London, W.
1859. ‡Stone, Dr. William H. 14 Dean's-yard, Westminster, S.W.
1857. ‡Stoney, Bindon B., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1878. *Stoney, G. Gerald. 9 Palmerston Park, Dublin.
1861. *Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 9 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. §Stopes, Mrs. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. ‡Stopes, Miss Lucy. 84 East Hill, Colchester.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Fern Bank, Stalybridge.
1859. §Story, Captain James Hamilton. 17 Bryanston-square, London, W.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *Strachey, Lieut.-General Richard, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1882. ‡Strange, Rev. Cresswell, M.A. Holy Trinity Vicarage, Southampton.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
Strickland, William. French Park, Roscommon, Ireland.
1884. §Stringham, Irving. The University, Berkeley, California, U.S.A.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Whitgift House, Croydon.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. High School, Newcastle, Staffordshire.
1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.
1884. §Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Queen's College, Cork.

Year of Election.

1883. §Summers, Alfred. Sunnyside, Ashton-under-Lyne.
1883. ‡Summers, William, M.P. Sunnyside, Ashton-under-Lyne.
1884. §Sumner, George. 107 Stanley-street, Montreal, Canada.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1884. §Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1881. ‡Sutton, William. Town Hall, Southport.
1881. ‡Swales, William. Ashville, Holgate-road, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph W. Mosley-street, Newcastle-on-Tyne.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
1879. §Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1858. ‡SYDNEY, The Right Rev. ALFRED BARRY, D.D., D.C.L., Bishop of Sydney.
1883. §Sykes, Alfred. Highfield, Huddersfield.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡*Sykes, H. P.* 47 *Albion-street, Hyde Park, London, W.*
1862. ‡Sykes, Thomas. Cleckheaton.
1847. ‡*Sykes, Captain W. H. F.* 47 *Albion-street, Hyde Park, London, W.*
SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford.
1870. ‡SYMES, RICHARD GLASCOTT, B.A., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1881. *Symington, Thomas. 13 Dundas-street, Edinburgh.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.R.S., Sec.R.M.S. 62 Camden-square, London, N.W.
1883. ‡Symons, Simon. Belfast House, Farquhar-road, Norwood, S.E.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. 7 Great Charles-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡TAIT, P. M., F.R.G.S., F.S.S. Oriental Club, Hanover-square, London, W.

Year of Election.

1874. §Talmage, C. G., F.R.A.S. Leyton Observatory, Essex, E.
1883. §Tapscott, R. L. 41 Parkfield-road, Prince's Park, Liverpool.
1866. ‡Tarbotton, Marrott Ogle, M.Inst.C.E., F.G.S. Newstead-grove, Nottingham.
1878. ‡Tarpey, Hugh. Dublin.
1861. *Tarratt, Henry W. 9 Magdala-villas, Margate.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1863. ‡*Tate, John. Alnmouth, near Alnwick, Northumberland.*
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1876. ‡Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1879. ‡Tattershall, William Edward. 15 North Church-street, Sheffield.
1878. *Taylor, A. Claude. Clinton-terrace, Derby-road, Nottingham.
1874. ‡*Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.*
1867. ‡Taylor, Rev. Andrew. Dundee.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1881. *Taylor, H. A. 9 Courtfield-gardens, South Kensington, London, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡Taylor, John Ellor, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. §Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A., Chaplain of Lower Assam, Gauhatti, Assam. (Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.)
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1883. ‡*Taylor, William. Park-road, Southport.*
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1884. §Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1880. ‡Tebb, Miss. 7 Albert-road, Regent's Park, London, N.W.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. *Temperley, Ernest., M.A. Queen's College, Cambridge.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.
1880. §Temple, Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1882. §Terrill, William. 3 Hanover-street, Swansea.
1881. ‡Terry, Mr. Alderman. Mount-villas, York.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.

Year of
Election.

1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., M.A., B.Sc., F.R.S., F.L.S. 11 Brunswick-villas, Kew Gardens-road, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1879. *Thomas, Arthur. Endcliffe House, Sheffield.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
1883. ‡Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.
1884. §THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
1883. §Thomas, Miss Fanny. 115 Scotswood-road, Newcastle-on-Tyne.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redlands, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. *Thomas, Joseph William, F.C.S. The Laboratory, West Wharf, Cardiff.
1883. ‡Thomas, P. Bossley. 4 Bold-street, Southport.
1881. ‡Thomas, Sydney G. 27 Tedworth-square, London, S.W.
1883. §Thomas, T. H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1882. §Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1883. *Thompson, Francis. 1 Avenue-villas, St. Peter's-road, Croydon.
1859. ‡Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1883. *Thompson, Isaac Cooke. Woodstock, Waverley-road, Liverpool.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in University College, Bristol.
1884. §Thompson, Sydney de Courcy. 16 Canonbury-park South, London, N.
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., D.Sc., F.R.S. L. & E. 2 Florentine-gardens, Hillhead-street, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1874. ‡*Thomson, John. Harbour Office, Belfast.*

Year of Election.

1883. ‡Thomson, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S. King's College, London, W.C.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helen's.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lyppiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. Stake-lane, Holmfirth.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871. ‡THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in Yorkshire College, Leeds.
1883. §Threlfall, Henry Singleton. 5 Prince's-street, Southport.
1883. ‡Thresh, John C., D.Sc. The Willows, Buxton.
1868. ‡THUILLIER, Lieut.-General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. 32 Cambridge-terrace, Hyde Park, London, W.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1884. §Tidy, Charles Meymott, M.D. 3 Mandeville-place, Cavendish-square, London, W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham. 36 Frederick-road, Birmingham.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. §Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. §Tillyard, Mrs. Fordfield, Cambridge.
Tinker, Ebenezer. Mealhill, near Huddersfield.
1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡*Tomes, Robert Fisher. Welford, Stratford-on-Avon.*
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. 7 Regent-street, Nottingham.
1884. §Torrance, John F. Folly Lake, Nova Scotia, Canada.
1884. *Torrance, Rev. Robert. Guelph, Ontario, Canada.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.

Year of Election.

1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1883. ‡Townsend, Francis Edward. 19 Aughton-road, Birkdale, Southport.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *Trail, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1883. §Traill, Dr. Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1883. §Traill, Mrs. Portrush, Ireland.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡Traquair, Ramsay H., M.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1865. ‡*Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.*
1884. §Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. §Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1871. ‡Tribe, Alfred, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡Trimen, Henry, M.B., F.L.S. British Museum, London, S.W.
1871. ‡Trimen, Rowland, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §Tristram, Rev. Henry Baker, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 7 Furnival's Inn, London, W.C.
1882. *Trotter, Rev. Coutts, M.A. Trinity College, Cambridge.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1881. ‡*Tully, G. T. 10 West Cliff-terrace, Preston.*
1883. §Tupper, Sir Charles, K.C.M.G., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1854. ‡Turnbull, James, M.D. 86 Rodney-street, Liverpool.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
1871. ‡Turnbull, William, F.R.S.E. Menslaws, Jedburgh, N.B.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
1882. §Turner, G. S. 9 Carlton-crescent, Southampton.
1883. ‡Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.
1875. ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *Turner, William, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1883. §Turrell, Miss S. S. High School, Redland-grove, Bristol.
1884. *Tutin, Thomas. 247 Sherwood-street, Nottingham.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1884. *Tweddell, Ralph Hart. Provender, Faversham, Kent.

Year of Election.

1847. ‡Twiss, Sir Travers, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. ‡Tylor, Edward Burnett, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.
1858. *Tyndall, John, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1883. §Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1883. §Unwin, John. Park-crescent, Southport.
1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.
1876. *Unwin, W. C., M.Inst.C.E., Professor of Hydraulic Engineering. 7 Palace-gate Mansions, Kensington, London, W.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1884. §Van Horne, W.C. Dorchester-street West, Montreal, Canada.
1883. *VanSittart, Mrs. R. F. A. 11 Lypiatt-terrace, Cheltenham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 2 Hamilton-road, Highbury Park, London, N.
1870. ‡Varley, Mrs. S. A. 2 Hamilton-road, Highbury Park, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. §Vasey, Charles. 112 Cambridge-gardens, London, W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1846. ‡Vaux, W. S. W., M.A., F.R.S. 22 Albemarle-street, London, W.
1881. §Veley, V. H., B.A., F.C.S. University College, Oxford.
1873. *Verney, Captain Edmund H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
1883. *Verney, Mrs. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. Sudbury Hall, Derbyshire.
1883. ‡Vernon, H. H., M.D. York-road, Birkdale, Southport.
1879. ‡Veth, D. D. Leiden, Holland.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1883. ‡Vines, Sydney Howard, M.A., D.Sc. Christ's College, Cambridge.
1856. ‡Vivian, Edward, M.A. Woodfield, Torquay.
*Vivian, Sir H. Hussey, Bart., M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1884. §Von Linden, François Hermann. Amsterdam, Holland.
1869. ‡Vose, Dr. James. Gambier-terrace, Liverpool.

Year of
Election.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1884. §Wait, Charles E. Rolla, Missouri, U.S.A.
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. §WAKE, CHARLES STANILAND. 2 Westbourne-avenue, Hull.
1884. §Waldstein, Charles, M.A., Ph.D., Director of the Fitzwilliam Museum, Cambridge. Cambridge.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869. *WALFORD, CORNELIUS. 86 Belsize Park-gardens, London, N.W.
1882. *Walkden, Samuel. (Care of Messrs. Guillaume & Sons, 9 Salisbury-square, Fleet-street, London, E.C.)
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1855. ‡*Walker, John. 1 Exchange-court, Glasgow.*
1866. *WALKER, JOHN FRANCIS, M.A., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1881. ‡Walker, John Sydenham. 83 Bootham, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. §Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.
1883. ‡Walker, Thomas A. 4 Saunders-street, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 14 Bootham-terrace, York.
1883. §Walker, Mrs. 14 Bootham-terrace, York.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, F.L.S., F.R.G.S. Nutwood Cottage, Frith Hill, Godalming.
1883. §Wallace, George J. Hawthornbank, Dunfermline.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.L.S., F.R.G.S., 3 Christchurch-road, Roupell Park, London, S.W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. §Wallis, Herbert. Redpath-street, Montreal, Canada.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
1881. §Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1884. §Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall, M.A. Christ's College, Cambridge.
1874. ‡Ward, John, F.S.A., F.G.S., F.R.G.S. Lenoxvale, Belfast.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1884. *Ward, John William. Newstead, Halifax.
1880. *Ward, J. Wesney. 41 Head-street, Colchester.
1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.

Year of Election.

*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1884. §Wardwell, George J. Rutland, Vermont, U.S.A.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1878. §WARINGTON, ROBERT, F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. W., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1883. *Warren, Dr. Samuel. Abberley Villa, Hoylake.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
1875. *Waterhouse, Major J. 1 Wood-street, Calcutta. (Care of Messrs. Trübner & Co., Ludgate-hill, London, E.C.)
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. ‡Waters, Arthur W., F.G.S., F.L.S. Woodbrook, Alderley Edge, near Manchester.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1884. §Watson, A. G., D.C.L. The School, Harrow, Middlesex.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1855. ‡Watson, Ebenezer. 1 Woodside-terrace, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
1882. §WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
1884. §Watson, John. Queen's University, Kingston, Ontario, Canada.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Analytical Laboratory, The Folds, Bolton-le-Moors.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1884. §Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1846. ‡Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. ‡Watts, W. W., B.A., F.G.S. Broseley, Shropshire.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
1859. *WAVENEY, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.

Year of Election.

1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*Webb, Rev. Thomas William, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *Webb, William Frederick, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Richard Everard, Q.C. 2 Pump-court, Temple, London, E.C.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.
1854. ‡Weightman, William Henry. Fern Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter, F.R.S. L.& E., F.C.S. Rede Hall, Burstow, near Crawley, Surrey.
1876. ‡Weldon, W. F. R., B.A. St. John's College, Cambridge.
1881. §Wellcome, Henry S. 111 Marylebone-road, London, N.W.
1879. §Wells, Charles A. Lewes; and 45 Springfield-road, Brighton.
1881. §Wells, Rev. Edward, B.A. 21 Buckland-crescent, South Hampstead, London, N.W.
1883. ‡Wells, G. I. J. Cressington Park, Liverpool.
1883. §Welsh, Miss. Girton College, Cambridge.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1870. *Westgarth, William. 10 Bolton-gardens, South Kensington, London, S.W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
1882. §Westlake, Ernest, F.G.S. Fordingbridge, Hants.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡Westlake, W. C. Grosvenor House, Southampton.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1875. *Weston, Joseph D. Dorset House, Clifton Down, Bristol.
1864. ‡Westropp, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡Westwood, John O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1882. §Wethered, Edward, F.G.S. 5 Berkeley-place, Cheltenham.
1884. §Wharton, E. R., M.A. 4 Broad-street, Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1884. §Wheeler, Claude L. 123 Metcalfe-street, Montreal, Canada.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.

Year of Election.
1883. *Wheeler, George Brash. 11 Queen Victoria-street, London, E.C.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1883. §Whelpton, Miss K. Newnham College, Cambridge.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. Charante, Torquay.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1884. §Whischer, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1883. §Whitaker, T. Helm View, Halifax.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. 33 East Park-terrace, Southampton.
1876. ‡White, Angus. Easdale, Argyleshire.
1883. §White, Charles. 23 Alexandra-road, Southport.
1882. §White, Rev. George Cecil, M.A. St. Paul's Vicarage, Southampton.
1876. *White, James. Overtoun, Dumbarton.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1883. §White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1884. §White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1883. *White, Mrs. 365 Euston-road, London, N.W.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Drood House, Old Trafford, Manchester.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1855. *_Whitehouse, Wildeman W. O. Science Club, Savile-row, London, W._
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1884. §Whiteley, Joseph. Huddersfield.
1881. §Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1870. ‡Whittem, James Sibley. Walgrave, near Coventry.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 92 Mortimer-street, Herne Bay, Kent.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. Stancliffe, Matlock, Derbyshire.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. Glenthorne-road, Hammersmith, London, W.
1865. ‡Wiggin, Henry. Metchley Grange, Harborne, Birmingham.
1881. *Wigglesworth, James. New Parks House, Falsgrave.
1883. ‡Wigglesworth, Mrs. New Parks House, Falsgrave.
1881. *Wigglesworth, Robert. Buckingham Works, York.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W., F.C.S. Plough-court, 37 Lombard-street, London, E.C.
1884. §Wilber, Charles Dana, LL.D. Grand Pacific Hotel, Chicago, U.S.A.
1881. ‡WILBERFORCE, W. W. Fishergate, York.

Year of Election.

1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1879. ‡Wilkinson, Joseph. York.
1859. ‡Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡Willett, Henry, F.G.S. Arnold House, Brighton.
Williams, Charles James B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 1 Gorse-lane, Swansea.
1875. *Williams, Herbert A., M.A. 91 Pembroke-road, Clifton, Bristol.
1883. §Williams, Rev. H. A. The Ridgeway, Wimbledon, Surrey.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §Williams, John, F.C.S. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡Williams, Matthew W., F.C.S. Sterndale House, Sterndale-road, Brook Green, London, W.
Williams, Robert, M.A. Bridehead, Dorset.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1869. ‡Williams, Rev. Stephen. Stonyhurst College, Whalley, Blackburn.
1883. §Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1883. ‡Williams, T. Howell. 125 Fortess-road, London, N.W.
1877. *Williams, W. Carleton, F.C.S. Firth College, Sheffield.
1865. ‡Williams, W. M. Stonebridge Park, Willesden.
1883. §Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *Williamson, Alexander William, Ph.D., LL.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry and of Practical Chemistry, University College, London. (General Treasurer.) University College, London, W.C.
1857. ‡Williamson, Benjamin, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. ‡Williamson, Stephen. 19 James-street, Liverpool.
Williamson, William C., LL.D., F.R.S., Professor of Botany in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1883. ‡Willis, T. W. 51 Stanley-street, Southport.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1859. *Wills, The Hon. Sir Alfred. 12 King's Bench-walk, Inner Temple, London, E.C.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡Wilson, Lieut.-Colonel Sir C. W., R.E., C.B., D.C.L., F.R.S., F.R.G.S., Director of the Topographical and Statistical Department of the War Office. Mountjoy Barracks, Phœnix Park, Dublin.

Year of Election.

1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Eastnor, Malvern Link, Worcestershire.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1855. ‡Wilson, Hugh. 75 Glasford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡WILSON, Rev. JAMES M., M.A., F.G.S. The College, Clifton, Bristol.
1884. §Wilson, James S. Grant. H.M. Geological Survey, Sheriff Court-buildings, Edinburgh.
1858. *Wilson, John. Seacroft Hall, near Leeds.
WILSON, JOHN, F.R.S.E., F.G.S., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Assistant Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1854. *Winfield, Edward Higgin. Edelstowe, Bromley Park, Bromley, Kent.
1868. ‡*Winter, C. J. W. 22 Bethel-street, Norwich.*
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helen's, Lancashire.
1884. §Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Bridge of Earn, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. §Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. §WOOD, H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, London, W.C.
1883. *WOOD, JAMES, LL.D. Woodbank, Mornington-road, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1883. §Wood, Mrs. Mary. Ellison-place, Newcastle-on-Tyne.
1883. ‡Wood, P. F. Ardwick Lodge, Park-avenue, Southport.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.

Year of
Election.

1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1884. §Woodbury, C. J. H. 31 Devonshire-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. §Woodcock T., B.A. The Old Hall School, Wellington, Shropshire.
1884. §Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. ‡Woodiwis, James. 51 Back George-street, Manchester.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡Woodman, William Robert, M.D. Ford House, Exeter.
*WOODS, EDWARD, M.Inst.C.E. 6B Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
*WOODWARD, C. J., B.Sc. 97 Harborne-road, Birmingham.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡WOODWARD, HORACE B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1881. §Wooler, W. A. Sadberge Hall, Darlington.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1877. ‡Woollcombe, Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. 69 Market-street, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of. Hartlebury Castle, Kidderminster.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. §Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.
Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1884. §Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1879. §Wrentmore, Francis, 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. The Rectory, Darlaston.
1871. §WRIGHT, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1884. §Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.

Year of Election.

1876. ‡Wright, James. 114 John-street, Glasgow.
1874. ‡Wright, Joseph. Cliftonville, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. §Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1865. *Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
WRIGHT, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas, M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1867. ‡*Wünsch, Edward Alfred. 146 West George-street, Glasgow.*
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. Clifford Cottage, Besley, Redditch.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.
1884. §Wylie, Professor Theophilus A. Bloomington, Indiana, U.S.A.
1883. ‡Wyllie, Andrew. 10 Park-road, Southport.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry, C.E. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1883. ‡Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1884. §Yee, Fung, Secretary to the Chinese Legation. 49 Portland-place, London, W.
1879. ‡Yeomans, John. Upperthorpe, Sheffield.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1879. *YORK, His Grace the Archbishop of, D.D., F.R.S. The Palace, Bishopsthorpe, Yorkshire.
1884. §York, Frederick. 11 Lancaster-road, Notting Hill, London, W.
1884. §Young, Frederick. 5 Queensberry-place, London, S.W.
1884. §Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. *Young, James, F.C.S. Kelly, Wemyss Bay, by Greenock.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1883. *Young, Sydney, D.Sc. University College, Bristol.
1868. ‡Youngs, John. Richmond Hill, Norwich.
1876. ‡Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.
1871. ‡YULE, Colonel HENRY, C.B., F.R.G.S. 3 Penywern-road, South Kensington, London, S.W.

CORRESPONDING MEMBERS.

Year of Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1880. Professor Ludwig Boltzmann. Halbärtgasse, 1, Gräz, Austria.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1882. Dr. R. Clausius, Professor of Physics. The University, Bonn.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1871. Professor Dr. Colding. Copenhagen.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Signor Guido Cora. 17 Via Providenza, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome.
1872. *Professor M. Croullebois. 18 Rue Sorbonne, Paris.*
1866. Dr. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1864. M. Des Cloizeaux. Paris.
1872. Professor G. Devalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
1882. Dr. Emil Du Bois-Reymond, Professor of Physiology. The University, Berlin.
1881. Captain J. B. Eads, M.Inst.C.E. St. Louis, United States.
1876. Professor Alberto Eccher. Florence.
1861. Professor A. Favre. Geneva.
1874. Dr. W. Feddersen. Leipzig.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1856. Professor E. Frémy. L'Institut, Paris.
1842. *M. Frisiani.*
1881. C. M. Gariel, Secretary of the French Association for the Advancement of Science. 4 Rue Antoine Dubois, Paris.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor Wolcott Gibbs. Harvard University, United States.
1870. Governor Gilpin. Colorado, United States.
1876. Dr. Benjamin A. Gould, Director of the Argentine National Observatory, Cordoba.
1852. Professor Asa Gray, LL.D. Harvard University, United States.
1884. Lieutenant A. W. Greely. Washington, United States.
1871. *Dr. Paul Güssfeld. 33 Meckenheimer-strasse, Bonn, Prussia.*
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.

Year of Election.

1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1881. M. Halphen. 21 Rue Ste. Anne, Paris.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
1877. Professor H. L. F. von Helmholtz. Berlin.
1868. A. Heynsius. Leiden.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1881. Dr. A. A. W. Hubrecht. Leiden.
1876. Professor von Quintus Icilius. Hanover.
1884. Professor C. Loring Jackson. Harvard University, Cambridge, Massachusetts, United States.
1867. Dr. Janssen, LL.D. 21 Rue Labat (18° Arrondissement), Paris.
1876. Dr. W. J. Janssen. Davos-Doerfl, Graubunden, Switzerland.
1862. Charles Jessen, Med. et Phil. Dr. Kastanienallee, 69, Berlin.
1881. Professor W. Woolsey Johnson. Annapolis, United States.
1876. Dr. Giuseppe Jung. 9 Via Monte Pietà, Milan.
1877. *M. Akin Kàroly. 5 Babenberger-strasse, Vienna.*
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1884. Professor Dairoku Kikuchi. Tokio, Japan.
1873. Dr. Felix Klein. The University, Leipzig.
1874. Dr. Knoblauch. Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
1856. Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
1877. Dr. Hugo Kronecker, Professor of Physiology. 35 Dorotheen-strasse, Berlin.
1882. Professor S. P. Langley. Allegheny, United States.
1876. Professor von Lasaulx. Breslau.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1883. Dr. F. Lindemann. Professor of Mathematics in the University of Königsberg.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society, Bremen.
1871. Professor Jacob Lüroth. University, Freiburg, Germany.
1871. Dr. Lütken. Copenhagen.
1869. Professor C. S. Lyman. Yale College, New Haven, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, United States.
1867. Professor Ch. Martins, Director of the Jardin des Plantes. Montpellier, France.
1848. Professor J. Milne-Edwards. Paris.
1855. M. l'Abbé Moigno. Paris.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1856. Edouard Morren, Professeur de Botanique à l'Université de Liége, Belgium.
1875. *Dr. T. Nachtigal. Berlin.*
1866. Chevalier C. Negri, President of the Italian Geographical Society, Turin, Italy.
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1884. Professor Simon Newcomb. Washington, United States.
1874. M. A. Niaudet. 6 Rue du Seine, Paris.
1856. M. E. Peligot, Memb. de l'Institut, Paris.
1857. Gustave Plarr, D.Sc. 22 Hadlow-road, Tunbridge, Kent.

Year of Election.

1870. Professor Felix Plateau. 64 Boulevard du Jardin Zoologique, Gand, Belgium.
1868. L. Radlkofer, Professor of Botany in the University of Munich.
1882. Professor G. vom Rath. Bonn.
1884. Captain P. H. Ray. Washington, United States.
1872. Professor Victor von Richter. St. Petersburg.
1873. Baron von Richthofen. The University, Leipzig.
M. de la Rive. Geneva.
1866. F. Römer, Ph.D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.
1881. Professor Henry A. Rowland. Baltimore, United States.
1857. Professor Robert Schlagintweit. Giessen.
1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersberg Castle, near Forchheim, Bavaria.
1883. Dr. Ernst Schröder. Karlsruhe, Baden.
1874. Dr. G. Schweinfurth. Cairo.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1872. Professor Carl Semper. Wurzburg, Bavaria.
1873. Dr. A. Shafarik. Prague.
1861. Dr. Werner Siemens. Berlin.
1849. Dr. Siljeström. Stockholm.
1876. Professor R. D. Silva. L'École Centrale, Paris.
1864. Adolph Steen, Professor of Mathematics. Copenhagen.
1866. Professor Steenstrup. Copenhagen.
1881. Dr. Cyparissos Stephanos. 28 Rue de l'Arbaléte, Paris.
1881. Professor Sturm. Münster, Westphalia.
1871. Dr. Joseph Szabó. Pesth, Hungary.
1870. Professor Tchebichef, Membre de l'Académie de St. Pétersbourg.
1852. M. Pierre de Tchihatchef, Corresponding Member of the Institute of France. 1 Piazza degli Zuaai, Florence.
1884. Professor Robert H. Thurston. Stevens Institute of Technology, Hoboken, New Jersey, United States.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1842. Professor Wartmann. Geneva.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1874. Professor Wiedemann. Leipzig.
1876. Professor Adolph Wüllner. Aix-la-Chapelle.
1875. Dr. E. L. Youmans. New York.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Admiralty, Library of the.
Anthropological Institute.
Arts, Society of.
Asiatic Society (Royal).
Astronomical Society (Royal).
Belfast, Queen's College.
Birmingham, Midland Institute.
Bristol Philosophical Institution.
Cambridge Philosophical Society.
Cardiff, University College of South Wales.
Chemical Society.
Civil Engineers, Institute of.
Cornwall, Royal Geological Society of.
Dublin, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
East India Library.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Geographical Society (Royal).
Geological Society.
Geology, Museum of Practical.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Greenwich, Royal Observatory.
Kew Observatory.
Leeds, Mechanics' Institute.
Leeds, Philosophical and Literary Society of.
Linnean Society.
Liverpool, Free Public Library and Museum.
——, Royal Institution.
London Institution.
Manchester Literary and Philosophical Society.
——, Mechanics' Institute.
Mechanical Engineers, Institute of.
Meteorological Office.
Meteorological Society (Royal).
Newcastle-upon-Tyne Literary and Philosophical Society.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Physicians, Royal College of.
Royal Engineers' Institute, Chatham.
Royal Institution.
Royal Society.
Salford, Royal Museum and Library.
Sheffield, Firth College.
Southampton, Hartley Institution.
Statistical Society.
Stonyhurst College Observatory.
Surgeons, Royal College of.
United Service Institution.
University College.
War Office, Library of the.
Wales (South), Royal Institution of.
Yorkshire Philosophical Society.
Zoological Society.

EUROPE.

Berlin ....Der Kaiserlichen Akademie der Wissenschaften.
—— ....Royal Academy of Sciences.
Breslau ....Silesian Patriotic Society.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra ....Meteorological Observatory.
Copenhagen ...Royal Society of Sciences.
Dorpat, Russia...University Library.

Frankfort ......Natural History Society.
Geneva ....Natural History Society.
Göttingen ......University Library.
Halle ....Leopoldinisch-Carolinische Akademie.
Harlem ....Société Hollandaise des Sciences.
Heidelberg ......University Library.
Helsingfors ......University Library.
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