S. I. A.

REPORT

OF THE

FORTY-SEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

PLYMOUTH IN AUGUST 1877.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
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ALERE FLAMMAM.

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OBJECTS AND RULES

OF

THE ASSOCIATION.

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 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 first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain,* at one third of the Publication Price. 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.

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 Assistant General 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. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General 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.*

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†, and of preparing Reports thereon,

* Passed by the General Committee, Edinburgh, 1871.

† *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

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 Meeting.

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 settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.*

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, 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 †.

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 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 ‡. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of

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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 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.

* Passed by the General Committee, Edinburgh, 1871.

† These rules were adopted by the General Committee, Plymouth, 1877.

‡ This and the following sentence were added by the General Committee, 1871.

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 Printers, who are 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 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 Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), 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 Assistant General 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 can be referred to the Committee of Recommendations or confirmed by the General Committee.

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, and the reading of communications, in the order previously made public, be 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.

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 Assistant General 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.

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, F.R.S., Astronomer Royal, &c. John Dalton, 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, 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, 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, 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, F.L.S., &c. Wm. Hutton, 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.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, 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 Edgecumbe.	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 D. T. 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, 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, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	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. Professor Powell, F.R.S.	Henry Clark, 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, 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. 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.	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. 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. 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.
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, M.R.I.A., Pres. R.S. 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, M.D. Professor W. P. Wilson.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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 Philos. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, 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, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, 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, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, 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 Hugall, 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 Honourable 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, LL.D.
RICHARD OWEN, 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, 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 M. 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. 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.
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 Reverend 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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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 Reverend 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, Esq., jun., 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, 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, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, 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., Lowndsean 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, 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.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de M. 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, 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.SS.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.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex. The Duke of Norfolk. The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.R.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. J. Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, LL.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. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Professor Phillips, D.C.L., F.R.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.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. Rev. Dr. Henry. Dr. Andrews, F.R.S. 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. 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.
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.

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., &c.	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 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.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

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.

Date and Place.	Presidents.	Secretaries.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., 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. R. 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.
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, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., 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.

Date and Place.	Presidents.	Secretaries.
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.

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.
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, J. H. Norten, M.D., 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 *	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.

* 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 xxxvii.

Date and Place.	Presidents.	Secretaries.
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. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	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.
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, J. 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.

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 *	Rev. W. L. P. Garnons, F.L.S....	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham........................	W. Yarrell, Prof. Burnett.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxvii.

Date and Place.	Presidents.	Secretaries.
	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.
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 p. xxxvii.]

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.

Date and Place.	Presidents.	Secretaries.

SECTION D (*continued*).—BIOLOGY*.

1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred 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, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool ...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. 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 John 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 Anthropol.* 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.

* 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.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

Date and Place.	Presidents.	Secretaries.
1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

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

Date and Place.	Presidents.	Secretaries.
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.

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* ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

Date and Place.	Presidents.	Secretaries.
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 .	C. 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. Birminghm†.	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. xxxiii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

Date and Place.	Presidents.	Secretaries.
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.

* 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. xxxv). The Section being then vacant was assigned in 1851 to Geography.

† *Vide* note on page xxxvi.

Date and Place.	Presidents.	Secretaries.
	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. Henthawn 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.
1859. Aberdeen ...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, 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, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. 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.

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.

Date and Place.	Presidents.	Secretaries.
1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles 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, W. Cooke Tayler, LL.D.
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, William 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.

Date and Place.	Presidents.	Secretaries.
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.
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.

Date and Place.	Presidents.	Secretaries.
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.

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 Robert Stephenson.	W. Carpmael, William Hawkes, Thomas 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.
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. Dr. 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.

Date and Place.	Presidents.	Secretaries.
1857. Dublin	The Right 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 ..	William 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. A. Tarbottom.
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.

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.

Date and Place.	Lecturer.	Subject of Discourse.
1846. Southampton	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.
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. Roy. .	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-on-Tyne.	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.

Date and Place.	Lecturer.	Subject of Discourse.
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.
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 connexion 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.D., 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	William 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.

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	William Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
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.

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, Esq., Astron. Royal .	172	8
1852, Sept. 1 ...	Belfast ...	Lieut.-General Sabine, F.R.S. ...	164	10
1853, Sept. 3 ...	Hull ...	William Hopkins, Esq., 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. Prof. 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.		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.	Sums paid on Account of Grants for Scientific Purposes.
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.		
						£ s. d.	£ s. d.
...	...	...	...	...	353	....	....
...	...	...	...	...	...	....	....
...	...	...	...	...	900	....	....
...	...	...	...	...	1298	....	20 0 0
...	...	...	...	...	...	....	167 0 0
...	...	...	...	...	1350	....	435 0 0
...	...	...	...	...	1840	....	922 12 6
...	...	...	1100*	...	2400	....	932 2 2
...	...	...	...	34	1438	....	1595 11 0
...	...	...	...	40	1353	....	1546 16 4
46	317	...	60*	...	891	....	1235 10 11
75	376	33†	331*	28	1315	....	1449 17 8
71	185	...	160	...	...	....	1565 10 2
45	190	9†	260	...	...	....	981 12 8
94	22	407	172	35	1079	....	831 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1320	....	208 5 4
54	25	376	197	15	819	707 0 0	275 1 8
93	33	447	237	22	1071	963 0 0	159 19 6
128	42	510	273	44	1241	1085 0 0	345 18 0
61	47	244	141	37	710	620 0 0	391 9 7
63	60	510	292	9	1108	1085 0 0	304 6 7
56	57	367	236	6	876	903 0 0	205 0 0
121	121	765	524	10	1802	1882 0 0	380 19 7
142	101	1094	543	26	2133	2311 0 0	480 16 4
104	48	412	346	9	1115	1098 0 0	734 13 9
156	120	900	569	26	2022	2015 0 0	507 15 4
111	91	710	509	13	1698	1931 0 0	618 18 2
125	179	1206	821	22	2564	2782 0 0	684 11 1
177	59	636	463	47	1689	1604 0 0	766 19 6
184	125	1589	791	15	3138	3944 0 0	1111 5 10
150	57	433	242	25	1161	1089 0 0	1293 16 6
154	209	1704	1004	25	3335	3640 0 0	1608 3 10
182	103	1119	1058	13	2802	2965 0 0	1289 15 8
215	149	766	508	23	1997	2227 0 0	1591 7 10
218	105	960	771	11	2303	2469 0 0	1750 13 4
193	118	1163	771	7	2444	2613 0 0	1739 4 0
226	117	720	682	45‡	2004	2042 0 0	1940 0 0
229	107	678	600	17	1856	1931 0 0	1622 0 0
303	195	1103	910	14	2878	3096 0 0	1572 0 0
311	127	976	754	21	2463	2575 0 0	1472 2 6
280	80	937	912	43	2533	2649 0 0	1285 0 0
237	99	796	601	11	1983	2120 0 0	1685 0 0
232	85	817	630	12	1951	1979 0 0	1151 16 0
307	93	884	672	17	2248	2397 0 0	960 0 0
331	185	1265	712	25	2774	3023 0 0	1092 4 2
238	59	446	283	11	1229	1268 0 0	1128 9 7

* Ladies were not admitted by purchased Tickets until 1843.

† Tickets for admission to Sections only. ‡ Including Ladies.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from September 6, 1876 (commencement of GLASGOW Meeting), to August 15, 1877 (PLYMOUTH). Not including Receipts on account of Plymouth Meeting.

RECEIPTS.

	£	s.	d.
To Balance brought from last Account (Glasgow Meeting)	964	8	2
Received for Life Compositions at Glasgow Meeting and since	445	0	0
" Annual Subscriptions, ditto ditto	912	0	0
" Associates' Tickets, ditto ditto	1265	0	0
" Ladies' Tickets, ditto ditto	712	0	0
" Dividends on Stock	237	0	0
" for Sale of Publications, Vol. XLIV. (Bristol)	74	6	2
" ditto. Sundries	32	1	4
" Sundry small Sums for Transmission of Papers to Members during Glasgow Meeting, Donations, &c.	42	3	11
" Balance of Grant made at Bristol returned by Committee on Close Time for Protection of Indigenous Animals	2	19	0
" Balance of Grant made at Bristol returned by Committee on Effect of Propeller on turning of Steam Vessels	3	0	0
	4689	18	7
	£4689	18	7

Examined with the vouchers and found correct.

G. C. FOSTER,
W. SPOTTISWOODE,
W. H. FLOWER, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
Paid Expenses of Glasgow Meeting, also Sundry Printing, Binding, Advertising, and Incidental Expenses				551	1	4
" Printing, Engraving, &c. Report of 45th Meeting, Vol. XLIV. (Bristol)				700	7	9
" Salaries (1 year)				470	0	0
" Rent and Office Expenses (Albemarle Street)				104	5	0
" Grants made at the Glasgow Meeting, viz.—						
Liquid Carbonic Acid 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			
Dipterocarpeæ, 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
1877. Aug. 15. Balance at London and Westminster Bank (current account)	235	14	11			
Ditto, ditto (deposit account)	1500	0	0			
				1735	14	11
				£4689	18	7

A. W. WILLIAMSON,
August 15, 1877.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE PLYMOUTH MEETING.

SECTION A.—MATHEMATICS AND PHYSICS.

President.—Professor G. C. Foster, B.A., F.R.S., President of the Physical Society.

Vice-Presidents.—Professor J. C. Adams, M.A., LL.D., F.R.S.; Professor W. G. Adams, M.A., F.R.S.; Professor Cayley, LL.D., F.R.S.,; Rev. Professor Haughton, M.A., D.C.L., F.R.S.; Rev. Professor Bartholomew Price, M.A., F.R.S.; Lord Rayleigh, M.A., F.R.S., F.R.A.S.; Sir William Thomson, M.A., D.C.L., F.R.S.

Secretaries.—Professor Barrett, F.R.S.E.; J. T. Bottomley, M.A., F.C.S.; J. W. L. Glaisher, M.A., F.R.S., F.R.A.S.; F. G. Landon, M.A.

SECTION B.—CHEMISTRY AND MINERALOGY, INCLUDING THEIR APPLICATIONS TO AGRICULTURE AND THE ARTS.

President.—F. A. Abel, F.R.S., Past President of the Chemical Society.

Vice-Presidents.—Dr. Gladstone, F.R.S., F.C.S.; A. G. Vernon Harcourt, F.R.S., F.C.S.; Dr. Longstaff, F.C.S.; Professor Odling, M.B., F.R.S., F.C.S.; W. H. Perkin, F.R.S., F.C.S.; Dr. W. J. Russell, F.R.S., F.C.S.; H. C. Sorby, F.R.S.; Professor A. W. Williamson, Ph.D., F.R.S., F.C.S.

Secretaries.—Dr. Oxland, F.C.S.; W. Chandler Roberts, F.R.S., F.C.S.; John M. Thomson, F.C.S.

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President.—W. Pengelly, F.R.S., F.G.S.

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Secretaries.—Dr. Le Neve Foster, F.G.S.; R. H. Tiddeman, M.A., F.G.S.; W. Topley, F.G.S.

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Vice-Presidents.—Dr. Acland, M.A, F.R.S.; Dr. Beddoe, F.R.S.; John Evans, D.C.L., F.R.S.; Francis Galton, M.A., F.R.S.; Professor A. Macalister, M.D.; Professor M'Kendrick, M.A., F.R.S.E.; Professor Newton, M.A., F.R.S.; Professor Redfern, M.D.; Professor Rolleston, M.A., M.D., F.R.S.; P. L. Sclater, M.A., Ph.D., F.R.S.

Secretaries.—E. R. Alston, F.L.S.; F. Brent; Dr. D. J. Cunningham; C. A. Hingston, M.D., B.Sc.; Professor W. R. M'Nab, M.D.; J. B. Rowe, F.L.S.; F. W. Rudler, F.G.S.

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President.—The Right Hon. the Earl Fortescue.

Vice-Presidents.—Sir T. D. Acland, Bart., M.A., D.C.L., M.P.; William Farr, M.D., F.R.S.; Dr. W. Neilson Hancock, M.R.I.A.; The Right Hon. Lord Houghton, M.A., D.C.L., F.R.S.; W. F. Moore, Mayor of Plymouth; Sir James Watson; Sir George Young, Bart.

Secretaries.—W. F. Collier; P. Hallett, M.A.; Joseph T. Pim.

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President.—Edward Woods, C.E.

Vice-Presidents.—W. H. Barlow, C.E., F.R.S.; C. Bergeron, C.E.; F. J. Bramwell, C.E., F.R.S.; Edward Easton, C.E.; William Froude, M.A., C.E., F.R.S.; C. W. Merrifield, F.R.S.; J. R. Napier, F.R.S.

Secretaries.—A. T. Atchison, M.A.; Dr. Merrifield, F.R.A.S.; J. N. Shoolbred, C.E., F.G.S.

OFFICERS AND COUNCIL, 1877-78.

PRESIDENT.

PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S.L. & E.

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The Right Hon. LORD BLACHFORD, K.C.M.G.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., 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.

PRESIDENT ELECT.

WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S.

VICE-PRESIDENTS ELECT.

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., M.R.I.A.
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.

* Nominated by the Council.

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Prof. R. S. BALL, M.A., F.R.S.
JAMES GOFF, Esq.
JOHN NORWOOD, Esq., LL.D.
Prof. G. SIGERSON, M.D.

LOCAL TREASURER FOR THE MEETING AT DUBLIN.

T. MAXWELL HUTTON, Esq.

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FARR, Dr. W., F.R.S.
FOSTER, Professor G. C., F.R.S.
FROUDE, W., Esq., F.R.S.
GRANT, Col. J. A., C.B., F.R.S.
HEYWOOD, J., Esq., F.R.S.
HOUGHTON, Rt. Hon. Lord, F.R.S
HUGGINS, W., Esq., F.R.S.
MASKELYNE, Prof. N. S., M.A., F.R.S.
MAXWELL, Professor J. CLERK, F.R.S.
NEWTON, Professor A., F.R.S.
OMMANNEY, Admiral Sir E., C.B., F.R.S.
PENGELLY, W., Esq., F.R.S.
PRESTWICH, Professor J., F.R.S.
ROLLESTON, Professor G., M.A., F.R.S.
ROSCOE, Professor H. E., Ph.D., F.R.S.
RUSSELL, Dr. W. J., F.R.S.
SANDERSON, Prof. J. S. BURDON, F.R.S.
SMITH, Professor H. J. S., F.R.S.
SMYTH, WARINGTON W., Esq., F.R.S.

GENERAL SECRETARIES.

Capt. DOUGLAS GALTON, C.B., D.C.L., F.R.S., F.G.S., 12 Chester Street, Grosvenor Place, London, S.W.
PHILIP LUTLEY SCLATER, Esq., M.A., Ph.D., F.R.S., F.L.S., 11 Hanover Square, London, W.

ASSISTANT GENERAL SECRETARY.

GEORGE GRIFFITH, Esq., M.A., F.C.S., Harrow-on-the-hill, Middlesex.

GENERAL TREASURER.

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

EX-OFFICIO MEMBERS OF THE COUNCIL.

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 General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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General Sir EDWARD SABINE, K.C.B., R.A., D.C.L., F.R.S.
Sir PHILIP DE M. GREY EGERTON, Bart., M.P., F.R.S., F.G.S.
Sir JOHN LUBBOCK, Bart., M.P., F.R.S., F.L.S.

PRESIDENTS OF FORMER YEARS.

The Duke of Devonshire.
The Rev. T. R. Robinson, D.D.
Sir G. B. Airy, Astronomer Royal.
General Sir E. Sabine, K.C.B.
The Earl of Harrowby.
The Duke of Argyll.
The Rev. H. Lloyd, D.D.
Richard Owen, M.D., D.C.L.
Sir W. G. Armstrong, C.B., LL.D.
Sir William R. Grove, F.R.S.
The Duke of Buccleuch, K.G.
Sir Joseph D. Hooker, D.C.L.
Professor Stokes, M.A., D.C.L.
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Prof. Sir W. Thomson, D.C.L.
Dr. Carpenter, F.R.S.
Prof. Williamson, Ph.D., F.R.S.
Prof. Tyndall, D.C.L., F.R.S.
Sir John Hawkshaw, C.E., F.R.S.
Prof. T. Andrews, M.D., F.R.S.

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F. Galton, Esq., F.R.S.
Dr. T. A. Hirst, F.R.S.
Gen. Sir E. Sabine, K.C.B., F.R.S.
W. Spottiswoode, Esq., F.R.S.
Dr. Michael Foster, F.R.S.

AUDITORS.

Professor W. H. Flower, F.R.S.
Professor G. C. Foster, F.R.S.
W. Spottiswoode, Esq., F.R.S.

Report of the Council for the Year 1876–77, *presented to the General Committee at Plymouth on Wednesday, August* 15*th*, 1877.

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.

The following Resolution was referred by the General Committee at Glasgow to the Council for consideration, and for action, if it should seem desirable:—

> "That the Council be requested to consider and take steps, if they think it desirable, to urge upon Her Majesty's Government the advisability of forming a Museum of Scientific Instruments and Chemical Products, as suggested in the Memorial presented in June last to the Lord President of Her Majesty's Council."

The Council having considered this Resolution, came to the conclusion that while they believe that a Permanent Museum of Scientific Instruments might be of great value, it is their opinion that the objects of the Memorial referred to in the Resolution submitted to the Council are, as a whole, neither so clearly defined, nor so free from valid objections, as to justify the Council of the British Association in supporting the proposals of the Memorial in its present form.

The attention of the Council having been drawn to the character of some of the Sectional Proceedings at late Meetings of the Association, a Committee was appointed to consider and report to the Council on the possibility of excluding unscientific or otherwise unsuitable papers and discussions from the Sectional Proceedings of the Association.

The Committee recommended that papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees, and that, in the rules for conducting the business of the Sectional Committees, the following rules should be inserted, viz.:—

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.

The Council propose that this alteration of rules shall be carried into effect.

The Committee in their Report further considered that some of the subjects brought before Section F could not be considered scientific in the ordinary sense of that word, and that the question of the discontinuance of Section F deserved the serious consideration of the Council.

The Council have requested the Committee to report more fully the reasons which had induced them to come to this conclusion, but the Committee have not yet made a further report.

The Council regret to state that Mr. Griffith has informed them that he is desirous of withdrawing from the office of Assistant General Secretary, which he has held for nearly sixteen years.

The Council having carefully considered the steps expedient to be taken in consequence of Mr. Griffith's proposed withdrawal, have resolved to select Mr. J. E. H. Gordon, B.A., of Caius College, Cambridge, for nomination as Assistant Secretary after the Dublin Meeting in 1878. The Council propose that Mr. Gordon be requested to attend the present Meeting, and to assist generally during the ensuing year.

To cover his expenses during this preliminary period, the Council recommend that a grant of £100 be made to him.

The following Foreign Men of Science, who had attended the Glasgow Meeting, have been elected Corresponding Members:—

Professor Cremona.
Professor Ecker.
Dr. B. A. Gould.
Professor Häckel.
Professor Von Quintus Icilius.
Dr. G. Jung.
Dr. Lasaulx.
Professor R. D. Silva.
Baron Von Wrangell.
Professor Wüllner.
Dr. W. J. Janssen.

The Council have been informed that invitations for the Meeting in 1879, or following years, will be presented from Swansea and Nottingham, and from York for the year 1881, being the fiftieth anniversary of the British Association, the first meeting of which was held in that city.

The following are the names of Members of Council for the past year who, in accordance with the regulations, are not eligible for re-election this year, viz.:—

Sir Rutherford Alcock.
Professor Flower.
Mr. Gassiot.
Mr. Merrifield.
Mr. Gwyn Jeffreys.

The Council recommend the re-election of the other ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Abel, F. A., Esq., F.R.S.
*Barlow, W. H., Esq., F.R.S.
Bramwell, F. J., Esq., C.E., F.R.S.
Cayley, Professor, F.R.S.
De La Rue, Warren, Esq., D.C.L., F.R.S.
Evans, J., Esq., F.R.S.
Farr, Dr. W., F.R.S.
*Foster, Professor G. C., F.R.S.
Froude, W., Esq., F.R.S.
*Grant, Lieut.-Col. J., C.B., F.R.S.
Heywood, J., Esq., F.R.S.
Houghton, Lord, F.R.S.
Huggins, W., Esq., F.R.S.
Maskelyne, Prof. N. S., M.A., F.R.S.
Maxwell, Professor J. Clerk, F.R.S.
Newton, Professor A., F.R.S.
Ommaney, Admiral Sir E., C.B., F.R.S.
Pengelly, W., Esq., F.R.S.
Prestwich, Professor J., F.R.S,
Rolleston, Professor G., M.A., F.R.S.
Roscoe, Professor H. E., Ph.D., F.R.S.
Russell, Dr. W. J., F.R.S.
*Sanderson, Professor Burdon, F.R.S.
Smith, Professor H. J. S., F.R.S.
*Smyth, Warington W., Esq., F.R.S.

Recommendations adopted by the General Committee at the Plymouth Meeting in August 1877.

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

Involving Grants of Money.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher (Secretary), be reappointed; and that the sum of £100 be placed at their disposal for the purpose of calculating a Factor Table of the fourth million, as a continuation of Burckhardt's tables which extend from 1 to 3,000,000.

That the Committee, consisting of Professor G. Forbes and Professor Sir William Thomson, for the purpose of making arrangements for the taking of certain observations in India, be reappointed with the addition of the name of Professor Everett; and that the sum of £15 be placed at their disposal in order to enable them to have observations on Atmospheric Electricity undertaken at Madeira.

That the Committee, consisting of Mr. James Glaisher, Mr. R. P. Greg, Mr. Charles Brooke, Dr. Flight, and Professor A. S. Herschel, on Luminous Meteors, be reappointed; and that the sum of £10 be placed at their disposal.

That the Committee, consisting of Dr. Joule, Professor Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. Clerk Maxwell, for effecting the Determination of the Mechanical Equivalent of Heat, be reappointed; and that £65, being the portion that has lapsed of the £100 granted last year, be renewed.

That the Committee, consisting of Professor Sir William Thomson, Professor Tait, Professor Grant, Dr. Siemens, and Professor Purser, for the Measurement of the Lunar Disturbance of Gravity, be reappointed; and that the grant of £50 which has lapsed be renewed.

That Dr. Crum Brown and Messrs. Dewar, Dittmar, and Dixon be a Committee for the purpose of investigating some Methods that have been recently proposed for the Quantitative Estimation of Atmospheric Ozone; that Mr. E. M. Dixon be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. W. Chandler Roberts, Dr. C. R. Alder Wright, and Mr. A. P. Luff be a Committee for the purpose of investigating the Chemical Composition and Structure of some of the less-known Alkaloids—Veratrine and Beberine in particular; that Dr. Wright be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Dr. J. Evans, Sir John Lubbock, Bart., Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Professor W. B. Dawkins, Mr. W. A. Sandford, and Mr. J. E. Lee be a Committee for the purpose of continuing the exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Dr. J. Evans, the Rev. T. G. Bonney, Mr. W. Carruthers, Mr. F. Drew, Mr. R. Etheridge, Jun., Mr. G. A. Lebour, Professor L. C. Miall, Professor H. A. Nicholson, Mr. F. W. Rudler, Mr. E. B. Tawney, Mr. W. Topley, and Mr. W. Whitaker be a Committee for the purpose of carrying on the Geological Record; that Mr. Whitaker be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. Godwin-Austen, Professor Prestwich, Mr. Davidson, Mr. Etheridge, Mr. Willett, and Mr. Topley be a Committee for the purpose of assisting the Kentish Boring Exploration; that Mr. Willett and Mr. Topley be the Secretaries, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Harkness and Mr. Jolly be a Committee for the purpose of investigating the Fossils in the N.W. Highlands; that Mr. Jolly be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Rev. Dr. Haughton, Professor Leith Adams, Professor Barrett, Mr. Hardman, and Dr. Macalister be a Committee for the purpose of Exploring the Fermanagh Caves; that Dr. Macalister be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Professor A. S. Herschel and Mr. G. A. Lebour be reappointed a Committee for the purpose of making experiments on the Thermal Conductivities of certain rocks; that Professor Herschel be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Professor Hull, Rev. H. W. Crosskey, Captain D. Galton, Mr. Glaisher, Mr. H. H. Howell, Mr. G. A. Lebour, Mr. W. Molyneux, Mr. Morton, Mr. Pengelly, Professor Prestwich, Mr. Plant, Mr. W. Whitaker, and Mr. De Rance be reappointed a Committee for the purpose of investigating the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quantity and Character of the Water supplied to various towns and districts from those formations; that Mr. De Rance be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That Sir John Lubbock, Bart., Professor Prestwich, Professor Busk, Professor T. M'K. Hughes, Professor W. Boyd Dawkins, Professor Miall, Rev. H. W. Crosskey, Mr. H. C. Sorby, and Mr. R. H. Tiddeman be a Committee for the purpose of assisting in the exploration of the Settle Caves, Victoria Cave; that Mr. R. H. Tiddeman be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. Dew-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. Sclater, Dr. M. Foster, Mr. F. M. Balfour, and Professor Ray Lankester be reappointed a Committee for the purpose of arranging with Dr. Dohrn for the occupation of a Table at the Zoological Station at Naples during the ensuing year; that Mr. Dew-Smith be the Secretary, and that the sum of £75 be placed at their disposal for the purpose,

That Colonel Lane Fox, Professor Rolleston, Dr. John Evans, Mr. Hilton Price, and Mr. Park Harrison be reappointed a Committee for the purpose of Exploring Ancient Earthworks; that Colonel Lane Fox be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Professor McKendrick and Mr. J. T. Bottomley be a Committee for the purpose of investigating the Phenomena of the Pulse by means of Sir William Thomson's Siphon Recorder; that Dr. McKendrick be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Professor Rolleston, Colonel Lane Fox, Professor Busk, Professor Boyd Dawkins, Dr. John Evans, and Mr. F. G. Hilton Price be a Committee for the purpose of examining two Caves containing Human Remains in the neighbourhood of Tenby, and certain adjacent Tumuli whence it is possible that some of these remains may have been derived; that Professor Rolleston be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, Bart., and Mr. 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 be placed at their disposal for the purpose.

That Dr. Allen Thomson, Professor Sir William Thomson, Dr. Henry Muirhead, Mr. J. T. Bottomley, and Professor McKendrick be a Committee for the purpose of an investigation "On the Transmission of Electrical Impulses through Nerve Structure as bearing on the general phenomena of Nervous Action;" that Professor McKendrick be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Dr. Farr, Dr. Beddoe, Mr. Brabrook, Sir George Campbell, the Earl of Ducie, Mr. F. P. Fellows, Colonel Lane Fox, Mr. F. Galton, Mr. Park Harrison, Mr. J. Heywood, Mr. P. Hallett, Professor Leone Levi, Sir Rawson Rawson, and Professor Rolleston be reappointed a Committee for the purpose of continuing the collection of observations on the Systematic Examination of Heights, Weights, &c. of Human beings in the British Empire, and the publication of Photographs of the typical races of the Empire; that Colonel Lane Fox be the Secretary, and that the sum of £66, being the balance of the grant made last year but not drawn, be placed at their disposal for the purpose.

That the Committee on Instruments for Measuring the Speed of Ships, consisting of Mr. W. Froude, Mr. F. J. Bramwell, Mr. A. E. Fletcher, Rev. E. L. Berthon, Mr. James R. Napier, Mr. C. W. Merrifield, Dr. C. W. Siemens, Mr. H. M. Brunel, Mr. W. Smith, Mr. J. N. Shoolbred, Professor James Thomson, and Professor Sir William Thomson, be reappointed; that Mr. James N. Shoolbred be the Secretary, and that the sum of £50 be placed at their disposal.

That the Committee, consisting of Professor Sir William Thomson, Major-General Strachey, Captain Douglas Galton, Mr. G. F. Deacon, Mr. Rogers Field, Mr. E. Roberts, and Mr. J. N. Shoolbred, be reappointed for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto, and for the tabulation and comparison of other Datum-marks, with power to communicate with the Government; that Mr. James N. Shoolbred be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That "The Rules of Zoological Nomenclature," drawn up by the late Mr. H. E. Strickland, and adopted by Section D, be reprinted and published at the cost of the Association, and that Mr. Sclater be requested to edit the New Edition.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Professor Sir William Thomson, Professor Clerk Maxwell, Professor Tait, Dr. C. W. Siemens, Mr. F. J. Bramwell, Mr. W. Froude, and Mr. J. T. Bottomley, for commencing secular experiments upon the Elasticity of Wires, be reappointed.

That the Committee, consisting of Professor Everett, Professor Sir William Thomson, Professor J. Clerk Maxwell, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Ansted, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, and Mr. Joseph Dickinson, on Underground Temperature, be reappointed.

That the Committee, consisting of Dr. W. Huggins, Mr. J. N. Lockyer, Professor J. Emerson Reynolds, Mr. G. J. Stoney, Mr. Spottiswoode, Dr. De La Rue, and Dr. W. M. Watts, for the purpose of preparing and printing Tables of Wave-frequency (Inverse Wave-lengths), be reappointed.

That a Committee, consisting of Professor Cayley, Dr. Farr, Mr. J. W. L. Glaisher, Dr. Pole, Professor Fuller, Professor A. B. W. Kennedy, Professor Clifford, and Mr. C. W. Merrifield, be appointed to consider the advisability and to estimate the expense of constructing Mr. Babbage's Analytical Machine, and of printing tables by its means; and that Mr. C. W. Merrifield be the Secretary of the Committee.

That a Committee, consisting of Professor Sir William Thomson, Mr. W. Froude, Professor Osborne Reynolds, Captain Douglas Galton, and Mr. James N. Shoolbred (with power to add to their number), be appointed for the purpose of obtaining information respecting the phenomena of the stationary tides in the English Channel and in the North Sea, and of representing to the Government of Portugal and the Governor of Madeira that in the opinion of the British Association, tidal observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with the view to the advancement of our knowledge of the tides in the Atlantic Ocean; and that Mr. James N. Shoolbred be the Secretary.

That the Committee, consisting of Mr. Spottiswoode, Professor G. G. Stokes, Professor Cayley, Professor H. J. S. Smith, Professor Sir William Thomson, Professor Henrici, Lord Rayleigh, and Mr. J. W. L. Glaisher, on Mathematical Notation and Printing, be reappointed.

That the Committee, consisting of Professor Balfour Stewart, Professor Clerk Maxwell, and Professor W. F. Barrett, on the Magnetization of Iron, Nickel, and Cobalt, be reappointed.

That the Committee, consisting of Professor Stokes, Dr. De La Rue, Professor Clerk Maxwell, Professor W. F. Barrett, Mr. Howard Grubb, and Mr. G. Johnstone Stoney, for examining and reporting upon the reflective powers of Silver, Gold, and Platinum, whether in mass or chemically deposited on glass, and of Speculum Metal, be reappointed.

That Professor G. C. Foster, Professor W. G. Adams, Professor R. B. Clifton, Professor Cayley, Professor J. D. Everett, Professor Clerk Maxwell, Lord Rayleigh, Professor G. G. Stokes, Professor Balfour Stewart, Mr. Spottiswoode, and Professor P. G. Tait be a Committee for the purpose of endeavouring to procure reports on the progress of the chief branches of Mathematics and Physics; that Professor G. Carey Foster be the Secretary.

That Professor Clifford be requested to prepare a report on the Physical Applications of Quaternions.

That Mr. C. W. Merrifield be requested to report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data.

That Dr. F. Clowes and Dr. W. A. Tilden be a Committee for the purpose of examining the action of Ethylbromo-butyrate on Ethyl-sod-acetate; that Dr. Clowes be the Secretary.

That Mr. W. N. Hartley, Dr. E. J. Mills, and Mr. W. Chandler Roberts be a Committee for the purpose of investigating the conditions under which liquid Carbonic Acid occurs in Minerals; that Mr. W. N. Hartley be the Secretary.

That Mr. W. N. Hartley, Mr. J. M. Thomson, and Mr. W. Chandler Roberts be a Committee for the purpose of investigating the constitution of double compounds of Cobalt and Nickel; that Mr. Thomson be the Secretary.

That Dr. W. Wallace, Professor Dittmar, and Mr. Thomas Wills be a Committee for the purpose of reporting on the best means for the development of Light from Coal-gas of different qualities; that Dr. Wallace be the Secretary.

That Professor Prestwich, Professor Harkness, Professor Hughes, Professor W. Boyd Dawkins, Rev. H. W. Crosskey, Professor L. C. Miall, Messrs. G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, J. Plant, W. Pengelly, Dr. Deane, Mr. C. J. Woodward, and Mr. Molyneux be 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; that the Rev. H. W. Crosskey be the Secretary.

That the Rev. H. F. Barnes, Mr. Spence Bate, Mr. H. E. Dresser, Mr. J. E. Harting, Dr. Gwyn Jeffreys, Professor Newton, and the Rev. Canon Tristram be reappointed a Committee for the purpose of inquiring into the possibility of establishing a "close time" for the protection of indigenous animals; that Mr. Dresser be the Secretary.

That Mr. Spence Bate be requested to continue his Report "On the present state of our knowledge of the Crustacea."

That the Right Hon. J. G. Hubbard, M.P., Mr. Chadwick, M.P., Mr. Morley, M.P., Dr. Farr, Sir George Campbell, M.P., Mr. Hallett, Professor Jevons, Mr. Newmarch, Mr. Shaen, Mr. Macneel Caird, and Mr. Stephen Bourne (with power to add to their number) be a Committee for the purpose of further developing the investigations into a Common Measure of Value in Direct Taxation; that Mr. Hallett be the Secretary.

That the Committee, consisting of Mr. W. H. Barlow, Mr. H. Bessemer, Mr. F. J. Bramwell, Captain Douglas Galton, Sir John Hawkshaw, Dr. C. W. Siemens, Professor Abel, and Mr. E. H. Carbutt, for the purpose of considering the use of Steel for structural purposes, be reappointed; and that Mr. E. H. Carbutt be the Secretary.

That the Committee, consisting of Dr. A. W. Williamson, Professor Sir William Thomson, Mr. Bramwell, Mr. St. John Vincent Day, Dr. C. W. Siemens, Mr. C. W. Merrifield, Dr. Neilson Hancock, Professor Abel, Mr. J. R. Napier, Captain Douglas Galton, Mr. Newmarch, Mr. E. H. Carbutt, and Mr. Macrory, be reappointed, for the purpose of watching and reporting to the Council on Patent Legislation; and that Mr. F. J. Bramwell be the Secretary.

That the Committee, consisting of Mr. James R. Napier, Sir William Thomson, Mr. William Froude, Professor Osborne Reynolds, and Mr. J. T. Bottomley, for the purpose of making experiments and of reporting on the effect of the Propeller on the turning of Steam-vessels be reappointed (with power to communicate with the Government); and that Professor Osborne Reynolds be the Secretary.

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

That Dr. Gwyn Jeffrey's paper, "On the Post-Tertiary Fossils procured in the late Arctic Expedition, with notes on some of the Recent or living Mollusca from the same Expedition," be printed *in extenso* among the Reports.

That the paper of Mr. Stephen Bourne, F.S.S., "On the growth of Population with relation to the Means of Subsistence," be printed *in extenso* in the Sectional Proceedings.

That Mr. Baldwin Latham's paper, "On the Indication of the Movements of Water in the Chalk Formation," be printed, with the Appendix and the necessary diagrams, *in extenso* among the Reports.

Resolution referred to the Council for consideration and action if it seem desirable.

That the question of the appointment of a Committee, consisting of Mr. F. J. Bramwell, Mr. J. F. Bateman, Mr. G. F. Deacon, Mr. Rogers Field, Captain Douglas Galton, Mr. R. B. Grantham, Mr. Baldwin Latham, Mr. C. W. Merrifield, and Mr. G. J. Symons, for carrying on observations on the Rainfall of the British Isles, be referred to the Council for consideration and action if it seem desirable; and that the sum of £150 be placed at the disposal of the Council for the purpose.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Plymouth Meeting in August 1877. The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

*Cayley, Professor.—Continuation of Burckhardt's Tables	£100	0	0
*Forbes, Prof. G.—Observation of Atmospheric Electricity at Madeira	15	0	0
*Glaisher, Mr. J.—Luminous Meteors	10	0	0
*Joule, Dr.—Determination of the Mechanical Equivalent of Heat (renewed)	65	0	0
*Thomson, Sir William.—Measurement of the Lunar Disturbance of Gravity (renewed)	50	0	0

Chemistry.

*Brown, Prof. Crum.—Quantitative Estimation of Atmospheric Ozone	10	0	0
Roberts, Mr. Chandler.—Chemical Composition and Structure of some of the less-known Alkaloids	25	0	0

Geology.

*Evans, Mr. J.—Kent's Cavern Exploration	50	0	0
*Evans, Mr. J.—Record of the Progress of Geology	100	0	0
Godwin-Austen, Mr.—Kentish Boring Exploration	100	0	0
*Harkness, Professor.—North-West Highlands Fossils	10	0	0
Haughton, Rev. Dr.—Fermanagh Caves Exploration	30	0	0
*Herschel, Professor A.—Thermal Conductivities of Rocks	10	0	0
*Hull, Professor.—Circulation of Underground Waters in the New Red Sandstone	15	0	0
*Lubbock, Sir J., Bart.—Exploration of Victoria Cave, Settle ..	100	0	0
Carried forward	£690	0	0

* Reappointed.

Biology.

Brought forward	£690	0	0
Dew-Smith, Mr.—Table at the Zoological Station, Naples	75	0	0
*Fox, Col. Lane.—Exploration of Ancient Earthworks	25	0	0
McKendrick, Dr.—Investigation of Pulse Phenomena by Thomson's Siphon Recorder	10	0	0
Rolleston, Professor.—Examination of two Caves and Tumuli near Tenby	25	0	0
*Stainton, Mr.—Record of Zoological Literature	100	0	0
Thomson, Dr. Allen—Transmission of Electrical Impulses through Nerve-structure	30	0	0

Statistics and Economic Science.

*Farr, Dr.—Anthropometric Committee (renewed)	66	0	0

Mechanics.

*Froude, Mr. W.—Instruments for Measuring the Speed of Ships (renewed)	50	0	0
*Thomson, Sir W.—Datum-Level of the Ordnance Survey	10	0	0
Total	£1081	0	0

* Reappointed.

The Annual Meeting in 1878.

The Meeting at Dublin will commence on Wednesday, August 14, 1878.

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

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
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 Cooperation	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 Cooperation	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

	£	s.	d.
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	3
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	3	6
	£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 Cooperation	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	0
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	3
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 Catalogues 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 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

	£	s.	d.
1851.			
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.			
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.			
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.			
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.			
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.			
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.			
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
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.			
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.			
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.			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	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. 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
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

	£	s.	d.
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
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

	£	s.	d.
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
Kiltorcan Quarries Fossils	20	0	0
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 Corals 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
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 Secretion	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

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	£	s.	d.
Liquid Carbonic Acid 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 Explanation	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

General Meetings.

On Wednesday, August 15, at 8 P.M., in the Guildhall, Professor Thomas Andrews, M.D., LL.D., F.R.S., President, resigned the office of President to Professor Allen Thomson, M.D., LL.D., F.R.S., who took the Chair, and delivered an Address, for which see page lxviii.

On Thursday, August 16, at 8 P.M., a Soirée took place in the Guildhall.

On Friday, August 17, at 8.30 P.M., in the Guildhall, W. Warington Smyth, Esq., M.A., F.R.S., delivered a Discourse on "The Physical Phenomena connected with the Mines of Cornwall and Devon."

On Saturday, August 18, at 7 P.M., in the Guildhall, W. H. Preece, Esq., delivered a Lecture, on "The Telephone," to the Working Classes of Plymouth.

On Monday, August 20, at 8.30 P.M., in the Guildhall, Professor Odling, M.B., F.R.S., delivered a Discourse on "The new Element, Gallium."

On Tuesday, August 21, at 8 P.M., a Soirée took place in the Guildhall.

On Wednesday, August 22, the concluding General Meeting took place, 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 Dublin.*

* The Meeting is appointed to take place on Wednesday, August 14, 1878.

ADDRESS

OF

PROFESSOR ALLEN THOMSON, M.D., LL.D.,

F.R.S., F.R.S.E.,

PRESIDENT.

After the long interval of six and thirty years the British Association for the Advancement of Science holds its annual meeting, the forty-seventh since its foundation, in this beautiful and interesting locality; and, it so happens that, on this occasion as on the former, it passes from Glasgow to Plymouth. We are delighted to be assembled here, and are even surprised that the Association has been able so long to resist the power of attraction by which it has been gravitating towards this place. While we are prepared to be charmed with the surpassing beauty of its scenery, and know the deep interest of its prehistoric vestiges, its historic memories, and its artistic associations, we have been frequently reminded of its scientific vigilance by the records of its active work; and we are now ready and anxious to witness all we can behold of its energy and success in the application of scientific discovery to the practical arts. Should we, as might be expected in a place hitherto so famous in its relations to our naval and military history, find most prominent that relating to the mechanism of war, we shall still hope that the attainment of greater perfection in the engines of destruction may only be the means of rendering peace more permanent and secure.

It is a source of regret to myself, and may be, I fear, a cause of detriment to this Meeting, that the choice of a President should have fallen upon one whose constant occupation with special branches of science has fitted him very inadequately for the distinguished position to which he has been called. I can only derive comfort from knowing that, wherever it may be necessary, there are many others present most able to supply what may be wanting on my part; and I must therefore at once bespeak their assistance and your indulgence.

I have selected for the subject of the remarks which I am about to offer a biological topic, namely, the "Development of the Forms of Animal Life," with which my studies have been occupied, and which has important bearings on some of the more interesting biological questions now agitating the scientific world. But before proceeding with the discussion of my special subject, it is my desire to call your attention shortly to the remarkable change in the manner of viewing biological questions which has taken place in this country during the last half-century—a change so great, indeed, that it can scarcely be fully appreciated except by those who, like myself, have lived through the period of its occurrence.

In the three earlier decades of this century it was the common belief, in this country at least, shared by men of science as well as by the larger body of persons who had given no special attention to the subject, that the various forms of plants and animals recognized by naturalists in their systematic arrangements of genera and species were permanently fixed and unalterable, that they were not subject to greater changes than might occur as occasional variations, and that such was the tendency to the maintenance of uniformity in their specific characters that, when varieties did arise, there was a natural disposition to return, in the course of succeeding generations, to the fixed form and nature supposed to belong to the parental stock; and it was also a necessary part of this view of the permanency of species that each was considered to have been originally produced from an individual having the exact form which its descendants ever afterwards retained. To this scientific dogma was further added the quasi-religious view that in the exercise of infinite wisdom and goodness, the Creator, when He called the successive species of plants and animals into existence, conferred upon each precisely the organization and the properties adapting it best for the kind of life for which it was designed in the general scheme of creation. This was the older doctrine of "Direct Creation," of "Final Causes," and of "Teleological Relation of Structure and Function;" and those only who have known the firm hold which such views formerly had over the public mind can understand the almost unqualified approbation with which the reasoning on these questions in writings like the 'Bridgewater Treatises' (not to mention older books on Natural Theology) were received in their time, as well as the very opposite feelings excited by every work which seemed to present a different view of the plan of creation.

On the Continent of Europe, it is true, some bold speculators, such as Goethe, Oken, Lamarck, and Geoffroy St.-Hilaire, had, in the end of the last and commencement of this century, broached the doctrine that there is in living beings a continuous series of gradations as well as a consistent and general plan of organization, and that the creation, therefore, or origin of the different forms of plants and animals must have been the result of a gradual process of development or of derivation one from another, the whole standing connected together in certain causal relations. But in Britain such views, though known and not altogether repulsive to a few, obtained little favour, and, by some strange process of reasoning, were looked upon by the great majority as little short of impious questionings of the supreme power of the Almighty.

How different is the position of matters in this respect in our day!—when the cautious naturalist receives and adopts with the greatest reserve the statement of fixed and permanent specific characters as belonging to the different forms of organized beings, and is fully persuaded of the constant tendency to variation which all species show even in the present condition of the earth, and of the still greater liability to change which must have existed in the earlier periods of its formation—when the belief prevails that, so far from being the direct product of distinct acts of creation, the various forms of plants and animals have been gradually evolved in a slow gradation of increasing complexity—and when it is recognized by a large majority of naturalists that the explanation of this wonderful relation of connexion between previously existing and later forms is to be found in the constant tendency to variation during development and growth, and the perpetuation of such variations by hereditary transmission through successive generations in the long but incalculable lapse of the earth's natural mutations. These, together with the adaptation of structure and function to external conditions securing the survival of the fittest, are, as you must all be aware, in their essential features the views now known as Darwinism, first simultaneously brought forward by Wallace and Darwin in 1858, and which, after being more fully elaborated in the works of the latter and ably supported by the former, secured, in the incredibly short space of ten or twelve years, the general approval of a large portion of the scientific world. Opinion has, in fact, now undergone such a change that there are few works on Natural History, whether of a special or more general character, in which the relation the scientific facts bear to the newer doctrines is not carefully indicated; that, with the general public also, the words "Evolution" and "Development" have ceased to excite the feelings, amounting almost to horror, which they at first produced in the minds of those to whom they were equally unfamiliar and suspicious; and that, even in popular literature, illustrations are not unfrequently drawn in such terms of Darwinian theory as "struggle for existence," "natural selection," "survival of the fittest," and the like.

It cannot be doubted that in this country, and partly on the Continent, the influence of authority had much to do with the persistence of the older teleological views; and, as has been well remarked by Haeckel, one of the ablest and keenest supporters of the modern doctrine, the combined influonce more especially of the opinions held by three of the greatest naturalists and biologists who have ever lived, Linnæus, Haller, and Cuvier (men unsurpassed in the learning of their time, and the authors of important discoveries in a wide range of biological science), was decidedly adverse to the free current of speculative thought upon the more general doctrines of biology. And if it were warrantable to attribute so great a change of opinion as that to which I have adverted as occurring in my own time to the influence of any single intellect, it must be admitted that it is justly due to the vast range and accuracy of his knowledge of scientific facts, the quick appreciation of their mutual interdependence, and, above all, the unexampled clearness and candour in statement of Charles Darwin.

But while we readily acknowledge the large share which Darwin has had in guiding scientific thought into the newer tracks of biological doctrine, we shall also be disposed to allow that the slow and difficult process of emancipation from the thraldom of dogmatic opinion in regard to a system of creation, and the adoption of large and independent views more consistent with observation, reason, philosophy, and religion, has only been possible under the effect of the general progress of scientific knowledge and the acquisition of sounder methods of applying its principles to the explanation of natural phenomena.

I have already referred to Goethe, Oken, Lamarck, and Geoffroy St.-Hilaire as among the most prominent of the earlier pioneers in the modern or reformed conceptions of biological laws. But were it desirable to mark the progress of opinion by quoting other authors and labourers whose contributions have mainly supplied the materials out of which the new fabric has been constructed, I should have to produce a long catalogue of distinguished names, among which would be found those of Lyell and Owen, as earliest shaping the doctrines and guiding opinion in this country, Johannes Müller and Von Baer, as taking the places of Haller and Cuvier on the Continent, and a host of other faithful workers in Biology belonging to the earlier part of this century, such as G. Treviranus, J. F. Meckel, Carus, and many more *. To Huxley more especially and Herbert Spencer the greatest influence on British thought in the same direction is to be ascribed.

Let us hope that in these times, when it has been found necessary to modify the older teleological views to so great an extent, although there may still be much that is unknown, and wide differences of opinion in regard to the nature and sequence of natural phenomena and the mode of their interpreta-

* It would also be unjust to omit to mention here one of the earliest attempts to bring British opinion into a new channel, by the remarkable work entitled 'Vestiges of Creation,' which appeared in 1844, nor to conceal from ourselves the unmerited ridicule and obloquy attempted to be thrown upon the author, not perhaps so much on account of the many inaccuracies unavoidable in the endeavour at that time to overtake so large a field, as directed against the dangerous tendencies supposed to lurk in its reasoning.

tion, all naturalists will now concur in one important principle, viz. that as truthful observation and candid judgment must alone be our guides in the interpretation of Nature, that theory of Creation is best deserving of our adoption which is most consistent with the whole body of facts carefully observed and compared.

To attempt to trace, within the limits to which my remarks must be confined, the influence which the progress of knowledge has exercised upon the scientific and general conception of biological doctrines would be impossible, for the modification of opinion on these subjects has proceeded not less from the rapid advance which our age has witnessed in the progress of general science, especially of physics and chemistry, than from that in the department of biology itself.

Thus, to go no further than the most general laws of nature, the whole doctrine of the conservation and transmutation of force in Physics, so ably expounded to this Association by Mr. Justice Grove, the theory of compound radicals and substitution, with the discovery of organic synthesis, in Chemistry, and the more recent advance in speculation with regard to the molecular constitution and properties of matter, with which we must associate the names of our last President and of Clerk Maxwell, in completely changing the aspect of physical and chemical sciences within the last thirty-five years, have paved the way for views of the constitution and action of organized bodies very different from those which could be formed at the time of the first Meeting of the Association in this place. And if, confining ourselves to the department of Biology, we note the discovery by microscopical observation of the minuter elementary forms of organization, more especially as flowing from the comprehensive views of organized structure promulgated by Schleiden and Schwann nearly forty years ago, the later discovery and investigation of living protoplasmic substances, the accumulated evidence of progressive and continuous types of animal and vegetable forms in the succession of superimposed strata composing the crust of the earth, the recent discoveries as to the conditions of life at great depths in the ocean, the vast body of knowledge brought together by the labours of anatomists and physiologists as to the structure and functions of almost every plant and animal, and (still more, perhaps, than any other single branch of biological inquiry) if we note the rapid and immense progress which has been made during the last fifty years in the study of the entirely modern science of the development of individual living beings, we shall be able to form some conception of the enormous extension in our time of the basis of observation and fact from which biological phenomena may now be surveyed, and from which just views may be deduced as to their mutual relations and general nature.

It is now familiarly known that almost all (if not, indeed, all) the plants and animals existing on the earth's surface derive their origin from parents or previously existing beings whose form and nature they closely reproduce in their life's history. By far the greater number spring from germs in the form of visible and known spores, seeds, or eggs; a few may be traced to other germs, or to vestiges of the parental body, the exact nature of which may be doubtful; and some, including even a certain number of those also produced from known germs, are either constantly or occasionally multiplied by budding, or by a process of cleavage or direct and visible division of the parent body.

The germ constituting the basis of new formation, whether it be of unknown nature or in the form of spore, seed, or ovum, is of the simplest kind of organization, and the process by which a new plant or animal is produced is necessarily one of gradual change and of advance from a simpler to a more complex form and structure: it is one of "evolution" or, more appropriately named, of "development." But before proceeding to discuss the subject of development in beings of which the germs are known, it is right to advert to the preliminary and often debated question, which naturally presents itself, viz.:—Do all living or organized beings, without exception, spring from germs, or from any kind of organized matter that has belonged to parents? or may there not be some, especially among the simpler forms (with regard, indeed, to which alone there has of late been any question), which are produced by the direct combination of their component elements, in the way of the so-called spontaneous or equivocal generation, heterogenesis or abiogenesis?

The importance of the right solution of this problem is not confined merely to the discovery of the mode of origin of the lowly organisms which have been the more immediate object of investigation by naturalists in recent times, but is one of much wider significance, seeing that, if it shall be satisfactorily proved or even rendered probable that in the course of cosmical development all the various kinds of plants and animals have been gradually produced by evolution out of preexisting simpler forms, and thus the whole series of organized beings in nature is shown to be one of hereditary connexion and derivation, then it would follow that the history of the origin of the simplest organisms may be the key to that of the first commencement of life upon the earth's surface, and an indication of the relation in which the whole succeeding progenies stand to their parental stocks.

From the very lucid and masterly view of this subject given by Prof. Huxley in his Address to the Association at Liverpool, so recently as in 1870, in which the conclusion he formed was mainly based on the exhaustive and admirable researches of Pasteur, I might have dispensed with making further reference to it now, but for the very confident statements since made by the supporters of the doctrine of Abiogenesis, among whom Dr. Bastian stands most prominent in this country, and for the circumstance that the life-history of many of the lower organisms was still imperfectly known.

During the last seven or eight years, however, renewed investigations by most competent inquirers have followed one another in quick succession, from a review of which we cannot but arrive at a conclusion adverse to the theory of Heterogenesis, namely, that no development of organisms, even of the most simple kind, in fermenting or putrefying solutions, has been satisfactorily observed to occur when the conditions of the experiments were such as entirely to exclude the possibility of their being descended from germs, or equivalent formative particles, belonging to preexisting bodies of a similar kind. I can do no more here than name the authors of the most conclusive experiments on this subject, nearly in the order of their publication, as those of Mr. W. N. Hartley in 1872, Messrs. Pode and Ray Lankester in 1873, Dr. Burdon Sanderson in that and the following years, Dr. W. Roberts in 1874, Professor Lister in 1875, and most recently of Professor Tyndall, Professor Cohn, and of Messrs. Dallinger and Drysdale*.

But, admitting that the evidence from direct experiment is such as entirely to shut us out from entertaining the view that spontaneous generation occurs in the present condition of the earth, we are not relieved from the difficulty of explaining how living organisms or their germs first made their appearance, nor are we debarred from attempting to form hypotheses as to how this may have taken place. First, upon the theory of Evolution, which, strictly carried out, supposes the more complex organisms to be derived from the more simple, it might be held that the conditions affecting the combination of the primary elements of matter into organic forms may at one time have been different from those which now prevail, and that, under those different conditions, abiogenesis may have been possible, and may have operated to lay the foundations of organic life in the simpler forms in which it at first appeared—a state of things, however, which can

* I may refer to Dr. Bastian's paper in 'Nature' of June 30, 1870, and to his two works, 'The Origin of the Lowest Organisms' and 'The Beginnings of Life,' and papers to Roy. Soc. 1873. Mr. Hartley's researches, which were commenced in 1865, are described in a paper printed in the Proceedings of the Royal Society for 1872, and in his 'Lectures on Air,' 2nd edition, 1876, where an interesting account of the whole subject will be found. The experiments of Mr. Pode, of Oxford, and Professor Ray Lankester are described in a paper on the "Development of *Bacteria* in Organic Infusions," in the Roy. Soc. Proc. 1873, vol. xxi. p. 349. Dr. Burdon Sanderson's researches are contained in the Reports of the Medical Officer of the Privy Council, and in various papers in 'Nature'; Dr. W. Roberts's paper is printed in the Transactions of the Royal Society for 1874, vol. clxiv. p. 457. Professor Lister's "Contribution to the Germ Theory of Putrefaction and other Fermentative Changes," &c. is contained in the Transactions of the Royal Society of Edinburgh for 1875, p. 313, and is also given in 'Nature.' Professor Tyndall's researches are described in his papers in the Proceedings of the Royal Society during the last two years. The work of Professor Cohn, of Breslau, entitled 'Beiträge zur Biologie der Pflanzen,' 1873–76, contains many memoirs bearing upon this subject, which have been partly published in abstract in the 'Microscopical Journal,' in which also will be found, in a series of contributions extending from 1873 to the present time, the interesting observations of Mr. W. H. Dallinger and Dr. J. Drysdale.

only be vaguely surmised, and in regard to which no exact information can be obtained. Or, secondly, evading the difficulty of strict cosmical evolution, we might suppose that vital conditions may have been coeval with the first existence of physical and chemical properties in the rest of natural bodies. But this hypothesis would be exposed to the objection that, according to the cosmical view generally held by physicists, the whole materials composing the earth have originally been subjected to incandescent heat. Nor is the difficulty abolished, but only removed to a more remote period, by the supposition of the transport of germs from another planet or their introduction by means of meteorites or meteoric dust; for, besides the objection arising from the circumstance that these bodies must have been subjected to a very high temperature, we should still have every thing to learn as to the manner in which the germs originated in the far distant regions of space from which they have been conveyed.

The incompleteness of the geological record leaves us in the dark as to the time at which the first dawnings of life appeared in the lower strata of the earth's surface. The most recent researches tend to carry the origin of life back to a much earlier period than was at one time believed, and (if the famous *Eozoon* be admitted as evidence) even into that of the Laurentian strata. But if doubts should still prevail with regard to the presence of definite organized forms in the older sedimentary strata, the occurrence in them of carbon in the form of graphite in large quantities makes the previous existence of living organisms at least possible, and it may be that the complete metamorphosis which these rocks have undergone has entirely removed all definite traces of organization.

Nor have we the means from geological data of determining whether the beings of the vegetable or of the animal kingdom first made their appearance. If we adopt the view which has for some time been entertained by physiologists that animals are entirely dependent, directly or indirectly, on plants for the material which constitutes their living substance, and that plants, as constructive agents, alone have the power to bring together the elements of lifeless matter, from such states as carbonic acid, water, and ammonia, into the condition of the living solid, the inference would be inevitable, at least for the great majority of the animal creation, that they must have been preceded by plants. But palæontology is as yet silent on this interesting question; and, if we consider the remarkable approach which is made in structure and properties between the lowest and simplest members of the two kingdoms of organic nature, so that at last all distinction between them seems entirely to vanish, and a set of organisms is found partaking equally of animal and vegetable characters, or, rather, exhibiting properties which are common to them both, we shall hesitate to postulate confidently for the primitive antecedence of vegetable life, although, perhaps, in later epochs the preexistence of vegetables may be looked upon as necessary to the life of more developed animal organisms.

But while we thus speculate on the first appearance of organized bodies in nature, we ought to keep in mind that we are equally ignorant of the mode of origin of the inorganic elements and their compounds; and we may therefore be excused if we suspend all theory and conjecture until we shall be guided to more reliable hypotheses through the plain track of observation and experiment.

The practical applications of the increased knowledge of the origin of minute animal and vegetable organisms are so numerous that it would occupy a much longer time than is at my disposal to give any detailed account of them; but they are of such immense importance in their commercial, social, and sanitary relations that they ought never to be lost sight of.

It is now proved beyond doubt that the origin of putrefaction and fermentation is dependent on the presence in the substances which are the seat of change in these processes, or in the surrounding air, of the germs of minute organisms of an animal or vegetable nature, and that the maintenance of the chemical changes in which these processes mainly consist is coincident with and casually (if not essentially) dependent upon the growth and multiplication of these organisms.

Professor Lister had the merit of being the first to apply the germ theory of putrefaction to explain the formation of putrid matters in the living body; and he has founded on this theory the now well-known antiseptic treatment of wounds, the importance of which it would be difficult to overestimate.

The success or failure of plans for the preservation of meat and other articles of food without question depends on the possibility of the complete exclusion of the germs which are the cause of putrefaction and fermentation; and the management of such plans must therefore be founded on the most accurate knowledge of these organisms, and the circumstances influencing the persistence of their vitality and the vigour of their growth.

The theory of Biogenesis has also lately been the guide in the investigation of the causes of various forms of disease, both in the lower animals and in man, with the result of showing that in many of them the infective substance consists, in all probability, of germs of minute animal or vegetable organisms.

There is very great probability, indeed, that all the Zymotic diseases (by which we understand the various forms of fevers) have their origin in germs. As has been well remarked by Baxter in an able paper on "The Action of Disinfectants," the analogies of action of contagia are similar to those of septic organisms, not to processes simply of oxidation or deoxidation. These organisms, studied in suitable fluids, multiply indefinitely when introduced in all but infinitesimal proportions. Thus they are, as near as we can perceive, the very essence of contagia*.

* For the most interesting information on this subject, I cannot do better than refer to the very able Papers by Dr. Burdon Sanderson in the 'Reports of the Medical Officer of the Privy Council,' 1873, 1874, and 1875.

Leaving, however, these and many other general questions regarding the origin of the lowest forms of animal and vegetable life, let us now turn our attention to the mode of development of a new being in those possessing more obvious and known germs. The general nature of the formative process, in all instances where fertilized germs are produced, will be best understood by a short sketch of the phenomena ascertained to occur in different kinds of plants.

In the higher or Phanerogamic plants it is generally well known that the combination of two parts of the flower is necessary to the production of a seed containing the embryo or young plant. Beginning with the discovery of the pollen-tubes by Amici in 1823, the careful and minute investigations of a long line of illustrious vegetable physiologists have brought to light the details of the process by which fertilization is effected, and have shown, in fact, how the minute tube developed from the inner membrane of the pollen-granule, as soon as it falls upon the stigmatic tissue of the seed-bearing plant, insinuates itself by a rapid process of development between the cells of the style, and reaches at last the ovule, in the interior of which is the embryo-sac; how, having passed into the micropyle or orifice of the ovule, it makes its way to the embryo-sac; how a minute portion of the fertilizing substance of the fovilla transudes from the pollen-tube into the cavity of the embryo-sac, in which by this time a certain portion of the protoplasm has become differentiated into the germinal vesicle—thereby stimulating it to further growth and development, the earliest phenomena of which manifest themselves by the formation of an investing cell-wall, and by the occurrence of cell-division which results in the formation of the embryo or plantule of the seed.

Thus it appears that the essential part of the process of production in Phanerogamic plants is the formation in the parent plant of cells of two different kinds, which by themselves have little or no independent power of further growth, but which, by their union, give rise to a product in which the power of development is raised to the highest degree.

By further researches it is now known that the same law prevails in all the remaining members of the vegetable kingdom, with the exception only of the very simplest forms *.

In viewing the reproductive process in the series of Cryptogamic plants, two facts at once strike us as remarkable in the modifications which are observed to accompany the formation of a productive germ, viz.:—first, that the difference between the two productive elements becomes more prominent, or as it were more highly specialized, in the Cryptogamic than in the Phanerogamic plants; and second, that in the simpler and lower forms this difference gradually disappears till it is lost in complete uniformity of the productive elements.

* It will be observed that I leave entirely out of view the whole subject of the multiplication of plants by budding or simple division.

Thus in the whole tribe of the Ferns and Vascular Cryptogams, in the higher Algæ and Fungi, in the Characeae and in the Mosses, the differentiation of the productive elements is carried to a very high degree; for while that belonging to the embryo or germ presents the structure of a simple cell which remains at rest, or in a comparatively passive state, and, absorbing into itself the substance of the other, becomes the seat of subsequent development, the other, corresponding to the pollen of the staminiferous phanerogam, is usually separated from the place of its formation, and, having undergone a peculiar modification of structure by which it acquires active moving cilia, it changes place and is directed towards the germinal structure, and, coming in contact with its elementary cell, is more or less absorbed or lost in the fertilizing process. The protoplasm of the germinal cell thus acted on and fertilized then proceeds to undergo the changes of development by which the foundation is laid for the new plant.

In the Algæ and Fungi, however, there are gradations of the differentiation of the two reproductive elements which are of the greatest interest in leading to a comprehension of the general nature of the formative process. For in the lower and simpler forms of these plants, such as the Desmidieæ, Mesocarpeæ, and other Conjugatæ, we find that there is no distinction in structure or form to be perceived between the two cells which unite in what is termed conjugation; and a complete fusion or intermixture of the two masses of protoplasm results in the production of a single, usually spherical, mass holding the place of an embryo. And that there is an absence of specialization between the two uniting cells is clearly shown, in both *Desmidium* and *Mesocarpus*, by the fact that the embryo or zygospore is formed in the mass resulting from the union of the protruded portions of the two cells; while in more ordinary cases, as in *Spirogyra*, where the embryo is formed in one of the two cells, it seems to be indifferent in which of them it is formed.

From this, which may be regarded as the most elementary type of new production by the union of two cells, the transition is not a great one to the development of a progeny without any such union. We might conjecture, then, that the capacity for separate or individual existence extends in the lowest organisms to the whole or to each structural element of their organization, while as we rise in the scale of vegetable life (and the same view might apply to the animal kingdom) this capacity is more and more divided between the two productive elements, or, at least, is only called into full action by their combination.

The germinal element of plants thus consists of a simple primordial cell, varying in different kinds, but in all of them probably containing the essential substance protoplasm; and the most immediate result or effect of fertilization is the multiplication by repeated fissiparous division of the previously existing cells. The new individual resulting from this cellular growth usually remains within the parent body, without, however, direct union or continuity of tissue, till the embryo has attained some advancement, as in the well-known case of the seeds of a phanerogam; but there are many varieties in the mode of its disposition among the lower plants.

A remarkable exception to the more direct relation of the process of fertilization to the formation of the new individual or embryo occurs in some plants, simulating in some respects that kind of variation in animal reproduction which has been named alternate generation. A well-known instance of this is observed in the Vascular Cryptogams. The prothallium of the Ferns, for example, results from the development of so-called spores or unicellular buds, which are familiar as being formed in small capsules on the lower leaf-surface; and in this prothallium, when it has reached a certain stage of vegetation, there are formed the archegonia, containing the oospheres or germ-cells, which are fertilized by the moving ciliated particles developed in the cells of the antheridia, the process resulting in the production of a new spore-bearing frond or fern-plant.

Recent researches have also called attention to the remarkable arrangements in many Phanerogamic plants for the prevention of fertilization of the pistils by pollen from the same flower, or even from the same plant. In the latter case this is effected by the separation of stamens and pistils in different flowers. In the former case, where both organs occur in the same flower, the adaptations, whether of a mechanical or of a physiological character, by which self-fertilization is prevented, as ascertained by numerous recent investigations (among which those of Darwin are most conspicuous), are of the most varied and often the most complicated kind.

Let us now turn to the consideration of the Development of Animals; and let me say in the outset that it will be necessary for me to confine my remarks chiefly to the higher or vertebrated animals, and to certain parts only of the history of their development—more particularly the structure and formation of the ovum or egg, some of its earlier developmental changes, and the relation of these to the formation of the new animal.

I cannot enter upon the consideration of this topic without adverting to the very recent acquisition of some of the most important facts upon which this branch of knowledge is founded; and I feel it to be peculiarly appropriate, in the year of his death, to refer to a Biologist whose labours contributed more powerfully than those of any other person to give to animal embryology the character of a systematic branch of science, and to whom we owe some most important original discoveries—I mean Karl Ernest von Baer of Königsberg, St. Petersburg, and Dorpat.

Of observers who, previous to Von Baer, were mainly instrumental in preparing the way for the creation of a more exact modern science of embryology only two can be mentioned, viz. Caspar Frederick Wolff of St. Petersburg, well known as the author of a work entitled 'Theoria Generationis,' published in 1759, by which the *epigenesis* or actual formation of organs in a new being was first demonstrated, and Christian Pander, who, by his researches made at Würzburg, explained, in a work published in 1817, the principal changes by which the embryo arises and is formed.

Von Baer was born in the Russian province of Esthonia on the 29th of February, 1792. After having been fifteen years Professor in the Prussian University of Königsberg, he was called to St. Petersburg, and having some years later been appointed to a newly established professorship of Comparative Anatomy and Physiology, he remained in that city for nearly thirty years as the most zealous and able promoter of scientific education and research, stimulating and guiding all around him by his unexampled activity, comprehensive and original views, sound judgment, and cordial cooperation. In 1868, at the age of 76, he retired to Dorpat, from the University of which he had received his degree in 1814, and continued still to occupy himself with working and writing in his favourite subjects, as well as interesting himself in every thing connected with educational and scientific progress, to very near the time of his death, which occurred on the 28th of November, 1876, in his 85th year.

Although Von Baer's researches, according to the light in which we may now view them, contributed in no small degree to the introduction of the newer views of the morphological relations of organic structure which have culminated in the Theory of Descent, yet he was unwilling to adopt the views of Darwin; and one of his latest writings, completed in the last year of his life, was in vigorous opposition to that doctrine.

It would have been most interesting and instructive to trace the history of the progress of discovery in Embryology from the period of Von Baer down to the present time; but such a history would not be suitable to the purpose of this address; and I can only venture here, in addition to Rathke, the colleague of Baer in Königsberg, to select two names out of the long list of distinguished workers in this field during the last forty years, viz.:—Theodor F. W. von Bischoff, of Giessen and Munich, to whom we owe the greatest progress in the knowledge of the development of Mammals, by his several memoirs, appearing from 1842 to 1854; and Robert Remak, of Berlin, whose researches on the development of Birds and Batrachia, appearing from 1850 to 1855, gave greatly increased exactness and extension to the general study of development.

The germinal element from which, when fertilized, the new animal is derived is contained within the animal ovum or egg—a compact and definite mass of organic matter, in which, notwithstanding great apparent variations, there is maintained throughout all the members of the animal kingdom, excepting the Protozoa, which are destitute of true ova, a greater uniformity in some respects than belongs to the germinal product of plants.

Usually more or less spherical in form, the animal ovum presents the essential characters of a "complete cell," in the signification given by Schwann to that term. The germinal substance is enclosed by an external vesicular membrane or *cell-wall*. Within this covering the *cell-substance* (generally named yolk or vitellus, from the analogy of the fowl's egg) consists, to a greater or less extent, of a mass of protoplasm; and imbedded in this mass, in a determinate situation, there is found a smaller internal vesicular body, the *germinal vesicle* or nucleus, and within that the somewhat variable *macula* or nucleolus.

Now the first thing which strikes us as remarkable connected with the ovum is the very great variation in its size as compared with the entire animal to which it belongs, while in all of them the same simple or elementary structure is maintained. The ovum of mammals, for example (discovered by Von Baer in 1827) is a comparatively small body, of the average diameter of about $\frac{1}{150}$ of an inch, and consequently scarcely weighing more than a minute fraction of a grain, perhaps not more than the $\frac{1}{12000}$ part. And further, in two animals differing so widely in size as the elephant and the mouse, the weights of which may stand towards each other in the proportion of 150,000 to 1, there is scarcely any difference in the size of the mature ovum.

On the other hand, if we compare this small ovum of the mammal with the yolk of the egg in the common fowl, the part to which it most nearly corresponds, it may be estimated that the latter body would contain above three millions of the smaller ova of a mammal.

The attribute of size, however, in natural objects ceases to excite feelings of wonder or surprise as our knowledge of them increases, whether that be by familiar observation or by more scientific research. We need not, at all events, on account of the apparent minuteness of the ovum of the mammifer or of any other animal, have any doubts as to the presence of a sufficient amount of germinal substance for explaining in the most materialistic fashion the transmission of the organic and other properties and resemblances between the parent and offspring. For we are led to believe, by those who have recently given their attention to the size of molecules composing both living and dead matter, that in such a body as this minute ovum of the mammal there may be as many as five thousand billions of molecules; and even if we restrict ourselves to the smaller germinal vesicle, and, indeed, to the smallest germinal particle which might be made visible by the highest microscopic enlargement, there are still sufficient molecules for all the requirements of the most exacting material biologist *.

* According to a calculation made by Mr. Sorby, the number of molecules in the germinal vesicle of the mammalian ovum is such that if one molecule were to be lost in every second of time, the whole would not be exhausted in seventeen years. See Address to the Microscopic Society, in Journ. of Microscop. Science, vol. xv. p. 225, and 'Nature,' vol. xiii. p. 332. See also Darwin on "Pangenesis," in his work on 'Variations,' &c. (1868),

This great disparity of size, however, is connected with an important difference in the disposition of the yolk-substance, according to which ova may be distinguished as of two kinds—the large- and the small-yolked ova, between which there are also many intermediate gradations. The larger-yolked ova belong to the whole tribe of birds, scaly reptiles, osseous and cartilaginous fishes, and the Cephalopods among the Invertebrates; and are distinguished by the strictly germinal part or protoplasm being collected into a small disk, known familiarly as the cicatricula of the fowl's egg, and to be seen as a whitish spot on that side of the yolk which naturally floats uppermost, while the rest of the yolk, of a deeper yellow colour, contains a large quantity of vitelline granules or globules of a different chemical nature from the protoplasm.

The phenomena of embryonic development are, in the first instance at least, confined to the germinal disk, and the rest of the yolk serves in a secondary or more remote manner to furnish materials for nourishment of the embryo and its accessory parts. Thus we distinguish the germinal from the nutritive or food-yolk, or, as the younger Van Beneden has named them, the *protoplasm* and the *deutoplasm*.

In the smaller ovum of the mammal, on the other hand, it seems as if the whole, or nearly the whole, of the yolk were protoplasmic or germinal. There may be some admixture of yolk-granules; but there is not the marked separation or limitation of the protoplasmic substance which is so distinct in birds, and the earliest changes of development extend to the whole component substance of the yolk, or, in other words, the yolk is entirely germinal. Hence some have given the names of *meroblastic* and *holoblastic* (meaning partially and entirely germinal) to these two contrasting forms of ova. There are many of the invertebrate animals of which the ova present the same entirely germinal arrangement as in those of mammals, and the *Amphioxus* may be included in the same group.

The Amphibia stand in some measure between the two extremes—the purely protoplasmic or germinal part occupying one side, and the nutritive or vitelline the other. But among the Invertebrates the gradations are often such as to make it difficult to determine under which group the ova should be placed.

The genesis or formation of the ovum itself, if it be considered with reference to its first origin, carries us back to a very early period of the development of the parent in which it is produced; and it is one of the most interesting problems to determine what is the source of the cells in the parent from which the reproductive elements originally spring. All that I can venture to say at present in regard to this point is, that the primordial ova or

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vol. ii. p. 374, and the Review by Ray Lankester of Haeckel's work, 'Perigenesis der Blastidule,' &c., in 'Nature' for 1876, p. 235, and Ray Lankester's essay on 'Comparative Longevity,' 1870.

germs appear in the parental body, while still embryonic, at a very early period of its development, and clearly derive their origin from a deeply-seated part of the formative cells which are undergoing transformation into the primitive organs; but the exact seat of the origin of the two kinds of reproductive cells is still a matter of doubt.

When the ovum attains its full maturity in the ovary, the seat of its formation within the parent, it is separated from that organ, and when fertilized proceeds to undergo embryonic development, differing in this respect from the germinal product of the higher plants, in which the embryo is developed in the place of formation of the seed.

The period of maturation of the ovum is marked in the greater number of animals by a series of phenomena which have generally been interpreted as the extrusion or absorption of the germinal vesicle; and various observers have actually traced the steps of the process by which that vesicle appears to leave the yolk and is lost to sight, or has passed into the space between the yolk and its membrane in the shape of the peculiar hyaline bodies named the *polar* or *directing* globules. But recent researches, afterwards to be referred to, tend to show that some part at least of the substance of the germinal vesicle remains to form, when combined with the fertilizing element, the newly endowed basis of future development.

Among the earliest changes to which the perfect animal ovum is subject, I have first to refer to the segmentation of the germ, a series of phenomena the observation of which has been productive of most important results in leading to a comprehension of the intimate nature of the formative process, and which is of the deepest interest both in a morphological and histological point of view. This process, which was first distinctly observed by Prevost and Dumas more than fifty years ago, and is now known to occur in all animal ova, consists essentially in the cleavage or splitting up of the protoplasmic substance of the yolk, by which it becomes rapidly subdivided into smaller and more numerous elements, so as at last to give rise to the production of an organized stratum of cells out of which, by subsequent changes, the embryo is formed.

The process of yolk-segmentation may at once be distinguished as of two kinds, according as it affects in the small-yolked ova the whole mass of the yolk simultaneously, or in the large-yolked ova is limited to only one part of it. The cleavage process, in fact, affects the germinal and not the food-yolk; so that to take the two most contrasting instances of the bird and mammal, to which I have before referred, it appears that while the mammal's ovum undergoes entire segmentation, this process is confined to the substance of the cicatricula or germinal disk of the bird's egg. This process is essentially one of cell-division, but it is also in some measure one of cell-formation. The best idea of its nature will be obtained from a short description of the total segmentation occurring in the mammal's ovum.

When, as before mentioned, the germinal vesicle has been in part extruded or lost to sight, the whole yolk-substance of the ovum forms a nearly uniform mass of finely granular protoplasm, enclosed within the external cell-membrane. Within a few hours later a clear nucleus has arisen in this mass. To this more definite form of organization assumed by the germinal substance of the future animal, which is about to be the subject of the segmenting process, the name of the first segment-sphere may be given.

By the process of cleavage which now begins, this first segment-sphere and its nucleus undergo division into two nucleated spheres of smaller size, the whole substance of the yolk, in a holoblastic ovum, such as that of the mammal, being involved in the segmenting process.

The second stage of division follows after the lapse of a few hours, and results in the formation of four nucleated segment-spheres; and the process of division being repeated in a certain definite order, there result in the succeeding stages (that is, the third, fourth, fifth, and up to the tenth) the numbers of 8, 12, 16, 24, 32, 48, 64, and 96 nucleated yolk-spheres, germ-spheres, or formative cells.

In the rabbit's ovum the tenth stage is reached in less than three days; and as during that time the size of the whole ovum has undergone very little increase, it follows that the spheres of each succeeding set, as they become more numerous, have diminished greatly in size. These segment-spheres are all destitute of external membrane, but are distinctly nucleated; and their protoplasmic substance is more or less granular, presenting the usual histological characters of growing cells.

By the time that segmentation has reached the seventh or eighth stage, when 32 or 48 spheres have been formed, the ovum has assumed the appearance of a mulberry, in which the outer smaller spheres, closely massed together, project slightly and uniformly over the whole surface; while the interior of the ball is filled with cells of a somewhat larger size and a more opaque granular aspect, also resulting from the process of segmentation.

Already, however, the mutual compression of the spheres or cells on the surface, by their crowding together, has led to the flattening of their adjacent sides; and by the time the tenth stage is reached, when the whole number of the cells is about 96, the more advanced superficial cells, having ranged themselves closely together, form a nucleated cellular layer or covering of the yolk, enclosing within them the larger and more opaque cells, derived like the first from the segmenting process. In a more advanced stage, the deeper cells now referred to having taken the form of an internal layer, there results at last the bilaminar blastoderm or embryonic germinal membrane.

The process of partial segmentation, such as occurs in the bird's egg, though perhaps fundamentally the same as that of the mammal previously described, stands in a different relation to the parts of the whole yolk or egg, and consequently differs in its general phenomena. The segmentation is mainly restricted in the meroblastic ova of birds to the germinal disk or cicatricula, and does not immediately involve any part of the larger remainder of the yolk. This takes place during the time of the descent of the yolk through the oviduct, when the yolk is receiving the covering of the white or albumen, the membrane, and the shell, previous to being laid—a process which, in the common domestic fowl, usually occupies less than twenty-four hours. Corresponding essentially to the more complete segmentation of the mammal's ovum, the process leads to the same result in the production of two layers of nucleated formative cells in the original seat of a protoplasmic disk—a bilaminar blastoderm resulting as in the mammal's ovum, though in a somewhat different relation to the yolk.

I will not fatigue you with a description of the details of these phenomena, interesting as they may be, but only mention generally that they consist in the formation of deep fissures with rounded edges running from the surface into the substance of the germ-disk. The first of these fissures crosses the disk in a determinate direction, dividing it into two nearly equal semicircular parts. In the next stage another fissure, crossing the first nearly at right angles, produces four angular segments. Then come four intervening radial fissures which subdivide the four segments into eight; and next afterwards the central angles of these eight radial segments are cut off from their peripheral portions by a different fissure, which may be compared to one of the parallels of latitude on the globe near the pole where the radial or *longitude* fissures converge. And so thereafter, by the succession and alternation of radial and circular clefts (which, however, as they extend outwards, come soon to lose their regularity), the whole germinal disk is divided into the two layers of nucleated cells, constituting the blastoderma or germinal membrane of Pander and subsequent embryologists*. If a laid egg be subjected to the heat of incubation for eight or ten hours, the cicatricula, now converted into this segmented blastoderm, is found to be considerably expanded by a rapid multiplication of its constituent cells; and in as many more hours, by further changes in its substance, the first lineaments of the chick begin to make their appearance. Similar changes affect the blastoderm of the mammal; and thus it appears that the result of segmentation, in the bird as well as in the mammal and other animals, is the production of an organized laminar substratum, which is the seat of the subsequent embryonic development.

I must still request your attention to some details connected with the process of segmentation, which bear upon the question of the origin of the

* The more exact nature of the process of segmentation was first made known by the interesting researches of Bagge in 1841, and more especially of Kölliker in 1843. The phenomena of complete segmentation were first fully described in the mammal's ovum in Bischoff's description of the development of the Rabbit, 1842, and followed out in his succeeding memoirs on the Dog, Guineapig, and Roedeer. The phenomena of partial segmentation were first made known, in their more exact form, by Kölliker's researches on the development of the Cephalopoda, published in 1844. In birds the process was first described by Bergmann in 1846, and more fully by Coste in 1848.

new cells, and on which recent research has thrown a new and unexpected light.

With respect to the nature of the first segment-sphere of the ovum and the source of its nucleus, as well as of the other segment-spheres or cells which follow each other in the successive steps of germ-subdivision, it appears probable, from the researches of several independent observers, and more especially of Edward Van Beneden and Oscar Hertwig, that in the course of the extrusion of the germinal vesicle a small portion of it remains behind in the form of a minute mass of hyaline substance, to which Van Beneden has given the name of *pronucleus*, and that, as the result of the fertilizing process, there is formed a second similar hyaline globule or pronucleus, situated near the surface, which gradually travels towards the centre and unites with the first pronucleus, and that these two pronuclei, being fused together, form the true nucleus of the first segment-sphere. According to this view the original germinal vesicle, when it disappears or is lost to sight, as described by so many embryologists, is not dissipated, but only undergoes changes leading to the formation of the new and more highly endowed nucleus of the first embryonic or segmental sphere. It further appears that the subdivision of each segmenting mass is preceded by a change and division of the nucleus, and that this division of the nucleus is accompanied by the peculiar phenomenon of a double conical or spindle-shaped radial lineation of the protoplasm, which, if we were inclined to speculate as to its nature, seems almost as if it marked out the lines of molecular force acting in the organizing process. These lines, however, it will be understood, if visible with the microscope, even of the highest magnifying-power yet attained, belong to much larger particles than those of the supposed molecules of the physicist; but, considered in connexion with what we know of the movements which frequently precede the act of division of the yolk-spheres, we seem in this phenomenon to have made some near approach to the observation of the direction in which the molecular forces operating in organization may be supposed to act*.

With respect to the nature of the blastoderm, the organized cellular stratum resulting from segmentation, and its relation to the previous condition of

* The observations referred to above as to the division of the nucleus are so novel and of such deep interest that I am tempted to add here a short abstract of their more important results from a very clear account given of them by Dr. John Priestley, of Owens College, Manchester, in the 'Journal of Microscopical Science' for April 1876.

The researches now referred to are those of Auerbach, Butschli, Strasburger, Hertwig, and Edw. Van Beneden; and the following may be stated as the points in which they mainly agree:—

The nucleus when about to divide elongates into a spindle-shaped body, becomes irregular and indistinct, acquires a granular disk or zone in the plane of its equator; this divides the ovum on the one hand, and the future embryo on the other, there is presented to us, by modern research, the interesting view that the blastoderm consists, after completion of the segmenting process, of two layers of cells—an outer or upper (usually composed of smaller, clearer, and more compact nucleated cells), named *ectoderm* or *epiblast*, and an inner or lower (consisting of cells which are somewhat larger, more opaque and granular, but also nucleated), named *endoderm* or *hypoblast*.

In the meroblastic ova, such as those of birds, the bilaminar blastoderm is discoid and circumscribed as it lies on the yolk-surface, and only comes to envelop the whole of the food-yolk in the progress of later development; while in the holoblastic ova, and more especially in mammals, the blastoderm from the first extends over the whole surface of the yolk, and thus forms an entire covering of the yolk known as the "vesicular blastoderm," the space within being occupied by fluid.

Huxley long ago presented the interesting view that these two layers are essentially the same, in their morphological relations and histological structure, as the double wall of the body in the simplest forms of animals above the Protozoa. Haeckel has more recently followed out this view, supporting it by his researches in the Calcareous Sponges, and has founded upon it his well-known *Gastræa* theory. According to this view all animals take their origin from a form of *Gastrula*, or simple stomach-like cavity. In the lower tribes, as in the instance of the common freshwater polype or Hydra, they proceed no further than the Gastrula stage, unless by mere enlargement and slight differ-

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into two, and each half moves towards the pole of the spindle on its own side, there being radiated lines of protoplasm between the poles and the equatorial disk.

The disk segments are the new nuclei, and the subsequent division of the cell takes place in the intermediate space.

Although these observers still differ in opinion upon some of the details of this process, and especially as to the fate of the germinal vesicle, all of them seem to agree that there are two pronuclei or distinct hyaline parts of the yolk-protoplasm, a superficial and a deep one, engaged in the formation of the new nucleus; and both Hertwig and Van Beneden are of opinion that the two proceed from different productive elements.

The radiated structure of the nuclei had been previously recognized by Fol and Flemming, and further observed by Oellacher.

1. Butschli's researches are published in the Nov. Act. Nat.-Cur. 1873, and in the Zeitschr. für wissensch. Zool. vol. xxv.

2. Auerbach's observations in his Organolog. Studien, 1874.

3. Strasburger's observations in his memoir 'Ueber Zellbildung und Zelltheilung,' Jena, 1875.

4. Edward Van Beneden's researches, partly in his memoir "On the Composition and Significance of the Egg," &c., presented to the Belgian Academy in 1868, and more particularly in the extremely interesting preliminary account of "Researches on the Development of Mammalia," &c., 1875, and in a separate paper in the Journ. of Microscopical Science for April 1876.

5. Oscar Hertwig's memoirs are contained in the Morpholog. Jahrbuch, 1875, and his most interesting and novel observations in the same work, 1877.

entiation of the two primitive layers of cells representing the persistent ectoderm and endoderm *.

If, pursuing this idea, we take a survey of the whole animal kingdom in its long gradation of increasing complexity of form and structure from the simplest animal up to man himself, we find that all the various modifications of organic structure which present themselves are found, in the history of the individual or ontological development of the different members of the series, to spring originally from two cellular laminæ, ectoderm and endoderm, the component elements of which may again be traced back to the first segment-sphere and primitive protoplasmic elements of the ovum.

Time does not admit of my conducting you through the chain of observation and reasoning by which Haeckel seeks to convince us of the universal applicability of his theory; but I cannot avoid calling your attention to the extremely interesting relation which has been shown to exist between the primary phases of development of the ovum and the foundation of the blastoderm in very different groups of animals, more especially by the researches of Haeckel himself, of Kowalevsky, Edward Van Beneden, and others, and which has received most efficient support from the investigations and writings of E. Ray Lankester in our own country; so that now we may indulge the well-grounded expectation that, notwithstanding the many and great difficulties which doubtless still present themselves in reconciling various forms with the general principle of the theory, we are at least in the track which may lead to a consistent view of the relations subsisting between the ontogenetic, or individual, and the phylogenetic, or race history of the formation of animals and of man.

In all animals, then, above the Protozoa, the ovum presents, in some form or other, the bilaminar structure of ectoderm and endoderm at a certain stage of its development, this structure resulting from a process of segmentation or cell-cleavage; and there are three principal modes in which the double condition of the layers is brought about. In one of these it is by inward folding or invagination of a part of the single layer of cells immediately resulting from the process of segmentation that the doubling of the layers is produced; in the second, perhaps resolvable into the first, it may be described rather as a process of enclosure of one set of cells within another; while in the third the segmented cells, arranged as a single layer round a central cavity of the ovum, divide themselves later into two layers. But the distinction of ectodermic and endodermic layers of cells is maintained, whether it be primitive and manifested from a very early period, or acquired later by a secondary process of differentiation. Thus in many Invertebrates, as also

* At this place I will only refer to one of the most recent of Haeckel's works, in which the views alluded to above are fully exposed in a series of most interesting memoirs, viz. 'Studien zur Gastræa-Theorie,' Jena, 1877; and to Dr. E. Percival Wright's translation of the account of Haeckel's views in Journ. of Microsc. Science, vol. xiv. 1874.

in *Amphioxus* among the Vertebrates, a distinct invagination occurs, while in Mammals, as recently shown by Van Beneden's most interesting observations in the rabbit's ovum, and probably also in some invertebrates, the cells of the ectoderm gradually spread over those of the endoderm during the progress of segmentation, and thus the endodermic comes to be enclosed by the ectodermic layer of cells.

From the very novel and unexpected observations of Van Beneden it further appears that from the earliest period in the process of segmentation in the mammal's ovum it is possible to perceive a distinction of two kinds of segment-spheres or cells, and that when this process is traced back to its first stage it is found that the whole of the cells belonging to the ectoderm are the progeny of, or result from the division of the upper of the two first formed segments, and that the whole of the endodermic cells are the descendants of the lower of the two first segmented cells. This, however, is not an isolated fact belonging only to mammalian development, but one which very nearly repeats a process ascertained to occur in a considerable number of the lower animals, and it seems to promise the means of greatly advancing the comprehension of the whole process of blastodermic formation. Thus ectoderm and endoderm, which are in fact the primordial rudiments of the future animal and vegetative systems of the embryo, are traced back as distinct from each other to the first stage of segmentation of the germ.

Accepting these facts as ascertained, they may be regarded as of the deepest significance in the phylogenetic history of animals; for they appear to open up the prospect of our being able to trace transitions between the earliest embryonic forms occurring in the most different kinds of ova, as between the discoid or meroblastic and the vesicular or holoblastic, through the intermediate series which may be termed amphiblastic ova*.

In the lowest animals, the two layers already mentioned, viz. ectoderm and endoderm, are the only ones known to constitute the basis of developmental organization; but as we rise in the scale of animals we find a new feature appearing in their structure, which is repeated also in the history of the formation of the blastoderm in the higher animals up to man. This consists in the formation of an intermediate layer or layers constituting the *mesoderm*, with which, in by far the greater number, is connected the formation of some of the most important bodily structures, such as the osseous, muscular, and vascular systems.

I will not stop to discuss the very difficult question of the first origin of the mesoderm, upon which embryologists are not yet entirely agreed, but will

* I ought here to refer to the elaborate memoirs of Professor Semper on the morphological relations of the Vertebrate and Invertebrate animals, contained in the 'Arbeiten aus dem Zoolog.-zootom. Institut in Würzburg,' 1875 and 1876, in which the conclusions arrived at do not coincide with the views above stated.

only remark that a view originally taken of this subject by the acute Von Baer appears more and more to gain ground; and it is this—that the mesoderm, arising as a secondary structure, that is, later than the two primary layers of ectoderm and endoderm (corresponding to the serous and mucous layers of Pander), is probably connected with or derived from both of these primitive layers, a view which it will afterwards appear is equally important ontogenetically and phylogenetically.

But whatever may be the first origin of the mesoblast, we know that in the Vertebrata this layer, separating from between the other two, and acquiring rapidly by its cell-multiplication larger proportions and much greater complexity than belongs to either ectoderm or endoderm, speedily undergoes further subdivision and differentiation in connexion with the appearance of the embryonic organs which arise from it, and in this respect contrasts greatly with the simplicity of structure which remains in the developed parts of the ectodermic and endodermic layers. Thus, while the ectoderm supplies the formative materials for the external covering or epidermis, together with the rudiments of the central nervous organs and principal sense-organs, and the endoderm by itself only gives rise to the epithelial lining of the alimentary canal and the cellular part of the glands connected with it, the mesoblast is the source of far more numerous and complex parts, viz. the whole of the true skin or corium, the vertebral column and osseous system, the external voluntary muscles and connective tissue, the muscular walls of the alimentary canal, the heart and blood-vessels, the kidneys, and the reproductive organs, thus forming much the greatest bulk of the body in the higher animals.

There is, however, a peculiarity in the mode of the earliest development of the mesoblast which is of great importance in connexion with the general history of the disposition of parts in the animal body, to which I must now refer. This consists in the division of the mesoblast in all but its central part into two laminæ, an outer or upper and an inner or lower, and the separation of these by an interval or cavity which corresponds to the space existing between the outer wall of our bodies and the deeper viscera, and which, from the point of view of the vertebrate animals is called the pleuro-peritoneal cavity, but, viewed in the more extended series of animals down to the Annuloida, may receive the more general appellation of pleuro-splanchnic or parieto-visceral cavity, or, shortly, the *cœlom*. Thus, from an early period in the vertebrate embryo, and in a considerable number of the invertebrate, a division of the mesoderm takes place into the somatopleural or outer lamina and the splanchnopleural or inner lamina—the outer being the seat of formation of the dermal, muscular, and osseous systems (the voluntomotory of Remak), and the inner of the muscular wall of the alimentary canal, as well as of the contractile substance of the heart and the vascular system generally.

It is interesting to find that there is a correspondence between the later division of the mesoderm of the higher animals derived from the two primitive blastodermic laminæ and the original absence of mesodermic structure in the lowest animals, followed by the gradual appearance, first of one layer (the external muscular in the higher Cœlenterata), and soon afterwards by the two divisions or laminæ with the intermediate cœlom.

In this account of what may be termed the organized foundation of the new being, I have entered into some detail, because I felt that our conception of any relation subsisting between the ontogenetic history of animals and their phylogenetic evolution can only be formed from the careful study of the earliest phenomena of embryonic organization. Notwithstanding the many difficulties which unquestionably still block the way, I am inclined to think that there is great probability in the view of a common bilaminar origin for the embryo of all animals above the Protozoa, and that the Vertebrate equally with the Invertebrate animals may be shown to possess, in the first stages of their blastodermic or embryonic formation, the two primitive layers of ectoderm and endoderm*.

To attempt, however, to pursue the history of the development of animals in detail would be equivalent to inflicting upon you a complete system of human and comparative anatomy. But I cannot leave the subject abruptly without an endeavour to point out in the briefest possible manner the bearing of some of the leading facts in embryology upon the general relation of ontogeny and phylogeny.

We are here brought into the contemplation of those remarkable changes, all capable of being observed and demonstrated, by which the complex organization of the body of man and animals is gradually built up out of the elementary materials furnished by the blastodermic layers—a process which has been looked upon by all those who have engaged in its study with the greatest interest and admiration. By comparing these phenomena as observed in individuals belonging to different classes and orders of animals, it is found that not only are they not different, but, on the contrary, that they present features of the most remarkable resemblance and conformity, and we are led to the conclusion that there is a general plan of development proved to extend to the members of considerable groups, and possibly capable

* If we reserve the words ectoderm and endoderm to designate the two layers of the primary bilaminar blastoderm, we may apply the terms epiblast and hypoblast to their derivatives after the formation of the mesoderm, and indicate the relations of the whole to the secondary or quadrilaminar blastoderm by the following Table:—

Primary Blastoderm	Ectoderm ...	....	Epiblast	Secondary Blastoderm.
		Mesoderm ...	Somatopleure	
			Splanchnopleure ..	
	Endoderm ...	....	Hypoblast	

of being traced from one group to another; this being in fact equivalent to the statement that there is a similar type of structure pervading the animals of each group, and a probability of a common type being ascertained to belong to them all. The main question, therefore, to be answered is whether there is or is not a general correspondence between the phenomena of development and the gradation of type in animal structure upon which anatomists and zoologists are agreed; and my object will now be to bring rapidly before you one or two of the most marked illustrations of the correspondence, drawn from the early history of development in the higher animals.

As one of the examples of the earlier phenomena of development I may refer to the change which is perceptible as early as the 18th or 20th hour of incubation in the chick, and which is reproduced in the course of development of every member of the Vertebrate subkingdom. It consists in the formation of cross clefts on each side of the primitive neural cavity, which divide off from each other a number of segments of this wall in the length of the axis of the embryo. At first there are only one or two such clefts; but they rapidly increase in a backward direction in the body of the embryo, and as development proceeds they extend into the tail itself. These are the *protovertebræ* of embryologists—not corresponding, as might at first be supposed, with the true or actual vertebræ which are formed later, but representing in an interesting manner transverse *vertebral segments* of the body, and containing within each the elements of the several structures belonging to the body-wall afterwards to be developed, including the true cartilaginous or osseous vertebral arches and the muscular plates.

This change, however, belongs to the mesodermic lamina, and occurs in an elongated thick portion of it, which makes its appearance on each side of the primitive neural canal between the epiblast and the hypoblast. The transverse cleavage is ascertained to commence near what afterwards forms the first cervical vertebra, but does not extend into the base of the cranium. And it is most interesting to note in this cleavage the formation at so early a period of the succession of *metameres* or series of similar parts, which forms a main characteristic of vertebral organization.

As intimately connected with the formation of the vertebral column, the appearance of the chorda dorsalis or *notochord* presents many points of peculiar interest in embryological inquiries.

The notochord is a continuous median column or thread of cellular structure running nearly the whole length of the rudimentary body of the embryo, and lying immediately below the cerebro-spinal canal. It occupies, in fact, the centre of the future bodies of the vertebræ. It exists as a primordial structure in the embryo of all Vertebrates, including man himself and extending down to the Amphioxus, and, according to the remarkable discovery of Kowalevsky in 1866, it is to be found among the Invertebrates in the larva of the Ascidia*.

In Amphioxus and the Cyclostomatous Fishes the notochord, growing with the rest of the body into a highly developed form, acts as a substitute for the pillar of the bodies of the vertebræ, no vertebral bodies being developed; but in Cartilaginous and Osseous Fishes various gradations of cartilaginous and osseous structures come to surround the notochord and give rise to the simpler forms of vertebral bodies, which undergo more and more distinct development in the higher vertebrates. In all instances the substance forming the vertebral bodies is deposited on the surface of or outside the notochord and its sheath, so that this body remains for a time as a vestigial structure within the vertebral bodies of the higher animals.

The observations of Kowalevsky with respect to the existence of a notochord in the Ascidia, which have been confirmed by Kupfer and others, have produced a change little short of revolutionary in embryological and zoological views, leading as they do to the support of the hypothesis that the Ascidian is an earlier stage in the phylogenetic history of the mammal and other Vertebrates. The analogy between the Amphioxus and Ascidian larva is certainly most curious and striking as regards the relation of the notochord to other parts; and it is not difficult to conceive such a change in the form and position of the organs in their passage from the embryonic to the adult state as is not inconsistent with the supposition that the Vertebrates and the Ascidia may have had a common ancestral form. Kowalevsky's discovery opens up at least an entirely new path of inquiry; and necessitates the modification of our views as to the entire separation of the Vertebrates from the other groups of animals, if we do not at once adopt the hypothesis that through the Ascidian and other forms the origin of the Vertebrates may be traced downwards in the series to the lower grades of animal organization.

The notochord extends a short way forward into the cranial basis; and an interesting question here presents itself, beginning with the speculations of Goethe and Oken, and still forming a subject of discussion, whether the series of cranial or cephalic bones is comparable to that of the vertebræ. On the whole it appears to me that it is consistent with the most recent views of the development and anatomy of the head to hold the opinion that it is composed of parts which are to some extent homologous with vertebral metameres †.

The history of the formation of the vertebral column presents an interesting example of the correspondence in the development of the individual and the race, in that all the stages which have been referred to as occurring in the gradual evolution of the vertebral column in the series of Vertebrates are

* Mém. de l'Acad. de St. Pétersbourg, vol. x.

† See the interesting and valuable memoirs of W. K. Parker, "On the Anatomy and Development of the Vertebrate Skull," in Trans. of Roy. Soc., the researches of Gegenbaur, Mihalkovics, and more particularly the memoir by F. M. Balfour, "On the Development of the Elasmobranchs," in the Journ. of Anat. and Physiol. vols. x. and xi.

repeated in the successive stages of the embryonic development of the higher members of the series.

There is perhaps no part of the history of development in the Vertebrates which illustrates in a more striking manner the similarity of plan which runs through the whole of them than that connected with what I may loosely call the region of the face and neck, including the apparatus of the jaws and gills. The embryonic parts I now refer to consist of a series of symmetrical pairs of plates which are developed at an early period below the cranium, and may therefore, in stricter embryological terms, be styled the *subcranial plates.*

Without attempting to follow out the remarkable changes which occur in the development of the nose and mouth in connexion with the anterior set of these plates (which, from being placed before the mouth, are sometimes named *preoral*), I may here refer shortly to the history of the plates situated behind the mouth, which were discovered by Rathke in 1826, and formed the subject of an elaborate investigation by Reichert in 1837.

These plates consist of a series of symmetrical bars, four in number in mammals and birds, placed immediately behind the mouth, separated by clefts passing through the wall of the throat, and each traversed by a division of the great artery from the heart—thus constituting the type of a branchial apparatus, which in fishes and amphibia becomes converted into the well-known gills of these animals; whilst in reptiles, birds, and mammals they undergo various changes leading to the formation of very different parts, which could not be recognized as having any relation to gill-structure, but for the observation of their earlier embryonic condition. The history of this part of development also possesses great interest on account of the extraordinary degree of general resemblance which it gives to the embryos of man and the most different animals at a certain stage of advancement (so great, indeed, that it requires a practised eye to distinguish between them though belonging to different orders of mammals, and even between some of them and the embryos of birds or reptiles), as well as in connexion with the transformations of the first pair of branchial apertures, which lead to the formation of the passage from the throat to the ear in the higher Vertebrata. There is equal interest attached to the history of the development of the first pair of arches which include the basis of formation of the lower jaw with the so-called *cartilage of Meckel*, and which, while furnishing the bone which suspends the lower jaw in reptiles and birds, is converted in mammals into the hammer-bone of the ear.

The other arches undergo transformations which are hardly less marvellous, and the whole series of changes is such as never fails to impress the embryological inquirer with a forcible idea of the persistence of type and the inexhaustible variety of changes to which simple and fundamental parts may be subject in the process of their development.

It is also of deep significance, in connexion with the foregoing phenomena, to observe the increase in the number of the gill-bars and apertures as we descend in the scale to the cartilaginous fishes and lampreys, and the still further multiplication of these metameres or repeated parts in the Amphioxus; and it is interesting to note that in the Ascidia the arrangement of the gills is exactly similar to that of the Amphioxus.

The study of the comparative anatomy of the heart and its mode of formation in the embryo furnishes another striking illustration of the relation between ontogenetic and phylogenetic development in the Vertebrates, and is not without its applications to some of the invertebrate groups of animals.

I need only recall to your recollection the completely double state of this organ in warm-blooded animals, by which a regular alternation of the systemic and pulmonary circulations is secured,—the series of gradations through the class of Reptiles by which we arrive at the undivided ventricle of the Amphibian, and the further transition in the latter animals by which we come at last to the single heart of Fishes; and state that in the embryo of the higher animals the changes by which the double heart is ultimately developed out of an extremely simple tubular shape, into which it is at first moulded from the primitive formative cells, are, in the inverse order, entirely analogous to those which I have just now indicated as traceable in the descending series of vertebrate animals; so that at first the embryonic heart of man and other warm-blooded animals is nothing more than a rhythmically contractile vascular tube. By the inflection of this tube, the constriction of its wall at certain parts, and the dilatation at others, the three chambers are formed which represent the single auricle, the single ventricle, and the aortic bulb of the fish. By later changes a septum is formed to divide the auricles, becoming completed in all the air-breathing animals, but remaining incomplete in the higher animals so long as the conditions of fœtal life prevent the return of arterialized blood to the left auricle. The growth of another septum within the ventricular portion gradually divides that cavity into two ventricles, repeating somewhat in its progress the variations observed in different reptiles, and attaining its complete state in the crocodile and warm-blooded animals.

I must not attempt to pursue this interesting subject further; but I cannot avoid making reference to the instructive view presented by the embryological study of the nature of the malformations to which the heart is subject, which, as in many other instances, are due to the persistence of transitory conditions which belong to different stages of progress in the development of the embryo. Nor can I do more than allude to the interesting series of changes by which the aortic bulb, remaining single in fishes and serving as the channel through which the whole stream of blood leaving the heart is passed into the gills, becomes divided in the higher animals into the roots of the two great vessels, the aorta and the pulmonary artery, and the remarkable transformations of the vascular arches which proceed from the aortic bulb along the several branchial arches, and which, in the gills of fishes and aquatic Amphibia, undergo that minute subdivision which belongs to the vascular distribution of gills, but which in the higher non-branchiated animals are the subject of very different and various changes, in the partial obliteration of some and the enlargement of others, by which the permanent vessels are produced.

These changes and transformations have for many years been a subject of much interest to comparative anatomists, and will continue to be so, not only from their presenting to us one of the most remarkable examples of conformity in the plan of development and the type of permanent or completed organization in the whole series of vertebrated animals, but also because of the manifest dependence of the phenomena of their development upon external influences and atmospheric conditions affecting the respiration, nutrition, and modes of life of the animal.

Nor is the correspondence to which I now refer entirely limited to the Vertebrata. For here, again, through the Amphioxus and the Ascidia, we come to see how an affinity may be traced between organs of circulation and respiration which at first appear to belong to very different types. The heart of vertebrates is, as is well known, essentially a concentrated form of vascular development in the ventral aspect of the body, while the heart of the invertebrate, whether in the more concentrated form existing in the Articulata and Mollusca or in a more subdivided shape prevalent in the Annelida, is most frequently dorsal; yet the main aorta of the Vertebrates is also dorsal; and it is not impossible, through the intermediate form of Amphioxus, to understand how the relation between the Vertebrate and the Invertebrate type of the blood-vascular system may be maintained.

But I am warned by the lapse of time that I must not attempt to pursue these illustrations further. In the statement which I have made of some of the more remarkable phenomena of organic production—too long, I fear, for your endurance, but much too brief to do justice to the subject—it has been my object mainly to show that they are all more or less closely related together by a chain of similarity of a very marked and unmistakable character; that in their simplest forms they are indeed, in so far as our powers of observation enable us to know them, identical; that in the lower grades of animal and vegetable life they are so similar as to pass by insensible gradations into each other; and that in the higher forms, while they diverge most widely in some of their aspects in the bodies belonging to the two great kingdoms of organic nature, and in the larger groups distinguishable within each of them, yet it is still possible, from the fundamental similarity of the phenomena, to trace in the transitional forms of all their varieties one great general plan of organization.

In its simplest and earliest form that plan comprises a minute mass of the common nitrogenous hydrocarbon compound to which the name of protoplasm has been given, exhibiting the vital properties of assimilation, reproduction, and irritability. The second stage in this plan is the nucleated and enclosed condition of the protoplasmic mass in the organized cell. We next recognize the differentiation of two productive elements, and their combination for the formation of a more highly endowed organizing element in the embryonic germ-sphere or cell; and the fourth stage of advance in the complexity of the organizing phenomena is in the multiplication of the fertilized embryo-cell and its conversion into continuous organized strata, by further histological changes in which the morphological foundations of the future embryo or new being are laid.

I need not now recur to the further series of complications in the formative process by which the bilaminar blastoderm is developed and becomes trilaminar or quadrilaminar, but only recall to your recollection that while these several states of the primordial condition of the incipient animal pass insensibly into each other, there is a pervading similarity in the nature of the histological changes by which they are reached, and that in the production of the endless variations of form assumed by the organs and systems of different animals in the course of their development, the process of cell-production, multiplication, and differentiation remains identical. The more obvious morphological changes are of so similar a character throughout the whole, and so nearly allied in the different larger groups, that we cannot but regard them as placed in some very close and intimate relation to the inherent properties of the organic substance which is their seat, and the ever-present influence of the vital conditions in which alone these properties manifest themselves.

The formative or organizing property therefore resides in the living substance of every organized cell and in each of its component molecules, and is a necessary part of the physical and chemical constitution of the organizing elements in the conditions of life; and it scarcely needs to be said that these conditions may be as varied as the countless numbers of the molecules which compose the smallest particles of their substance. But, setting aside all speculation of a merely pangenetic kind, it appears to me that no one could have engaged in the study of embryological development for any time without becoming convinced that the phenomena which have been ascertained as to the first origin and formation of textures and organs in any individual animal are of so uniform a character as to indicate forcibly a law of connexion and continuity between them; nor will his study of the phenomena of development in different animals have gone far before he is equally strongly convinced of the similarity of plan in the development of the larger groups, and, to some extent, of the whole. I consider it impossible therefore for any one to be a faithful student of embryology, in the present state of science, without at the same time becoming an evolutionist. There may still be many difficulties, some inconsistencies, and much to learn, and there may remain beyond much which we shall never know; but I cannot conceive any doctrine professing to bring the phenomena of embryonic development within a general law which is not, like the theory of Darwin, consistent with their fundamental identity, their endless variability, their subjugation to varying external influences and conditions, and with the possibility of the transmission of the vital conditions and properties, with all their variations, from individual to individual, and, in the long lapse of ages, from race to race.

I regard it, therefore, as no exaggerated representation of the present state of our knowledge to say that the ontogenetic development of the individual in the higher animals repeats in its more general character, and in many of its specific phenomena, the phylogenetic development of the race. If we admit the progressive nature of the changes of development, their similarity in different groups, and their common characters in all animals, nay, even in some respects in both plants and animals, we can scarcely refuse to recognize the possibility of continuous derivation in the history of their origin; and however far we may be, by reason of the imperfection of our knowledge of Palæontology, Comparative Anatomy, and Embryology, from realizing the precise nature of the chain of connexion by which the actual descent has taken place, still there can be little doubt remaining in the minds of any unprejudiced student of embryology that it is only by the employment of such an hypothesis as that of Evolution that further investigation in these several departments will be promoted, so as to bring us to a fuller comprehension of the most general law which regulates the adaptation of structure to function in the Universe.

REPORTS

ON

THE STATE OF SCIENCE.

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Thirteenth Report of the Committee for Exploring Kent's Cavern, Devonshire—the Committee consisting of JOHN EVANS, *F.R.S.*, Sir JOHN LUBBOCK, *Bart., F.R.S.*, EDWARD VIVIAN, *M.A.*, GEORGE BUSK, *F.R.S.*, Professor BOYD DAWKINS, *F.R.S.*, WILLIAM AYSHFORD SANFORD, *F.G.S.*, JOHN EDWARD LEE, *F.G.S., and* WILLIAM PENGELLY, *F.R.S. (Reporter).*

[PLATE I.]

THE Committee in their Twelfth Report, read at Glasgow last year*, brought up the history of their researches to the end of August 1876. They have now the pleasure of continuing that history to the end of July 1877. During the intervening eleven months the work has been continued without interruption, on the same method and under the same daily superintendence as heretofore. The workmen named in the Twelfth Report, George Smerdon (foreman) and William Matthews, are still employed on the exploration, and continue to give unqualified satisfaction.

On the 2nd November, 1876, Mr. Busk, a member of the Committee, visited the Cavern, accompanied by one of the Superintendents, when he inspected that portion of the work which was then in progress, as well as the principal parts where the exploration has been completed.

The researches continue to attract large numbers of visitors, most of whom are admitted by the authorized guide, who, under well-defined and strictly observed regulations, conducts them through such branches of the Cavern as are of general and popular interest, but not to those in which the work is in actual progress or has not been begun.

In addition to the foregoing, the following visitors have been accompanied by one of the Superintendents:—The Revs. T. G. Bonney, A. N. Mackray, and R. R. Wolfe, Professor Balfour, Captain Smith (India), Dr. A. M. Cash, and Messrs. S. Ashton, J. R. K. Aston, F. Atkins, T. Ball, A. Barclay, R. B. Barclay, F. Blood, R. A. Charlton, W. Cook, G. Critchett, T. Drane, S. Elliott, J. D. Enys (New Zealand), W. Findlater, D. A. Fox, A. Frederick, G. Goodrick, J. R. Grimshaw, C. H. B. Hambly, E. Hepworth, A. R. Hunt,

* See Report Brit. Assoc. 1876, pp. 1–8.

A. N. Johnson, W. H. Johnson, J. T. Kough, F. L. Latham (Bombay), A. S. Lukin, C. A. Merman, S. Morse, J. Nield, P. H. Nind, W. W. Phillips, J. Sivewright, J. Steele, L. Tetlow, A. Tylor, B. P. Walker, J. Whitehead, F. R. Wolfe, W. Wolfe, and C. L. Wolley.

The Bear's Den.—The Chamber termed "The Bear's Den" by the Rev. J. MacEnery measures about 67 feet in length, from north to south nearly, from 8 to 38 feet in width, and from 8 to 15 feet in height, the last dimension being measured, as everywhere else in the Cavern, from the bottom of the excavation. The limestone roof is extremely rugged, fretted, and waterworn. The "Lake" * opens out of the north-eastern corner of the Den, and nearly opposite, in the western wall, is the eastern mouth of the "Great Oven" †. On the same side as, and immediately south of, the latter opening is a vast boss of stalagmite, which the Superintendents of the work have preserved intact.

This boss is crowded with inscriptions, most of which are, unfortunately, difficult to decipher, partly because they cross one another, and also because they are much scratched, apparently by the nailed shoes of visitors. The following, however, have been distinctly made out:—

1. "William Petre, 1571."
2. "A. T., 1662."
3. "I. Bertie, 1706" (in a rude segment of a circle, of which the chord is 8·5 inches, and the height 5·5 inches).
4. "I. R., 1706" (in a rectangular figure, 2 × 1·5 inches).
5. "A. Chard, 1817."
6 "R. D., 1822."
7. "W. Crew."
8. "S. Crocker."
9. "F. Davy." (In letters 6 inches high, produced apparently with a series of blows with a pointed hammer. The last letter is Y by inference only. Its place is occupied by a triangle placed thus—∇, formed by the complete removal of a thin lamina of the stalagmite. This removal was probably accidental, and caused with the unintentional effect of the blows of the hammer in the attempt to form the Y.)
10. "Anton Hay."
11. "Dauid More" (in engrossed letters).
12. "John Skinner."
13. "F. D." (within a heart-shaped figure, measuring 5·5 inches from the indent to the point opposite, and 5 inches in greatest breadth).
14. "W. R."
15. "W. E."

There is also a date belonging to the second decade of the 17th century, but to what precise year cannot be determined, as the right or units numeral is not decipherable. All that can be made out is 161 [?].

No. 1 is of considerable interest on two accounts:—

First. The date, 1571, is, so far as is at present known, the earliest in the Cavern, and the only one belonging to the 16th century.

Second. Its genuineness can scarcely be doubted, as it is known that there were at the period in question two natives of South Devon named William

* See Report Brit. Assoc. 1869, pp. 186–9.
† *Ibid.* 1875, p. 12; and 1876, pp. 2–3.

Petre—Sir William Petre, the statesman, who obtained the manor of Brent, near Totnes, at the dissolution of Buckfast Abbey, about 1553; and William Petre, his nephew.

Mr. R. Dymond, F.S.A., of Exeter, writing to the Superintendents on the question, says:—"Sir Wm. Petre, the statesman, does not appear to have maintained much connexion with Devonshire after attaining manhood; and as the date of the inscription in Kent's Cavern (1571) was that of the year preceding his interment in Essex, it would seem unlikely that it referred to him.

"On the other hand, there is much that points to the conclusion that it was the work of William Petre, his nephew, who owned Hays in St. Thomas, a suburb of Exeter, but who was described as of Tor Newton, and was buried at Tor Brian, near Totnes, in 1614. His mother was a Ridgway of Tormohun, the parish in which the Cavern is situate; and his wife was a Southcote of Bovey Tracy, South Devon. Thomas Ridgway, the then owner of the land which contains Kent's Hole, was the trustee of his marriage settlement in 1585. He probably held frequent intercourse with these connexions, and was familiar with the objects of interest on their property. His monumental inscription (see Prince's 'Worthies of Devon,' p. 633) does not state his age, but he died in 1614. His marriage settlement was apparently a postnuptial one; and he was probably young in 1571, when the youthful freak of carving the name in stalagmite was perpetrated.

"May we not fairly conclude that he was identical with the 'William Petre' of the Cavern?—R. D., 20th May, 1877."

It may not be out of place to add here that Mr. J. T. White, whilst preparing his 'History of Torquay,' discovered a lease dated December 22nd, 1659, and appertaining to "closes, ffields, or pieces of ground" forming part of the property in which the Cavern is situate, in which occur the words "one close called Kent's Hole;" thus showing that in the middle of the 17th century the Cavern was so well known as to have given a name to a portion of an estate leased to a "husbandman," and rendering it eminently probable that the inscription of 1571, and all those of subsequent date, may be taken as genuine.

As Mr. MacEnery broke ground in every part of the Bear's Den, the condition in which he found it can only be learned from the description which he has left, and which may be given in the following very condensed form:—"The floor of the Bear's Den was studded with conical mounds of stalagmite, supporting corresponding pendants from the roof. Fallen masses of limestone were strewed about, and some of them were incorporated in the crust. An irregular sheet of stalagmite, about a foot thick, overspread the floor, and was based on a shallow bed of indurated rubble, containing tubes of stalactite collected in heaps in particular places, a great abundance of *album græcum*, an unusual proportion of Bears' teeth, and an iron blade much corroded, Points of stalagmitic cones were observed to protrude upwards into the rubbly bed, and were found to rise from a lower sheet of stalagmite. The cones of this lower sheet were precisely under those of the upper, denoting that they were successively deposited from the same tubes above; but the lowermost set exceeded by double the thickness of the uppermost, and the depth of the stalagmitic sheet was in the same proportion. The lower sheet extended over the entire area of the den; but the superincumbent bed of rubble, and its overlying thin sheet of stalagmite, disappeared gradually or 'thinned out' towards the sides. The removal of these partial beds displayed the entire surface of the lower sheet, which exhibited a most singular appearance. Over the whole area it was cracked into large slabs, résembling flags in a pavement. The upper sheet was not in the least fractured. The average thickness of the cracked sheet was about two feet. It possessed the hardness of rock, and, but for its division into insulated flags, it would have been almost impossible to pierce it. Powder made no impression on it.

"The first flag we turned over displayed a curious spectacle. Skulls and bones of Bear, crowded together, adhered to its under surface. Flag after flag disclosed the same phenomenon; but in one place numerous skeletons lay heaped on each other; the entire vertebral column and its various other bones, even to the phalanges and claws, were discovered lying in their natural relation in a state of preservation as if belonging to the same individual. The remains of Bear prevailed here to the exclusion of all other animals. Some of the teeth were of the most dazzling enamel, and the bones of their natural fresh colour. Others, on the contrary, were of a darkish brown; even the enamel was of a greenish tinge. Owing to the induration of their earthy envelope, or their incrustation by stalagmite, few were extracted entire. Two skulls were buried in the stalagmite as in a mould, and were brought away in that state. In no case were the remains broken or gnawed by the jaws of Carnivores. The long bones were generally found entire, and when observed broken it was only mechanically from pressure. The bones were highly mineralized, heavy, brittle, easy of fracture, and when struck rang like metallic substances." (See 'Trans. Devon Assoc.' vol. iii. (1869) pp. 238–40, 272–4, and 307–16.)

"The annexed section," says Mr. MacEnery, "will indicate the relative arrangement or position of the alternating strata of stalagmite and loam" (*ibid.* p. 311). It must not be supposed, however, that the section makes any thing like an approach to accuracy of scale or proportions (Plate I.).

The portions of the Stalagmitic Floor which Mr. MacEnery had failed to break up, chiefly adjacent to the walls and other confines of the Bear's Den, were sufficient to furnish the Committee with two good examples of the remarkably cracked condition of which he speaks. One of these was in the north-east corner, where a crack about half an inch wide extended from wall to wall, dividing the Bear's Den from the "Lake" area, passing quite through the stalagmite, which was nowhere less than 2 feet thick, but without "faulting" it in the slightest degree, or, so far as could be observed, in any way affecting the underlying deposits. Mr. MacEnery, however, states, though somewhat obscurely, that in some instances a derangement had taken place in the materials covered by the broken stalagmite (*ibid.* p. 309). The second existing crack varies from ·25 inch to 2·5 inches wide, and passes completely through the boss of stalagmite already mentioned, but without faulting it. It is, perhaps, worthy of remark that there is no unoccupied space between the base of this boss and the deposit beneath it. The two are in direct and undisturbed contact. No such cracks appear to be mentioned by Mr. MacEnery as occurring elsewhere, nor have the Committee met with any thing of the kind in any other branch of the Cavern.

The ground broken by Mr. MacEnery extended to a depth of from 8 to 20 inches over almost the entire area of the Bear's Den. As was his wont, he left the excavated materials almost where he found them, and, as in all previous cases of the kind, there were amongst them a large number of specimens which had been overlooked or neglected. These, carefully collected by the Committee, were kept apart from the relics they found in the deposits below his diggings, and, when the exploration of the Den was completed, such was their number and volume that a horse and cart were required for their removal from the Cavern. They included 1 tooth of Horse, 1 of Fox, 2 teeth of Deer, 4 of Hyæna, 4 of Mammoth, upwards of 200 of Bear, very numerous bones, especially of the vertebral column and feet, a crowd of broken bones and bone splinters, numerous balls of coprolite, and a few bits of coarse pottery.

It cannot be doubted that such cracks as Mr. MacEnery describes, if at all approaching in width to that still existing in the Stalagmitic boss, must be a possible, and, indeed, probable source of uncertainty respecting the position and relative chronology of some of the objects found in the underlying deposit, especially if, as he states, this deposit shared in the disturbance; for it must be supposed that portions of the overlying Cave-earth or, as Mr. MacEnery calls it, the Rubble-bed, together with teeth, bones, and coprolites, such as he found in it, would pass down through the cracks, and be lodged *on*, and perhaps *in*, the underlying Breccia.

In accordance with Mr. MacEnery's description and the foregoing considerations, the deposit the Committee had to excavate was the Breccia, with a small amount of Cave-earth lying on it here and there. Fallen blocks of limestone were extremely numerous; many of them were of great size, and required to be blasted before they could be removed; whilst others, still larger, penetrated the Breccia below the depth to which the excavation was carried, and were allowed to remain undisturbed.

The excavation in the Bear's Den was limited, as in other branches of the Cavern, to a depth of four feet below the bottom of the Stalagmite, and the Limestone Floor was nowhere reached.

The "finds" in the Den were 216 in number, of which 12 were in the Stalagmite, 101 in the first or uppermost foot-level of the underlying deposits, 47 in the second, 32 in the third, 23 in the fourth or lowest, and 1 in a small recess in the north-west corner of the Den, where no attempt was made to define the exact position of the objects. Omitting those found in the Stalagmite and the Recess, 32 of the "finds" were in Cave-earth, 65 in a mixture of Cave-earth and Breccia, and 96 in the Breccia, whilst the matrix of the remaining 10 must be regarded as uncertain. The colour and other characters of the specimens, however, indicate with tolerable certainty to what beds and eras they belong.

Besides a considerable number of bones and pieces of bone representing every part of the skeleton, the specimens included upwards of 620 teeth of Bear, 24 of Hyæna, 10 of Horse, 7 of Fox, 5 of Mammoth, 4 of Lion, and 1 of Dog (?) or Wolf (?). There were also 20 "finds" of coprolite and 11 flints.

Amongst the bones, the skull of a Bear may be mentioned, which, to requote the language of Mr. MacEnery, was "buried in the stalagmite as in a mould, and was brought away in that state." Many of the specimens are of considerable interest, but, perhaps, none of them differ so much from those mentioned in previous Reports as to require detailed description. There is, however, a portion of a large canine tooth, probably of Bear, which is noteworthy as having been apparently chipped artifically. From its colour and general characters, it belonged to the breccia, or oldest known deposit; but it was met with, as part of "find" No. 6993, in the cave-earth, with two teeth of Hyæna and a coprolitic ball, on 9th of June, 1877. Specimens similar in character, and found under corresponding conditions, have been previously met with in the Cavern, and were first pointed out by Professor Boyd Dawkins, a member of the Committee, in 1868.

None of the flints found in the Bear's Den are of so much interest as many of those exhumed in other branches of the Cavern, and described in previous Reports. The following, however, deserve more than a passing notice:—

No. 6895 is a small, delicately-proportioned, white, flake tool, 1·75 inch long, ·6 inch in greatest width, which it retains for about two thirds of its length, and ·2 inch in greatest thickness. Both its ends are blunt, but its edges are sharp; the inner face is almost flat, whilst the outer is strongly ridged. It was found in the first "foot-level," with 6 teeth of Bear and 1 of Mammoth, on 1st November, 1876, and is undoubtedly a true Cave-earth implement.

No. 6929 is an irregular rolled flint nodule, from which two flakes have been dislodged since it ceased to be exposed to any action capable of scratching its facets or injuring its edges. It is about 2·5 inches long, 1·4 inch in greatest breadth, 1·1 inch in greatest thickness, and was found, without any object of interest near it, in the Breccia, or lowest known deposit, in the fourth or lowest "foot-level," on 17th November, 1876. It has the dark, manganic smutty surface which occasionally characterizes the Breccia tools.

No. 6943 is a white flake implement, 2·2 inches long, ·5 inch in greatest breadth, and ·3 inch in greatest thickness. It is broadest at one end, whence it gradually tapers towards the other, but is somewhat scimitar-shaped in outline, and has lost its point. It is nearly flat on one face, but is strongly ridged on the other, whence three longitudinal flakes have been dislodged, and its lateral margins are thin and sharp. It was found on 28th November, 1876, in the Cave-earth, in the first "foot-level," with relics of Bear, Elephant, and Hyæna.

No. 6986 is a white flake, 1 inch long, ·6 inch wide, and ·2 inch in greatest thickness. It is a parallelogram in outline; slightly convex on the inner face, doubly ridged on the outer; quite thin at the lateral margins, one of which is somewhat notched, from which the other is free; thick at each end, and is in all probability the central portion of a tool of greater length. It was found with 4 teeth of Bear, 1 of Hyæna, and pieces of bone, on 30th December, 1876, in the first "foot-level," and belongs to the Cave-earth series.

No. 6997 is a cherty flint *nodule* implement, 3·2 inches long, 2·5 inches in greatest breadth, and 1·8 inch in greatest thickness. It may be described as a somewhat sharply-pointed, rudely heart-shaped tool, retaining some of its original surface as a rolled nodule. It was found on 10th January, 1877, in the second "foot-level," without any object of interest near it, in the Breccia, and is characteristic of that deposit.

No. 7040 is a very rough specimen, 2·75 inches long, 1·6 inch in greatest breadth, and ·95 inch in greatest thickness. It retains remnants of the original surface of the nodule, and was found in the Breccia, in the first "foot-level," without any object of interest near it, on 5th March, 1877.

No. 7059 is 2 inches long, 1·1 inch in greatest breadth, and ·6 inch in greatest thickness. It is irregularly convex on each face, pointed at one end and rounded at the other, and retains traces of the original surface of the nodule. It was found in the Breccia, in the second "foot-level," without any object of interest near it, on 15th March, 1877.

A column or pillar of stalagmite was met with in November 1876, adjacent to the east wall of the Bear's Den, and about 22 feet from its northern end, under the following peculiar circumstances:—It measured about 51 inches in basal circumference and 3·75 feet in height. The base was of nondescript outline, but everywhere above it the pillar was rudely elliptical in horizontal section, and it measured 30 inches in girth at the height of 2 feet, where it was least. When found, however, it was in two parts, having been divided along an almost horizontal plane where it was thinnest. Each of the segments stood perfectly erect, but not one on the other; for though the bottom of the upper segment was on precisely the same level as the top of the lower, the upper portion had been moved towards the right, or west, to the extent of 15 inches horizontally, and stood there on the Breccia. In other words, the pillar had been "faulted," so to speak, about 5 inches more than its thickness. It cannot be doubted that when the dislocation occurred the pillar had reached its full height, and the Breccia had accumulated round it to the height of 2 feet—that is, it had reached the level of the plane of fracture. It is difficult to see how, by any possibility, the deposit could at that time have reached a greater height, and difficult also to understand how any thing other than human hands could have shifted the upper segment of the pillar and placed it so as to preserve its erect position. On the other hand, it is just as difficult to see what motive man could have had for such a work. The whole pillar, when found, was completely buried in the Breccia, and the top of the upper segment was about a foot below the bottom of the thick remnant of the Stalagmitic Floor, which Mr. MacEnery had left intact, and which contained no cracks of any kind.

Rats still continue to follow the workmen into the Cavern. The foreman, George Smerdon, whose special work is that of excavating the deposits, uses a lump of clay, but little, if at all, less than 2 lbs. in weight, as his candlestick; and when he leaves work he removes the candle and places it in a box lest it should be carried off by rats, a precaution which experience has taught him to be necessary; but the lump of clay, which, it is needless to say, is more or less covered with candle-grease, he leaves to its fate. During the latter end of February and beginning of March 1877 he observed every morning that, not only had the candle-grease been removed during the night, but almost half of the clay (that is, nearly a pound in weight) had disappeared also, as if it had formed a part of the meal of the depredator or depredators. Having observed no rats for some time, he was inclined to ascribe the work to bats, of which he had frequently seen several flying about. On Saturday, 10th March, however, seeing a rat crossing the Bear's Den, he at once prepared a gin for it, and when he next entered the Den he found the rat was caught.

The Tortuous Gallery.—As soon as the work in the Bear's Den was completed, the exploration of a narrow passage opening out of its southern end, and termed "The Tortuous Gallery," was begun. At and near the entrance this Gallery is from 13 to 15 feet high; but at 11 feet from the Bear's Den a second, or branch, Gallery presents itself, almost immediately above it, the two being divided by a continuous sheet of limestone, forming the floor of one and the ceiling of the other. The branch extends, with some irregularities of direction, towards the south-east for a distance of 30 feet, where it becomes too narrow for a man to pass. Immediately beyond this point it is seen to be somewhat broader, but its further character and length are unknown. At the entrance, where its dimensions are greatest, it is 7 feet high and 3 feet broad. Throughout its entire accessible length its walls and roof have strongly marked indications of the action of water. With the exception of a few large blocks of limestone, it was entirely empty.

The principal gallery, "The Tortuous Gallery" proper, after throwing off a second and lower branch towards the west, turns sharply towards the cast at a distance of 23 feet from the Bear's Den; and at 11 feet further it expands into a small Chamber, the floor of which is a pavement of blocks of limestone, some of them of considerable size. The Gallery varies from 6 to 8 feet high, and from 1·5 to 4·5 feet wide, and has obviously been a water-course. Ground had been broken here and there by the earlier explorers up to 11 feet from the Bear's Den. Everywhere further in there was a continuous unbroken Floor of Stalagmite, from 1·5 to 3·5 feet below the limestone roof; but at 3 feet beyond the point at which, as already stated, the Gallery turns eastward, an unoccupied interspace was found between the lower surface of this Floor and the top of the underlying deposit. At first this hiatus did not exceed a foot, but as the work progressed it gradually reached 4 feet.

The underlying deposit was exclusively the Breccia, or, so far as is known, the oldest the Cavern contains. Its upper surface formed a continuous declivity, so great that at the small Chamber previously mentioned the level was 163 inches below that of the nearest part of the Bear's Den—a mean gradient of 1 in 2·5. For the first 9 feet the thickness of the Breccia was not more than from 3 to 3·5 feet, the limestone floor being everywhere reached within these limits; but elsewhere the ordinary four-feet sections failed to disclose the limestone.

The "finds" met with in the Tortuous Gallery up to the end of August 1877 were but 14 in number, and the objects they contained were of but little importance: 6 of them were met with in the first or uppermost foot-level (all near the entrance), 2 in the third, and 6 in the fourth (all at some distance from the entrance). They included, besides bones and bone-chips, 14 teeth of Bear, some of them being in portions of jaws, and 1 of Horse. The latter was found on the surface, near the Bear's Den, with 3 bits of coarse, friable, black pottery. A "core" of black flint—in all probability a "strike-light" of the present century—was found under the same conditions about a foot from them.

On reviewing the work of the last eleven months the Superintendents cannot but express disappointment at not having found the very large number of choice specimens which Mr. MacEnery's glowing description had led them to expect in the Bear's Den. Nevertheless the discoveries they have made not only justify his description, but show that in that branch of the Cavern the osseous remains were almost entirely confined to the uppermost foot of the Breccia, and mainly to its actual surface. So long as the lower levels remained untouched, the belief that they were equally rich would have naturally prevailed; and it cannot be doubted that in disposing of this belief very satisfactory work has been done.

The Committee have again to state that since their last Report was presented they have found no relic of *Machairodus latidens*. It is satisfactory, however, to know that since the last Meeting of the Association the crown of a canine tooth of this species has been found, by the Rev. J. M. Mello, in Robin-Hood Cave, Creswell Crags, Derbyshire.


Roof
uppermost
undermost
Water

Second Report of a Committee, consisting of E. C. C. Stanford, James Dewar, Alfred E. Fletcher, E. W. Parnell, T. R. Ogilvie, *and* Alfred H. Allen (*Secretary*), *appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products and the mode of stating the Results. Drawn up by* Alfred H. Allen *.

Determination of Potash.

The evidence on this subject obtained previously to the last meeting of the Association (Bristol) showed that the method of determining potassium by precipitation as a platinum salt was almost universally employed by chemists of large experience in the assay of potash salts. The Committee thought it desirable, therefore, to subject the process to an exhaustive examination, with a view of ascertaining the origin of the discrepancies known to occur between the results of chemists using different modifications of the general method of estimation by platinum chloride.

The process of determining potassium by platinic chloride is well known to depend on the sparing solubility of chloroplatinate of potassium and the easy solubility of the chloroplatinates of the associated metals. The precipitate is crystalline, of a bright yellow colour, and is easily dried. On account of its solubility in aqueous liquids it is necessary to operate on concentrated solutions and to employ alcohol for washing. When the precipitate is produced suddenly by addition of platinic chloride to a concentrated solution of potassium chloride, or by rapidly cooling a hot saturated aqueous solution of potassium chloroplatinate, it is obtained in a finely granular or pulverulent form. When the chloroplatinate is formed by gradual concentration of a dilute aqueous solution, or by adding chloride of platinum to a dilute solution of chloride of potassium and then concentrating, the precipitate assumes the form of dense crystalline scales, the subsequent manipulation of which is very easy.

The following modifications of the general process have been employed by the Committee with the view of testing their comparative accuracy under various conditions likely to occur in practice.

The information forming the basis of the experiments was communicated to the Committee chiefly during last year, and to a great extent was incorporated in the Report presented at the Bristol Meeting.

Modification I.—Essentially the process of Professor Fresenius described in his 'Manual of Quantitative Analysis,' being shortly as follows:—The solution of mixed chlorides of potassium and sodium, freed, if necessary, from calcium, magnesium, and sulphates, was evaporated nearly to dryness with excess of solution of platinic chloride. (In many of the experiments a considerable excess of platinum was employed beyond the quantity required to convert both the alkali metals into chloroplatinates.) The evaporated solution was then treated with alcohol of about 80 per cent., allowed to stand for some time, transferred to a small filter, washed with alcohol of 80 per cent., and carefully dried. The bulk of the precipitate was then transferred to a weighed capsule, dried at 100° C., and weighed. The filter with from 1 to 3 milligrammes of adherent precipitate was ignited, the weight of the filter-ash (·0004 gramme) subtracted, and the residue of $Pt+2KCl$ calculated to $PtCl_4+2KCl$, the amount thus obtained being added to the main quantity.

* Read at the Meeting at Glasgow, 1876.

Modification II.—The above process, with the following precautions, was recommended by Dr. Fresenius in a communication to this Committee:—

"To make sure not to keep any chloride of sodium along with the chloride of platinum and potassium, I first extract the chloride of platinum and sodium with spirits of wine of 80°, and then wash the chloride of platinum and potassium with a few cub. centims. of water, drop by drop; then I evaporate this solution, adding a little chloride of platinum, treat the small precipitate again with spirit of wine, and add the small quantity of chloride of platinum and potassium to the bulk."

Modification III.—The third modification is that of Drs. Frank and Berrand, of Leopoldshall. These chemists employ only about ·2 grm. of the potash salt, and manipulate like Fresenius, but they wash the precipitate with alcohol of 98 per cent., which is practically absolute. They dry the precipitate at 110° C.

Modification IV.—The fourth modification is that of Mr. R. R. Tatlock, who thus describes it in his communication to the Committee:—"A portion of the solution, equal to 10 grains of the original sample, is delivered into a small basin, diluted with 400 grains or so of water, and acidified slightly with hydrochloric acid. About 500 grains of platinic chloride solution (containing at least 25 grains of platinum) are added, and the fluid evaporated nearly to dryness on a water bath. A few drops of water are then added to the residue, and the evaporation repeated to expel the excess of hydrochloric acid. About 50 grains more of the strong platinic solution are mixed with the precipitate, and the whole stirred well and set aside in a cold place for at least an hour, with occasional stirring. The precipitate is then thrown on a very small filter (unweighed), the basin rinsed out with about 10 drops more of the platinum solution, and the precipitate on the filter washed with 10 or 15 drops more. The basin and the filter and contents are then washed with the smallest possible quantity of alcohol of 95 per cent. strength, and dried at 100° C. The dried precipitate is transferred as completely as possible to a small capsule, in which it is further dried until it assumes a distinct orange colour, and weighed. The filter, with a trace of adhering precipitate, is ignited on a crucible lid, and the residual metal, with its corresponding chloride of potassium, calculated to potassio-platinic chloride, and the weight added to that of the precipitate."

From the above descriptions it will be seen that the chief points of difference in the processes are as follows:—

Fresenius (Process I.) uses moderately strong alcohol (80 per cent.) for washing the precipitate; but in his modified process he subsequently uses a few centimetres of water, and recovers any potassium salt thus dissolved.

Frank and Berrand use a very small weight of the sample and wash with absolute alcohol. Tatlock washes first with a strong solution of platinic chloride, and then with strong alcohol. In all editions of his 'Quantitative Analysis' prior to the 7th English, Fresenius directs the drying of the precipitated chloroplatinate at 100° C. In the last edition drying at 130° C. is recommended. Frank and Berrand use 110° C. Until after the conclusion of the investigations the words "further dried" in Tatlock's method were understood by the Committee to signify longer drying at 100° C., but it has since been learnt that drying at a somewhat higher temperature was intended.

In all cases in which the temperature used for drying the precipitate is not expressly stated, the Committee employed 100° C. The experiments instituted to ascertain the influence the temperature used in drying had on the weight of the precipitate showed a loss of ·067 per cent., by subjecting the precipitate thoroughly dried at 100° C. to a temperature of 140° C. for one hour. This loss represents only ·02 for 100 parts of potassium chloride.

In order to obtain a satisfactory basis of investigation, it was necessary, in the first place, to obtain perfectly pure potassium salts; and as a necessary condition of the requisite purity was complete freedom from sodium compounds, their preparation was found less easy than might be expected *. In the first place an attempt was made to obtain pure potassium chloride by repeatedly evaporating pure nitre with hydrochloric acid. The result showed that the reaction took place with far less facility than was expected, and the process was abandoned. Chloride of potassium was next obtained by dissolving the purest commercial acid potassium carbonate in hydrochloric acid, filtering, and repeatedly crystallizing the product. Ignition of the crystals on platinum wire in the Bunsen flame showed the presence of sodium in abundance, and two determinations of the real chloride of potassium as platinum salt gave 98·93 and 98·85 per cent. respectively.

A highly satisfactory product was at length obtained by the following process:—Cream of tartar was dissolved in boiling water, the liquid filtered, and the acid tartrate of potassium obtained by cooling the solution. The product was recrystallized, and then tested for sulphates and sodium, neither of which was found. The dried crystals were ignited, the mass dissolved in water, the liquid filtered, nearly neutralized with hydrochloric acid, a few drops of ammonium oxalate added, the solution again filtered, and then evaporated to dryness. The resultant chloride of potassium was heated to fusion and reduced to powder. The product was absolutely free from sulphates, completely soluble in water, and the solution was perfectly neutral. The salt showed no trace of sodium when heated on platinum wire in the Bunsen flame.

The hydrochloric acid used in the experiments was prepared by acting on common salt by non-arsenical sulphuric acid and passing the washed gas into distilled water †.

The platinic chloride was obtained by reducing the commercial chloride (which contained iron and other impurities), by boiling with caustic soda and alcohol, thoroughly washing (first by decantation and afterwards on the filter) the resultant platinum black, boiling it for some time with hydrochloric acid, and again thoroughly washing with hot water and igniting in a muffle. The metallic platinum was boiled with nitric acid, rewashed and reignited, and then weighed and dissolved in aqua regia.

The platinic-chloride solution thus obtained was evaporated nearly to dryness, first with hydrochloric acid and then several times with water, in order to get rid of the free acid as much as possible‡. Ultimately the solution was diluted, filtered from any insoluble residue (which was ignited and weighed, and the weight deducted from the original), and the filtrate further diluted until 100 cub. centims. contained about 6 grammes of metallic platinum.

* A shorter method than those tried would probably have been to ignite pure potassium chlorate.—A. H. Allen.

† For some years all the hydrochloric acid used in my laboratory has been prepared by this process. It is more convenient, and furnishes a far superior product to that obtained by distilling the impure liquid acid.—A. H. Allen.

‡ This method of preparing pure chloride of platinum is practically identical with that recommended by Messrs. Chalmers and Tatlock in a paper read before the Chemical Section of the Philosophical Society of Glasgow, April 20th, 1868. The Committee has adopted the same process for recovering the platinum from the precipitates and filtrates obtained in the experiments.

As the projected researches required that the weight of potassium salt used in each experiment should be known with the greatest possible accuracy, it was considered desirable to avoid direct weighing of the solid salt, by employing a definite amount of solution of known strength.

For this purpose the capacity of a pipette, which nominally held 10 cub. centims., was accurately ascertained. The pipette was filled to the mark with distilled water at a temperature of 20° to 21° C. The contents were then allowed to flow into a small accurately tared beaker. The pipette was then allowed to drain for exactly thirty seconds, when the last drop of fluid was expelled by gentle blowing, the nose of the pipette being held in contact with the beaker so as to avoid any chance of loss. This plan was found to result in the delivery of a more constant weight of fluid than spontaneous draining, with or without subsequent contact of the point of the pipette with the main volume of the liquid. The same pipette was always employed, and the contents were delivered in the same manner. All the measurements were made at pretty nearly the same temperature. As a result it was found that in a series of nearly twenty experiments the extreme variation in the weight of distilled water delivered was 8 milligrammes, or about ·08 per cent. of the weight, while the great majority of the determinations were within 2 milligrammes of the mean. The result of using the pipette for measuring out 10 cub. centims. of a 10 per cent. solution of chloride of potassium would be that the maximum deviation from the mean would amount to ·04 per cent. of the weight, though the maximum difference in two successive measurements might equal twice this proportion.

The experiments showed that at 20° C. the pipettes delivered a mean weight of 9·9329 grammes of distilled water.

The most convenient quantity of chloride of potassium for precipitation with platinic chloride is about ·7 gramme, or 10 grains. A solution of pure chloride of potassium was therefore prepared of such strength that the pipette should deliver about that amount.

The exact amount of chloride of potassium contained in one pipette delivery of the solution was next ascertained. Two determinations were made by precipitating a pipette full with nitrate of silver, and one by direct evaporation of the liquid to dryness with subsequent cautious heating of the residue.

A 1......AgCl 1·3395=KCl ·6968 gramme.
A 2......AgCl 1·3400=KCl ·6971 „
B 1.... By evaporation=KCl ·6970 „

The mean of these closely concordant results is ·69697 gramme; ·697 gramme was therefore considered as the true amount of chloride of potassium in the solution delivered by the pipette.

At a somewhat advanced period of the investigations some irregularities in the results led to a doubt as to the degree of accuracy attainable by pipette measurements, and it was decided to commence an entirely new series of experiments on a different basis. Recognizing the advantage the employment of solutions has over direct weighing of the solid salt, it was decided to weigh each quantity of solution employed, merely trusting to measurement to obtain approximately the same quantity. By proceeding in this manner all errors due to unequal deliveries of the pipette or accidental alterations of temperature were entirely eliminated.

For these experiments a fresh solution of chloride of potassium was prepared, by dissolving a known weight of the pure potassium chloride in exactly ten times its weight of distilled water *. In the experiments made on the weighed solution, the required quantity was approximately measured by running it from a burette into an accurately tared beaker, and the exact quantity taken was then ascertained by weighing. In this manner the amount of potassium salt employed in each experiment was ascertained with great accuracy. The error in the amount taken could not be more than ·00005 of a gramme, or about ·007 per cent. of the quantity used. With the new solution the following experiments were made as a check on its strength :—

By precipitation with nitrate of silver,

	Weight of solution.	= KCl.	Weight of AgCl.	= KCl	= per cent.
A 1......	7·7065	·70060	1·3459	·70017	99·94
A 2......	7·7455	·70414	1·3534	·70408	99·99

By direct evaporation,

	Wt. of soln.	KCl.	Residue =	KCl per cent.
B 1......	7·711	·701	·7005	99·93

In this case half a milligramme loss of chloride of potassium, probably due to decrepitation on heating the residue, caused a difference of ·07 per cent.

In the foregoing and all subsequent experiments the following atomic weights and factors were employed :—

Chlorine	35·457	Stas, 1865.
Potassium	39·137	,, ,,
Silver	107·930	,, 1866.

$$AgCl \times \cdot 52023 = KCl.$$

The atomic weight of platinum was calculated from the original data of Berzelius, obtained by the analysis of potassium chloroplatinate, but substituting Stas's numbers for chlorine and potassium for those employed by Berzelius. This gives the result

$$Pt^{iv} = 197\cdot 1937.$$

Hence

$$K_2PtCl_6 \times \cdot 16033 = K_2$$
$$K_2PtCl_6 \times \cdot 19310 = K_2O$$
$$K_2PtCl_6 \times \cdot 30560 = 2KCl.$$

Fresenius, in the last edition of his 'Quantitative Analysis' (7th English), adopts the number 98·59 as the atomic weight of the divalent platinum, which also gives the factor ·3056, for calculating the chloroplatinate into chloride of potassium. In former editions Andrews's number 98·94 was adapted for platinum, which caused a sensible difference in the percentage of potassium chloride obtained. The factor ·30507, resulting from the employment of Andrews's atomic weight for platinum, is adopted by Drs. Frank and Berrand in their communication to this Committee.

The consequence of employing the above factors in calculating the percentage of chloride of potassium corresponding to the precipitate of chloroplatinate obtained is shown in the following statement :—

* It is obvious that the subsequent calculations would have been facilitated by dissolving a known weight of the pure potassium chloride in exactly nine times its weight of distilled water instead of ten. This consideration did not present itself till it was too late to take advantage of it.

	Precipitate.	Factor =	KCl per cent.
Committee	3·2723 ×	·30560*	100·00
Fresenius	3·2723 ×	·30560	100·00
Frank and Berrand	3·2723 ×	·30507	99·83

The Committee is informed that the factor ·194 is adopted by some chemists for calculating the chloroplatinate to anhydrous potash, a plan which would cause the result of 100·52 of chloride of potassium to be obtained instead of 100·00.

With the view of testing the relative accuracy of the different modifications of the platinum process when applied to the estimation of potassium in the form of pure chloride, the following experiments were performed:—

The letters P and W refer to the mode of taking the required quantity of chloride of potassium, P signifying pipette measurement and W the weighing of the solution used. In the former case the percentage of chloride of potassium was obtained by calculating the chloroplatinate precipitate to potassium chloride, dividing the result by ·697 and multiplying by 100. When a weighed quantity of potassium chloride solution was employed, the following equation was used for calculating the percentage of chloride of potassium found (S is the weight of solution used, P that of the precipitate obtained):—

$$\frac{P \times \cdot 3056 \times 11 \times 100}{S} = \frac{P \times \cdot 3361}{S} = \text{percentage of KCl found.}$$

Results bracketed together in the following tables were obtained from experiments executed side by side.

TABLE I.—Results of Experiments on pure Chloride of Potassium, using considerable excess of Platinum Solution.

Experiment.	Process.	Weight of solution.	=KCl taken.	Weight of precipitate.	=KCl found.	=KCl per cent.
1.	I. Fresenius	7·7080	·70072	2·3039	...	100·48 } W.
2.	,,	7·7540	·70490	2·3156	...	100·39 } W.
3. {	III. Frank & Berrand	7·7165	·70150	2·3092	...	100·60 } W.
4. {	,,	7·7345	·70310	2·3118	...	100·48 } W.
5.	IV. Tatlock	...	·697	2·2793	·69655	99·94 P.
6.	,,	...	·697	2·2792	·69652	99·93 P.
7.	,,	...	·697	2·2787	·69637	99·91 P.
8.	,,	7·7130	·70118	2·2947	...	100·01 } W.
9.	,,	7·7145	·70140	2·2945	...	99·98 } W.

These results, so far as they go, are decidedly in favour of Tatlock's method, and conclusively prove that it is capable of great accuracy.

At a later period of the investigations it was supposed that the excessive results obtained by some of the methods might be due to the fact that a very considerable excess of platinum solution was employed—a condition not in accordance with the directions of Fresenius and of Frank, but essential in Tatlock's method. The experiments made to elucidate this point did not immediately succeed those already detailed, but it is convenient to record the results here rather than in another place.

In the following experiments the quantity of platinum solution employed

* This factor was adopted by Messrs. Chalmers and Tatlock as long ago as 1868.

was but slightly in excess of the amount required to convert the whole of the potassium into chloroplatinate.

TABLE II.—Results of experiments on Pure Chloride of Potassium by Processes I. and III., employing only a *slight* excess of Platinum solution.

Experiment.	Process.	Weight of solution.	=KCl taken.	Weight of precipitate.	=KCl found.	=KCl per cent.	
10.	I. Fresenius	7·7180	·70164	2·2915	·70028	99·81	} W.
11.	,,	7·6995	·69996	2·2875	·66905	99·87	
12.	,,	7·7250	·70227	2·2947	·70125	99·85	
13.	,,	7·7020	·70114	2·2931	·70077	100·08	} W.
14.	,,	7·7125	·70150	2·2985	·70242	100·18	
15.	,,	7·7815	·70741	2·3218	·70954	100·30	} W.
16.	,,	7·7965	·70877	2·3262	·71088	100·30	
17.	III. Frank	2·232	·20291	·6633	·20269	99·90	} W.
18.	,,	2·232	·20291	·6637	·20283	99·97	
19.	,,	2·204	·20037	·6573	·20052	100·25	} W.
20.	,,	2·201	·20009	·6553	·19991	100·05	
21.	,,	2·2415	·20377	·6677	·20404	100·13	} W.
22.	,,	2·212	·20109	·6596	·20157	100·23	

These results showed a great improvement, and indicated pretty clearly the importance of avoiding a large excess of platinum solution when alcohol only was employed for washing the chloroplatinate.

The following Table shows the relative accuracy and limits of variation obtained in experiments on pure chloride of potassium by methods I., III., and IV.

TABLE III.—Analysis of the Results obtained in the estimation of Potassium when in the form of Pure Chloride.

Process.	No. of Experiments.	Highest Result.	Lowest Result.	Average.
I. Fresenius. With *large* excess of platinum solution......	2	100·48	100·39	100·44
With *slight* excess of platinum solution	7	100·30	99·81	100·06
III. Frank and Berrand. *Large* excess of platinum solution	2	100·60	100·48	100·54
Slight excess ditto	6	100·25	99·90	100·09
IV. Tatlock. *Large* excess of platinum solution	5	100·01	99·91	99·95

From these experiments, therefore, it was concluded that the method of estimating potassium by precipitation as chloroplatinate was very accurate when proper precautions were taken.

This conclusion is generally accepted, the chief discrepancies arising when mixed alkaline chlorides are analyzed, the different methods then giving results which sometimes exhibit wide variations.

The following Table shows the results obtained by the analysis of various mixtures of the pure chlorides of potassium and sodium :—

TABLE IV.—Results of Experiments on Mixtures of Pure Chlorides of Potassium and Sodium.

A. Using a considerable excess of Platinum Solution.

Experiment.	Process.	Weight of solution.	=KCl.	NaCl taken.	Weight of precipitate.	=KCl found.	=KCl per 100 parts taken.	
23.	I. Fresenius	3·8525	·3502	·350	1·1518	...	100·59	
24.	,,	3·8970	·3543	·355	1·1690	...	100·84	W.
25.	,,	3·8705	·3519	·350	1·1590	...	100·66	
26.	,,	3·8530	·3503	·350	1·1542	...	100·70	
27.	,,	3·8725	·3520	·350	1·1606	...	100·75	W.
28.	,,	3·8770	·3524	·350	1·1618	...	100·73	
29.	II. Fres. mod.	...	·697	·154	2·2887	·69942	100·34	P.
30.	,,	...	·697	·154	2·2932	·70080	100·54	
31.	,,	...	·697	·154	2·2908	·70007	100·35	P.
32.	,,	...	·697	·154	2·2912	·70019	100·46	
33.	,,	...	·3485	·350	1·1463	·35022	100·53	P.
34.	,,	...	·3485	·350	1·1517	·35196	100·99	P.
35.	,,	...	·3485	·350	1·1498	·35138	100·83	
36.	,,	...	·3485	·350	1·1458	·35015	100·47	P.
37.	,,	...	·3485	·350	1·1457	·35012	100·47	
38.	IV. Tatlock	...	·697	·154	2·2830	·69778	100·11	P.
39.	,,	...	·697	·154	2·2851	·69832	100·19	
40.	,,	...	·697	·154	2·2843	·69808	100·15	P.
41.	,,	...	·697	·154	2·2865	·69793	100·25	
42.	,,	...	·3485	·350	1·1329	·34621	99·34	P.
43.	,,	...	·3485	·350	1·1312	·34569	99·20	P.
44.	,,	...	·3485	·350	1·1308	·34711	99·60	P.
45.	,,	...	·3485	·350	1·1340	·34655	99·44	P.
46.	,,	3·8600	·3509	·350	1·1452	...	99·73	
47.	,,	3·8615	·3510	·350	1·1467	...	99·82	W.
48.	,,	3·8560	·3505	·350	1·1468	...	99 97	
49*.	,,	...	·7053	·350	2·2940	...	99·45	W.
50*.	,,	...	·7007	·350	2·2850	...	99·66	W.

* Experiments 49 and 50 were made on a special solution containing about two parts of KCl to one of NaCl. These two determinations were made by Mr. W. Galbraith, who has had much experience in the determination of potassium by Tatlock's method.

B. Using slight excess of Platinum Solution above that required to convert all the K and Na into Chloroplatinates.

Experiment.	Process.	Weight of solution.	=KCl taken.	=NaCl.	Weight of precipitate.	=KCl found.	=KCl per 100 parts taken.	
51.	I. Fresenius	3·880	·35273	·35	1·1569	·35354	100·23	W.
52.	,,	3·873	·35209	·35	1·1636	·35559	100·94	W.
53.	,,	3·8665	·3515	·35	1·1470	·35052	99·72	W.
54.	,,	3·8775	·3525	·35	1·1505	·35159	99·77	
55.	III. Frank and Berrand	2·200	·20000	·2	·65708	·2008	100·40	W.
56.	,,	2·2135	·20123	·2	·66038	·20181	100·30	
57.	,,	2·2195	·20177	·2	·66038	·20181	100·02	W.
58.	,,	2·2070	·20064	·2	·65838	·20120	100·28	
59.	,,	2·2320	·20291	·2	·6782	·20724	102·14	W.
60.	,,	2·2395	·20359	·2	·6801	·20783	102·09	

Table V.—Comparison of the Actual Composition of Mixtures of Potassium and Sodium Chlorides with the results obtained.

A. Using large excess of Platinum Solution.

Experiment.	Process.	KCl per cent. taken.	NaCl per cent. taken.	KCl per cent. obtained.	Error.
23.	I. Fresenius	50	50	50·29	+·29
24.	,,	50	50	50·42	+·42
25.	,,	50	50	50·33	+·33
26.	,,	50	50	50·35	+·35
27.	,,	50	50	50·37	+·37
28.	,,	50	50	50·36	+·36
	Average	...	...	...	+·35
29.	II. Fres. mod.	82	18	82·28	+·28
30.	,,	82	18	82·44	+·44
31.	,,	82	18	82·29	+·29
32.	,,	82	18	82·38	+·38
33.	,,	50	50	50·26	+·26
34.	,,	50	50	50·49	+·49
35.	,,	50	50	50·41	+·41
36.	,,	50	50	50·23	+·23
37.	,,	50	50	50·23	+·23
	Average	...	...	...	+·34
38.	IV. Tatlock	82	18	82·09	+·09
39.	,,	82	18	82·15	+·15
40.	,,	82	18	82·12	+·12
41.	,,	82	18	82·20	+·20
42.	,,	50	50	49·67	−·33
43.	,,	50	50	49·60	−·40
44.	,,	50	50	49·80	−·20
45.	,,	50	50	49·72	−·28
46.	,,	50	50	49·86	−·14
47.	,,	50	50	49·91	−·09
48.	,,	50	50	49·98	−·02
49.	,,	67	33	66·63	−·37
50.	,,	67	33	66·77	−·23
	Average	...	...	...	−·11

B. Using slight excess of Platinum Solution.

Experiment.	Process.	KCl per cent. taken.	NaCl per cent. taken.	KCl per cent. found.	Error.
51.	I. Fresenius	50	50	50·11	+·11
52.	,,	50	50	50·47	+·47
53.	,,	50	50	49·86	−·14
54.	,,	50	50	49·38	−·12
	Average	...	...	...	+·08
55.	III. Frank	50	50	50·20	+·20
56.	,,	50	50	50·15	+·15
57.	,,	50	50	50·01	+·01
58.	,,	50	50	50·14	+·14
59.	,,	50	50	51·07	+1·07
60.	,,	50	50	51·04	+1·04
	Average	...	...	...	+·43

From these experiments it appears that the employment of the processes of Fresenius and Frank leads to results sensibly above the truth if a large excess of platinum be employed. The fact that in *all* the experiments the error is in the same direction, indicates that it is not due to defective manipulation. When only a slight excess of platinum is employed in the above methods the results are decidedly better, but present greater differences among themselves, as if some other disturbing cause came into operation. This is notably the case with Frank's method, the error in only six experiments varying from ·01 per cent. to 1·07.

The results by Tatlock's method distinctly indicate a tendency to loss; but this is chiefly noticeable in the cases in which the proportion of sodium chloride was very high (50 per cent.). In fact four experiments with a mixture similar to that which usually occurs in practice (*i. e.* 82 per cent. KCl and 18 NaCl) gave results showing an error in *excess* of the truth varying from ·09 to ·20 per cent. The thirteen determinations by Tatlock's method show a maximum error of —·40 per cent.

In this experiment the quantity of material employed was *measured* in the pipette, and for several reasons this plan was found less trustworthy than the *weighing* of the solution used.

With the view of ascertaining the cause of the loss observed in some cases by Tatlock's method in presence of a large proportion of sodium chloride, an experiment was made by treating a mixture of 30 milligrammes of KCl and ·7 gramme of pure NaCl with 30 c. c. of the platinum solution (the usual quantity), and estimating the potassium in the usual way.

By employing a small quantity of KCl it was thought that other errors of manipulation would be avoided, and that the experiment would be practically to ascertain the extent to which chloroplatinate of potassium was soluble in a solution of platinic chloride containing much chloride of sodium (or, in other words, in a solution of sodium chloroplatinate). The weight of potassium chloroplatinate which should have been yielded by the above quantity of KCl is ·0982 gramme, whereas the weight actually obtained was only ·0915 gramme. Hence there was a loss of ·0067 gramme. In another experiment in which only ·35 gramme of NaCl were used, the quantities of KCl and platinum solution remaining as before, a loss of ·0042 gramme of chloroplatinate was observed. In this last experiment the potassium chloride corresponding to the chloroplatinate obtained was only 95·7 per cent. of the quantity added, while in the previous experiment it amounted to only 93·2 per cent. From these results, and those recorded in the Tables, it appears that the percentage error is larger the greater the proportion of sodium salts present, a fact which appears to point to the solubility of the precipitate in solution of sodium chloroplatinate as the origin of the loss. Thus in the experiments in which pure chloride of potassium was employed, and in those in which the amount of sodium chloride was small, the variation from the truth was exceedingly slight, but the errors became greater with the amount of sodium chloride present. In experiments 42 to 50 the amounts of chloride of sodium and platinum solution employed were the same as in the test experiment, in which a deficiency of ·0042 gramme of precipitate was observed. If we assume that this loss is the weight of K_2PtCl_6 dissolved by the use of ·35 gramme of NaCl and 30 c. c. of platinum solution, then a correction of ·0042 gramme ought to be applied to each of the results of experiments 42 to 50. This correction of ·0042 gramme in the weight of the precipitate corresponds to ·37 per cent. of KCl. The mean of the nine experiments above referred to is 99·58 per cent. of KCl, which, with the correction ·37, amounts to 99·95 per cent.

From these considerations it appears almost certain that the deficiency is due to the solubility of the precipitate in platinum solution containing sodium chloroplatinate.

If a loss of about four milligrammes produces an error of ·37 by Tatlock's method, the discrepancy would be much greater by Frank's, in which a smaller weight of the sample is employed. This fact, and the very strong alcohol required, renders this process less satisfactory than that of Fresenius. Why the latter process should give results in excess of the truth, even when the modified method (II.) was used, seemed difficult to explain. With a view of ascertaining the cause, three quantities of pure chloride of potassium, with equal weights of chloride of sodium, were treated by method I. After weighing, the precipitates were dissolved in hot water, 10 or 12 drops of platinum solution added, and the process of evaporation, &c. repeated. The following results were obtained :—

TABLE VI.

Experiment.	Weight of solution.	=KCl taken.	First precipitation. Weight of precipitate.	=KCl.	=KCl per cent.	After re-dissolving. Weight of precipitate.	=KCl.	=KCl per cent.
61.	3·8530	·35027	1·1542	·35272	100·70	1·1527	·35226	100·57
62.	3·8725	·35204	1·1606	·35469	100·75	1·1615	·35495	100·82
63.	3·8770	·35245	1·1618	·35504	100·73	1·1609	·35478	100·66

In these and in all previous experiments the precipitates were dried at 100° C. In the last edition of his 'Quantitative Analysis,' Fresenius directs the precipitate to be dried at 130° C. To ascertain if this difference of treatment was the cause of the error, some pure potassium chloroplatinate was prepared by rapidly cooling a saturated solution of the salt in boiling water. In this way it was obtained as a fine crystalline powder. By the slow evaporation of the mother liquor another sample was obtained in the form of "scales." The products were dried for half an hour at 100° C., and 3 grammes of each exposed to a higher temperature, with the following results :—

TABLE VII.

	Crystals. Loss on 3 grms.	Crystals. Loss per cent.	Scales. Loss on 3 grms.	Scales. Loss per cent.
After 1 hour additional at 100° C.	none	none	none	none
,, ½ ,, 130° C.	·0005	·017	·0015	0·05
,, 1 ,, 140° C.	·0015	·050	·0005	0·017
,, ½ ,, 200° C.	·0080	·270	·0075	0·250

It will be seen that no loss occurred on further drying at 100° C., and a very trifling loss at 130°. After heating to 140° there was a slight change of colour. At 200° decrepitation and incipient decomposition ensued. The total loss at a temperature not exceeding 140° was only ·067 per cent. of the weight of the precipitate. This, in the experiments by method I., would only cause a difference of ·02 per cent. in the quantity of chloride of potassium found. Hence it is clear that there is no advantage in drying the precipitate at 130° rather than at 100°. On the other hand the occurrence of decrepitation shows that the crystals contain cavities filled with water or platinum choride solution, and therefore that the production of large crystals should be avoided. It seems possible that the difference in the nature of the liquid filling the cavities may be the cause of the greater error observed when a large excess of platinum solution is employed than when little more than the theoretical amount is used.

In the foregoing Tables the results obtained by Frank's method were calculated with the Committee's factor ·3056 instead of that employed by Frank and Berrand themselves (·30507)*. By the use of the latter factor the results would come out about ·17 per cent. lower than the figures given in the Tables. Some of the results by this process are exceedingly good, but in other cases they are seriously in excess of the truth (see Experiments 3, 4, 59 and 60).

One very considerable advantage attaches in practice to Tatlock's method which is not shared by the others. In consequence of employing an aqueous liquid at first, any sulphates present can be readily washed out, and therefore there is no occasion to separate any moderate amount beforehand. The influence of sulphates is well shown by the following results by Tatlock's method:—

TABLE VIII.—82 per cent. KCl + 18 per cent. Na_2SO_4.

Experiment.	Weight of Solution.	=KCl.	Weight of precipitate.	=KCl found.	=KCl per cent.	
64.	..	·697	2·2838	·69793	100·13	P.
65.	..	·697	2·2865	·69875	100·25	

TABLE IX.—K_2SO_4 with sufficient NaCl (·5 grm.) to ensure the reaction $K_2SO_4 + 2NaCl + PtCl_4 = K_2PtCl_6 + Na_2SO_4$.

Experiment.	Weight of Solution.	$=K_2SO_4$.	Weight of precipitate.	$=K_2SO_4$ found.	$=K_2SO_4$ per cent.	
66.	7·7180	·70163	1·9560	·69820	99·51	W.
67.	7·7010	·70009	1·9549	·69780	99·67	
68.	7·7250	·70226	1·9591	·69930	99·57	
69.	7·7280	·70255	1·9637†	·70094	99·78	W.
70.	7·7095	·70087	1·9596	·69948	99·80	

* The factor employed by Frank and Berrand is based on Andrews's determination of the atomic weight of platinum. This observer states that potassium chloroplatinate retains ·55 per cent. of water even when dried at temperatures considerably above 100° C. If this be true, the low factor employed by Frank and Berrand would partly compensate the error thus introduced. In the experiments detailed in the text only ·25 per cent. was lost at a temperature of 200°, but decrepitation occurred on raising the temperature still higher.

† This precipitate, after drying at 130° C., gave 99·72 per cent. of K_2SO_4.

The next experiments were made to ascertain the effect of employing hydrochloric acid in place of chloride of sodium, according to the reaction $K_2SO_4+2HCl+PtCl_4=K_2PtCl_6+H_2SO_4$.

In Experiments 71, 72, and 73, 2 cub. centims. of hydrochloric acid were employed; in Experiments 74 and 75, 2½ cub. centims. were used. The acid in each case had a density of 1·11.

TABLE X.

Experiment.	Weight of Solution.	$=K_2SO_4$ taken.	Weight of precipitate.	$=K_2SO_4$ found.	$=K_2SO_4$ per cent.	
71.	7·7460	·70419	1·9661	·70180	99·66	W.
72.	7·7190	·70173	1·9483	·69547	99·11	W.
73.	7·7470	·70427	1·9579	·69887	99·23	
74.	7·7145	·70132	1·9590	·69927	99·71	W.
75.	7·7155	·70141	1·9595	·69944	99·72	

In the first three experiments the quantity of HCl appears to have been insufficient to effect complete conversion, but in the latter experiments the reaction seems to have been more perfect.

The following experiments were made in illustration of the use of Tatlock's process in the analysis of a German muriate, which was represented by a mixture containing 85 per cent. KCl, 10 per cent. $MgSO_4$ (anhydrous), and 5 per cent. NaCl.

TABLE XI.

Experiment.	Weight of Solution.	=KCl taken.	Weight of precipitate.	=KCl found.	=KCl per cent.	
76.	6·5440	·5949	1·9467	·59463	99·999	W.
77.	6·5415	·5947	1·9442	·59414	99·910	
78.	6·5460	·5951	1·9497	·59582	100·120	

A mixture containing 50 per cent. KCl, 25 per cent. NaCl, and 25 per cent. $MgSO_4$ was found by Mr. Galbraith to contain 99·83 per cent. of KCl for 100 introduced, equal to 49·915 per cent. in the actual sample.

In many of the experiments detailed it must be remembered that the actual departure from the truth is only a fraction of what it appears to be on calculation to 100 parts. Thus in the above Tables the results are compared with 100 parts of the potassium salt taken, whereas in practice the results would be stated on 100 parts of the sample. Hence in a mixture of equal parts of the chlorides of potassium and sodium, to obtain 100·5 parts of KCl instead of 100 would be expressed in practice by stating the sample to contain 50·25 of KCl and 49·75 of NaCl, thus reducing the actual error to half what it appears to be in some of the Tables. This view finds expression in Table V.

The next experiments were made by Tatlock's method on pure nitrate of potassium, to which was added enough chloride of sodium (·42 grm.) for the reaction—

$$2KNO_3+2NaCl+PtCl_4=K_2PtCl_6+2NaNO_3.$$

Table XII.

Experiment.	Weight of Solution.	$=KNO_3$.	Weight of precipitate.	$=KNO_3$ found.	$=KNO_3$ per cent.
79.	7·7090	·70082	1·6868	·69879	99·72 } W.
80.	7·7330	·70300	1·6944	·70212	99·87 } W.
81.	7·7325	·70296	1·6953	·70249	99·93 } W.

It appears therefore that Tatlock's process is applicable to the analysis of sulphates or nitrates, provided that there is sufficient chloride present for the formation of the chloroplatinate of potassium. If not, it must be added in the form of sodium chloride, or, in the case of sulphates, hydrochloric acid may be used. When much sulphate is present, the quantity of platinum solution used for washing the precipitate must be somewhat increased, or the results will be too high, owing to the insolubility of the sulphates in alcohol. Magnesium appears to cause no difficulty, the result 99·999 having been obtained in its presence.

When it is remembered that none of the foregoing experiments were made on a larger quantity than ·7 of a gramme (about 10 grains), it will be seen that the determination of potassium as chloroplatinate is, when due care is taken, as accurate as the estimation of most elements, and, when heavy metals are absent, quite as easily effected.

In practice it is rarely required to determine potassium very accurately in presence of large proportions of foreign metals, but in the accurate assay of the better class products is becoming daily more important. If the proportion of sodium salts present in a sample exceed 3 per cent. the product is unfit for certain purposes; and as the determination of the sodium is strictly dependent on that of the potassium, any error in the latter is reproduced.

Although the results obtained by Tatlock's method show a decided loss when a very large proportion of chloride of sodium is present, this error nearly disappears with smaller amounts; and as the method is available in presence of sulphates, nitrates, and magnesium, and is very readily conducted, it seems the best suited for the general assay of commercial potassium salts.

From a general consideration of the foregoing researches on the determination of potassium as chloroplatinate it appears that:—

1. Potassium in the form of pure chloride can be determined with great accuracy by precipitation as chloroplatinate. If a large excess of platinum solution be employed, and alcohol alone used for washing the precipitate, the results have a tendency to exceed the truth. By avoiding the use of a large excess of platinum solution more accurate results are obtained. If a small volume of platinum solution be employed in the first instance for washing the precipitate (as recommended by Tatlock), and the washing be then completed with alcohol in the usual way, the results are very accurate. Potassium chloroplatinate appears to be practically insoluble in a concentrated solution of platinic chloride.

2. In presence of a considerable proportion of sodium, washing the precipitate with alcohol alone tends to give results in excess of the truth. If the precipitate be first treated with platinum solution the results are somewhat low, apparently owing to the solubility of the precipitate in a solution

of sodium chloroplatinate. The error increases with the amount of sodium, but is never very large, and a correction may be applied if desired.

3. If Tatlock's method be employed there is no occasion to separate any sulphates, nitrates, or magnesium; but if the amount of chloride present is insufficient for the existence of all the potassium as chloride of potassium, the deficiency must be supplied by addition of chloride of sodium or hydrochloric acid. The results obtained are in many cases very accurate, but have a tendency to be somewhat below the truth.

4. There is practically no advantage in drying the chloroplatinate of potassium at 130° C. rather than at 100° C. The loss at the higher temperature was found not to exceed ·07 per cent. of the weight of the precipitate, but is probably governed by the conditions of precipitation.

5. The Committee is of opinion that a preliminary washing of the precipitate of chloroplatinate of potassium with a solution of platinic chloride is a valuable modification of the usual process. As the method so modified is capable of direct application to the commercial salts of potassium, and does not necessitate the previous removal of sulphates, nitrates, or magnesium, the Committee considers that it deserves to be generally applied for the determination of potassium in commercial products containing that metal.

So far the Committee has not thought it necessary to make any experiments on other methods of determining potassium than that in which it is converted into chloroplatinate.

Statement of the Results of Analysis of Potash Salts.

Your Committee has devoted considerable attention to the difficult question of the proper mode of stating the results of analyses of potash salts.

Hitherto the statements of various analysts appear to have been characterized by a lamentable want of system, and in many cases they are greatly at variance with the generally accepted principles of chemical combination and double decomposition.

The Committee has been furnished with copies of analyses of potash salts in which carbonate of potassium is reported as coexistent with sulphate and chloride of sodium, and the cases are numerous in which similar anomalous statements occur.

These various modes of statement are by no means solely due to eccentric notions respecting chemical affinity, but appear in many cases to be owing to the desire to attribute as high or low (as the case may be) a commercial value to the article analyzed as is compatible with its percentage composition. Thus a commercial carbonate is chiefly valuable on account of the potassium carbonate it contains; and therefore if the whole of the potassium be stated as existent in that form, while the valueless sulphate and chloride are relegated to the sodium, the apparent value is considerably greater than if only that portion of the potassium be assumed to exist as carbonate which is in excess of the quantity necessary to combine with the more powerful salt radicals.

The Committee believes it would be practically impossible to lay down general rules for statement of results which, if followed, would necessarily and invariably lead to an exact and scientific statement of the mode of existence of the various metals and salt radicals in a complex commercial salt of potash; but it is of opinion that whatever modifications in detail individual analysts may think proper to adopt, the following general principles should be adhered to:—

The plan should be adopted of combining the strongest metal with the strongest salt radical, after due allowance for the tendency to form insoluble or nearly insoluble salts. Thus the soluble calcium should always be stated as existent as sulphate. The excess of the salt radical should be combined with potassium on the ground that chloride, nitrate, or carbonate of potassium is incapable of coexistence with sodium sulphate.

In the case of artificial or acid sulphates, produced by treating "muriates" with vitriol, the Committee is of opinion that the free acid is sulphuric acid, not hydrochloric acid. The reason for this opinion is to be found in the fact that any free hydrochloric acid would inevitably have been volatilized at the temperature employed in the production of the sulphate. The same remark applies to sulphuric acid if actually *free*, but if in combination with sulphate of potassium, to form an acid salt, it might resist volatilization. The acid salt here mentioned as a compound of sulphuric acid and sulphate of potassium would be more correctly described as potassium-hydrogen-sulphate, $KHSO_4$; but your Committee believes that the practical inconvenience of stating a certain amount of potassium in this form and the rest as neutral sulphate would outweigh any advantage to be derived from a scientifically exact statement*.

It is evident that the presence of free sulphuric acid or of an acid sulphate in artificial sulphates can only be due to imperfect admixture of the vitriol and muriate, otherwise the following well-known reactions would have taken place:—

$$KHSO_4 + KCl = K_2SO_4 + HCl.$$
$$NaHSO_4 + NaCl = Na_2SO_4 + HCl.$$

In the event of the bulk of the muriate consisting of chloride of potassium, it may be argued that there is a greater probability of that salt remaining unacted on than that chloride of sodium should remain undecomposed; but it is evident that the circumstances are such as must vary with the conditions of each case; and your Committee therefore prefers to recommend the adoption of the arbitrary assumption that all potassium exists as sulphate, provided that there is sufficient of the salt radical present to combine with the whole of the potassium, after allowing for the free acid and the sulphate of calcium.

On the other hand, it may be argued that as sulphates are always converted into carbonate or caustic alkali, any chloride present in the sample would ultimately be lost in the worthless form of chloride of potassium, whatever the metal with which it was originally combined. This argument has considerable force, and to meet it the Committee recommends that all statements of the results of analyses of artificial sulphates should have appended the equivalent in chloride of potassium of the chloride found. In artificial sulphates there is considerable probability that the chlorine exists chiefly, if not wholly, as potassium chloride; but such cannot be assumed to be the case with other sulphates, and in the statement of the composition of these the Committee considers the above calculation undesirable from a scientific point of view, though it is clear that there are other considerations in its favour.

The distribution of the salt radicals among the remaining metals (sodium, magnesium, and iron) appears to the Committee to be a matter of indifference,

* The same remark applies to other double salts, such as $MgSO_4 + K_2SO_4$, and the curious compound $3K_2SO_4 \times Na_2SO_4$, often met with in kelp products. The recognition of the presence of such compounds in the statement of the results of analysis of commercial salts containing them appears to the Committee to be quite unnecessary.

as the precise arrangement will not affect the value of the sample, nor cause any alteration in the sum of the constituents, while there appears to be no reliable evidence of the actual mode of combination.

In the case of "muriates," and sulphates having an alkaline reaction, such as those made from kelp and beetroot, potassium and sodium are the only two metals present in larger quantities than traces. In the statement of all such analyses your Committee is of opinion that the only proper method is to calculate the potassium as sulphate, chloride, and carbonate in succession, assuming no sodium to exist as sulphate or chloride unless the amount of potassium present is insufficient to satisfy the latter or both of those salt radicals.

The impossibility of the coexistence of sodium sulphate or chloride with potassium carbonate is proved by the fact that double decomposition occurs when solutions of these salts are mixed and concentrated.

The non-deliquescent character of kelp sulphates and muriates also furnishes a strong independent proof of absence of potassium carbonate.

The same principles apply to the statement of the results of the analyses of commercial carbonates of potassium, and in their case its adoption becomes still more important.

In the case of saltpetres only that portion of the potassium can be properly considered to exist as nitrate which is in excess of the quantity required for calculation as potassium sulphate (after allowing for the sulphate present as calcium sulphate); whether some of the potassium will also exist as chloride, or whether there will be some sodium nitrate present, must depend on the respective amounts of potassium and NO_3 found; but having regard to the well-known reaction $KCl + NaNO_3 = NaCl + KNO_3$, your Committee is of opinion that the presence of both chloride of potassium and nitrate of sodium in the same sample is improbable.

In brief, the Committee is of opinion that in calculating the results of analyses of potash salts, the following method should be adhered to in combining the various metals and salt radicals present in the portion of the sample soluble in water.

Basic hydrogen, which is met with only in artificial sulphates, exists as sulphuric acid, or, more strictly speaking, as potassium-hydrogen-sulphate, $KHSO_4$.

Calcium does not occur in practice in excess of an equivalent amount of sulphate, so that it should always be calculated to $CaSO_4$.

The remaining constituents of the soluble portion of the sample should be arranged on the principle of combining the strongest metal with the strongest salt radicals.

The order of affinity which the Committee considers most in accordance with observed facts and theoretical propriety is shown in the following list, in which the strongest metals and salt radicals are placed first:—

Potassium.	Sulphate.
Sodium.	Nitrate.
Magnesium.	Chloride.
Iron.	Carbonate.

The Committee is of opinion that in all cases in which one of the constituents of a sample is determined by subtracting the sum of the others from 100·00, the fact ought to be indicated in the statement of results. This can readily be done by appending the words "by difference" or "estimated by difference" to the name of the constituent thus determined. The adoption of this plan would obviate many of the disadvantages attendant on indirect determinations; but the Committee strongly recommends the employment of direct processes whenever possible.

In all cases where such a course is possible it is very desirable that the various compounds of potassium present should be calculated into the salt which the name of the article indicates as the leading constituent of the sample. In the case of sulphates, muriates, and carbonates, the corresponding amount of anhydrous potash should be stated. Thus the Committee recommends that an analysis of a German muriate should be stated somewhat in the following manner:—

Centesimal composition.		=Potassium Chloride.	=Anhydrous Potash.
Calcium Sulphate.			
Potassium Sulphate.	A.		x
Potassium Chloride.	B.	B	y
Sodium Chloride			
Magnesium Chloride.			
Insoluble Matter.			
Water.			
	100·00	B+a.	x+y

In the case of carbonates, the anhydrous potash corresponding to the carbonate of potassium present should always be stated separately from that calculated from the sulphate and chloride, as it is only in certain cases that the potassium existing in the latter forms is of any real value.

Third Report of a Committee, consisting of E. C. C. STANFORD, A. E. FLETCHER, J. DEWAR, E. W. PARNELL, T. W. OGILVIE, *and* ALFRED H. ALLEN (*Secretary*), *on the methods of estimating Potash and Phosphoric Acid in Commercial Products containing them, and on the Statement of the results. Drawn up by* ALFRED H. ALLEN.

ESTIMATION OF POTASH.

Although the process of determining potassium by precipitation with chloride of platinum is the method almost universally adopted by chemists of large experience in the assay of commercial potash salts, the Committee thought it desirable to investigate also the volumetric method of Stolba, which is based on the precipitation of potassium as silicofluoride and the titration of the precipitate with standard alkali, according to the equation—

$$K_2SiF_6 + 4KHO = 6KF + H_4SiO_4.$$

This process is thus described on page 176 of the 7th English edition of Fresenius's 'Quantitative Analysis':—"To the moderately concentrated solution of the potash salt in a beaker add a sufficiency of hydrofluosilicic acid, and then an equal volume of pure strong spirit. The silicofluoride of potassium will separate as a translucent precipitate. When it has settled, filter, wash out the beaker with a mixture of equal parts strong spirit and water, and wash the precipitate with the same mixture till the washings are no longer acid to litmus paper. Put the filter and precipitate into the beaker previously used, treat with water, add some tincture of litmus, heat to boiling, and add normal alkali solution till the fluid is just blue, and remains so after continued boiling."

With a view of preparing pure chloride of potassium for these researches, the Committee abandoned the method employed last year, in favour of a simpler process suggested in a note appended to the last report.

Commercial chlorate of potassium was recrystallized and heated until no more oxygen was evolved, and the product was dissolved in water, filtered, a few drops of hydrochloric acid added to the clear solution, and the whole evaporated to dryness and ignited in a muffle at a low red heat. The product was powdered and bottled. When heated on clean platinum wire in a Bunsen flame it gave no trace of yellow colour to the flame.

Thirty-five grammes of this pure salt were dissolved in 315 grammes of pure water, in order to make a solution containing exactly one tenth of its weight of pure chloride of potassium.

In the following investigation a roughly measured quantity of this solution was run into a beaker and the exact weight taken. This method was adopted during the experiments of last year in preference to pipette measurements, which were not considered satisfactory.

The solution was first analyzed by precipitation by nitrate of silver. The following table shows the quantities taken, and the number of parts of KCl found for one hundred taken*:—

No. of Expt.	Weight of Solution.	Weight of AgCl obtained.	= KCl found	= KCl found for 100 parts taken.
1......	7·0805	1·3619	·70850	100·06
2......	7·0275	1·3509	·70278	100·00

The six following experiments were made by adhering strictly to the description of the process already quoted. A quantity of potassium chloride solution containing about ·7 gramme or 10 grains of the salt was employed in each case. The standard alkali employed was very carefully prepared and was strictly normal.

It was not found practicable to wash the precipitate till the washings were no longer acid to litmus. The washing was therefore arrested when the filtrate gave no reaction with silver nitrate.

Expt.	Wt. of Soln.	C. c. normal alkali used.	= KCl	= KCl found per 100 parts taken.
1......	7·1155	18·80 S	·70110	98·54
2......	7·1100	18·83 P	·70236	98·80
3......	7·0290	18·75 S	·69937	99·90
4......	7·0190	18·75 S	·69932	99·62
5......	7·1365	19·10 S	·71237	99·56
6......	7·0210	18·70 P	·69745	99·34

Although it was not to be expected that there could be any advantage in employing caustic potash in the titration instead of caustic soda, it was considered that the case was one in which it was just possible that there might be a choice, and therefore both alkalies were tried. The alkali employed in each experiment is distinguished by the letters P and S placed after the number of centimetres of normal alkali required.

* The following are the atomic weights employed in the investigation:—
K=39·137; Si=28; Ag=107·93; Cl=35·457; F=18·96.

In experiment 1 an excess of alkali was employed, and the liquid was then titrated back with sulphuric acid. It was hoped in this way to ensure the complete and speedy decomposition of the silicofluoride; but the end of the reaction was very difficult to read, perhaps owing to the formation of silicate. It was also found to be no advantage to add the acid in sensible excess and again titrate with alkali. In some cases decinormal alkali was employed towards the conclusion of the titration, but the end of the reaction was not sufficiently defined to make the precaution valuable. No. 2 can scarcely be considered a test experiment, for the precipitated silicofluoride was dried on the filter and then scraped off.

The next three experiments were made on about 1·5 gramme (twice the former quantity) of potassium chloride, the precipitated silicofloride being dried on the filter, scraped off, and weighed.

Expt.	Wt. of Soln.	Wt. of Precipitate.	= KCl	= KCl found per 100 parts taken.
7......	15·0525	2·2150	1·5018	99·77
8......	15·0475	2·2115	1·4994	99·64
9......	15·0365	2·2070	1·4964	99·52

These results do not show any great departure from the truth, especially as traces of the precipitate probably adhered to the filter and were thus lost. The manipulation was very easy, filtration occurring rapidly, and the precipitate being easily washed, dried, and separated from the filter.

After weighing, the precipitates obtained in the last experiments were suspended in boiling water and titrated with normal alkali, with the following results:—

Expt.	Wt. of ppt. taken.	C. c. normal alkali used.	K_2SiF_6 found per 100 parts taken.
7 A....	2·2150	39·60 P	98·4
8 A....	2·2115	31·60 S	98·6
9 A....	2·2070	40·10 S	99·95

In the last experiment the titration was slightly overdone. It appears, therefore, that the volumetric method gives results sensibly below the truth. Probably the error was greater in the last three experiments owing to the precipitates having been dried, and thus reacting less readily with alkali than the undried silicofluoride.

In these, as in all other experiments, the alkali was added very slowly towards the end of the reaction, and the liquid was well boiled after each addition.

Three more experiments by direct titration of the silicofluoride with alkali gave the following results:—

Expt.	Wt. of soln. taken.	C. c. of normal alkali used.	= KCl.	KCl found for 100 parts taken.
10....	15·0525	40·10 P	1·4956	99·4
11....	15·0475	39·90 S	1·4881	98·9
12....	15·0365	40·10 S	1·4956	99·4

In these last experiments the large quantity of silica produced rendered the end of the reaction difficult to observe. In fact the want of sharpness in the termination of the reaction is a serious defect of the process. A porcelain basin was found preferable to a beaker for conducting the titration.

Although in the above experiments the volume of alkali used was read to $\frac{1}{20}$ of a cubic centimetre, the end of the reaction could not be defined so closely, even after considerable practice. A difference of 0·1 cub. centim. in the volume of the standard alkali employed corresponds in the last three experiments to about ·25 per cent. of the chloride of potassium taken, and in the first six experiments to ·5 per cent. of the sample. As the quantity of potassium chloride worked on cannot be conveniently increased beyond the weights used in experiments 10, 11, and 12, it is evident that the process is not susceptible of great accuracy even if no other disturbing influence existed.

The fact that the volumetric method gives results below the truth is probably due to the difficulty of decomposing the last traces of silicofluoride by alkali, without introducing an excess of the latter. The trace of free alkali which suffices to change the tint of the litmus to blue seems incapable of reacting on the silicofluoride. An attempt was made to overcome this difficulty by adding a sensible excess of alkali, boiling well, and titrating back with standard acid; but the result was not satisfactory, the end of the reaction being very obscure.

In practice it would be preferable to set the standard alkali by its action on moist silicofluoride prepared from a known quantity of potassium chloride, rather than to trust to its theoretical neutralizing effect.

As the drying and weighing of the silicofluoride requires but little more time than the titration with alkali, and gives better results, the gravimetric estimation is to be preferred. Although the process is not to be compared in accuracy to the precipitation and weighing of potassium as potassium chloroplatinate, it might no doubt be advantageously employed in particular cases.

The next experiments were made on a mixture of 75 per cent. of chloride of potassium with 25 per cent. of chloride of sodium.

Expt.	Wt. of KCl soln. taken.	NaCl taken.	C. c. normal alkali used.	= KCl found.	KCl found for 100 parts taken.
13	....11·7505	·375	42·95 S	1·6019	136·3
14	....11·7530	·375	42·95 S	1·6019	136·3

These results show that 96·9 per cent. of the total amount of alkali metal present was precipitated as silicofluoride. In two other experiments of equal weights of potassium and sodium chlorides, 222 and 218 parts of KCl were found for 100 parts taken. The former number represents a precipitation of 96·8 per cent. of the sum of the alkali metals present.

Two experiments were next made on mixtures of potassium and sodium chlorides by precipitating the solution with hydrofluosilicic acid as before, but using a smaller proportion of spirit. One third of the bulk of solution and wash water consisted of rectified spirit, instead of one half, as in all previous experiments. The weights of the precipitates corresponded respectively to 169 and 188 parts of potassium chloride for 100 parts taken.

It is evident from these experiments that the process is quite worthless for the separation of potassium from sodium, and consequently that the number of cases in which it can be advantageously employed is greatly limited. Although this result was anticipated from the known properties of sodium silicofluoride, it was thought desirable to establish the fact by direct experiment.

Since the above experiments were completed the original paper of Stolba has been consulted *. The author recommends the suspension of the precipitated silicofluoride in a much larger quantity of water than was employed

* Zeitsch. für anal. Chem. iii. p. 298.

by the Committee. This plan would cause the more perfect solution of the precipitate, and probably yield somewhat higher results; but the author's experiments on pure potassium salts gave results sensibly below the truth. As the value of the process is greatly limited by its uselessness in presence of sodium compounds, the Committee did not think it necesssary to perform a fresh series of experiments with more rigid adherence to Stolba's directions.

Methods of determining Phosphoric Acid.

With respect to the general method of procedure in the assay of commercial phosphatic materials, the Committee has not thought it necessary to make any original experiments, the published and collected evidence on the subject being sufficient for the purpose.

As the result of a very careful consideration of the subject, the Committee make the following recommendations and suggestions. In most cases these are quite free from novelty; but as the evidence collected by the Committee, and the results of many commercial analyses, show that the following considerations and precautions are in many cases partly or wholly neglected, the Committee is of opinion that the general adoption of the following suggestions would tend greatly to diminish the number and extent of the discrepancies common in determinations of phosphoric acid.

Solution of the Manure.

The Committee is of opinion that for dissolving the soluble phosphate contained in a manufactured manure, cold water should invariably be employed. The water should be employed in successive small quantities, and the treatment and digestion with the solvent should not be extended over more than two or three hours. Hot water should be wholly avoided, both for the original extraction of the soluble matter and for washing the residue.

The neglect of the above precautions may cause an error in either direction. The effect of employing hot water for dissolving the soluble phosphate is shown by the fact that the cold aqueous extract of many superphosphates yields a precipitate on boiling. On the other hand the di- and tricalcic phosphates undergo change on boiling with water, with partial solution in some cases.

For the solution of the portion of the manure insoluble in water, or for the determination of the total phosphoric acid, hydrochloric acid is the most suitable. In manures containing iron the addition of a few drops of nitric acid is desirable, to ensure the complete peroxidation of any ferrous compound which may be present.

In manures containing silica the evaporation of the acid solution to dryness should never be omitted. The neglect of this precaution causes the precipitation of the silica at a subsequent stage, and is liable to cause a serious error. Another advantage of the evaporation to dryness is the partial elimination of any fluorine which may be present.

In cases in which much organic matter is present, iron and aluminium cannot be precipitated satisfactorily. In such cases the original sample or the residue insoluble in water should be ignited with an alkaline oxidizing mixture before treating it with acid.

Fresenius, Neubauer, and Luck* have recommended the employment of dilute sulphuric acid for the extraction of the total phosphoric acid from a manure. The advantage claimed for this modification is that the iron and

* Zeitschrift, x. p. 133.

aluminium remain chiefly undissolved. As, however, a small and not very constant amount of iron undergoes solution, the advantage of this method is considerably diminished.

Separation of the Iron and Aluminium.

In all cases in which more than traces of iron or aluminium are present, the Committee is strongly of opinion that they should be separated. In the first place several of the most satisfactory methods of determining phosphoric acid are vitiated by the presence of these metals; and secondly, the manurial value of the sample is affected by their presence. It is therefore doubly important that they should not be ignored.

The removal of the aluminium and iron from the solution is readily effected by neutralizing any excess of acid with ammonia and adding ammonium acetate, when iron and aluminium are thrown down as phosphates, which may be filtered off and weighed. The operation should be conducted in a cold or but slightly warm solution. If the liquid be heated, a calcium phosphate is thrown down.

The precipitate can be conveniently analyzed by the following method, contributed by Mr. R. Warington:—"The precipitated phosphates of iron and aluminium are washed, ignited, and weighed, redissolved in strong hydrochloric acid, and the iron determined volumetrically. From the iron the quantity of ferric phosphate in the precipitate is calculated, the phosphate of aluminium found by difference, and thus the iron, aluminium, and phosphoric acid in the precipitate are obtained. A little phosphoric acid is liable to be removed from the precipitate during washing, and basic salts are thus reckoned in the calculation as of normal composition."

The Oxalic-Acid Method.

In employing this method it is very desirable to previously separate iron and aluminium acetate. Besides the advantages already mentioned, this precaution renders it unnecessary to add an organic acid before precipitating the phosphate with magnesia. The use of an organic acid prevents the complete separation of the lime (oxalate of calcium being soluble in citrate of ammonium), and tends to falsify the subsequent precipitation with "magnesia mixture."

The presence of ammonium acetate facilitates rather than prevents the precipitation of the calcium as oxalate.

On rendering the filtrate from the oxalate of calcium precipitate alkaline with ammonia, a small additional precipitation of oxalate of calcium may occur. If the solution of the manure has been made with acid, and subsequent evaporation of the acid liquid to dryness has been neglected, the precipitate here formed may contain silica or fluoride of calcium. If the separation of the iron and aluminium has been omitted, citric acid must be added before making the solution alkaline with ammonia. Of course if a precipitate is formed at this stage, from whatever cause, it must be separated before adding "magnesia mixture."

Direct Citric-Acid Method.

In this method the iron, aluminium, and calcium are all retained in solution by means of citrate of ammonium, and no attempt is made to separate the calcium as oxalate; but the phosphate is at once precipitated from the ammoniacal solution by "magnesia mixture." Although in the hands of several chemists of high repute this convenient method gives very good results, the sources of error are too numerous to be wholly disregarded. Titration of the precipitate with uranium appears preferable to direct weighing.

Precipitation with "Magnesia Mixture."

Repeated experiments having shown that the employment of sulphate of magnesium for the precipitation of ammonio-magnesium-phosphate is attended with considerable tendency to error, the Committee is of opinion that it should be definitely abandoned in favour of the chloride.

The volume of "magnesia mixture" employed for the precipitation should only be in moderate excess of the amount necessary to completely precipitate the phosphate present.

The use of a large excess of the precipitant causes a more rapid separation of the double phosphate, but is attended with such a serious tendency to error that any advantage gained is more than counterbalanced. The precipitant should be added slowly.

The precipitation should be conducted in the cold, and solution should not be too concentrated. The proportion of free ammonia in the liquid should be large. The minimum amount of ammonia water should be employed for washing.

If the above precautions are duly observed, and silica, fluorine, iron, and aluminium be previously removed, it will rarely be necessary to purify the precipitate by solution in acid and reprecipitation with ammonia. In reprecipitating, some "magnesia mixture" should be added, as its presence tends to reduce the solubility of the precipitate in the ammoniacal liquid. Any correction for solubility of the precipitate should be applied to the ammoniacal washing, and not to the original filtrate.

In igniting the precipitate the heat should be very gentle at first and afterwards be raised as high as possible. If citric acid has been employed, the ignited precipitate is often discoloured. This may be remedied by cautious treatment in the crucible with strong nitric acid followed by reignition.

If the precipitate of ammonio-magnesium-phosphate be titrated by standard solution of uranium instead of being weighed, many of the above precautions are rendered superfluous.

Estimation by Uranium.

The removal of iron and aluminium by addition of an alkaline acetate in the cold, with determination of the phosphoric acid in the filtrate by means of a standard solution of uranium, is a method which, in the opinion of the Committee, deserves extended employment. The use of an acetate in a slightly acid solution brings the liquid into just the condition required for the use of the uranium process. The proportions of acetic acid and alkaline acetate employed, and the volume of the solution, should be approximately constant. The uranium nitrate should be standardized with an acetic-acid solution of pure precipitated ammonio-magnesium-phosphate or tricalcic phosphate, instead of with phosphate of sodium.

The titration should be *converse*, the solution of the phosphate being added to that of the uranium. The latter should be mixed with a constant proportion of acetic acid, and heated on a bath of boiling water. The indicator should be powdered potassium ferrocyanide on a white porcelain slab. Owing to the reversal of the usual process, the brown colour of the ferrocyanide of uranium becomes gradually fainter till the end of the titration.

Molybdic-Acid Method.

Sonnenschein's process of precipitation with molybdic acid, with subsequent treatment with magnesia mixture, and weighing as magnesium pyrophosphate, is probably the most uniformly accurate of all known processes for determining phosphoric acid. It appears always to be employed when great accuracy is desired, and some chemists use it habitually. In some respects, however, the process is not well fitted for general use, for the following reasons:—

A very large excess of molybdic acid above that which is actually precipitated as "phospho-molybdate of ammonium" is required for the complete separation of the phosphoric acid of the solution. The reagent is somewhat expensive, and there is no simple process of recovering the molybdenum from the filtrate.

The yellow precipitate contains less than four per cent. of anhydrous phosphoric acid, and thus becomes very bulky and unmanageable when the quantity of phosphoric acid present exceeds ·1 or ·2 of a gramme. This fact leads to the employment of very small quantities of the material; and as the yellow precipitate has to be subsequently redissolved and precipitated with magnesia mixture in the ordinary way, the error liable to occur from the use of an unusually small weight of the sample detracts greatly from the value of the method.

The above considerations, together with the loss of time and expense incident to the use of the process, prevent the Committee from recommending it for general adoption, though it is of opinion that in many instances the method may be used with great advantage, and that in some cases it is invaluable.

Pisani has described a method of determining molybdic acid by reducing its acid solution with zinc, and titrating the brown liquid with standard permanganate.

J. Macagno has proposed to apply this process to the determination of phosphoric acid, by first precipitating the latter with "molybdate solution" and then titrating the molybdic acid in the precipitate in the above manner. The Committee has instituted some experiments on this process, but the results were very unsatisfactory

Reduced Phosphates.

It is well known that the soluble phosphate of some superphosphates has a tendency to pass back into the insoluble condition. It is plausibly argued that the finely divided insoluble phosphate thus produced is equal in manurial value to the soluble phosphate originating it, and therefore that in judging of the value of the manure the insoluble "reduced" phosphate should be stated separately, and regarded as of equal manurial value to the actual soluble phosphate.

The methods which have been employed for the determination of "reduced" phosphate are based on the ready solubility of such precipitated phosphate, in certain liquids, or on its easy decomposition by certain alkaline salts. For its solution, citrate of ammonium has been employed, and for its decomposition with formation of a soluble phosphate, oxalate of ammonium* or bicarbonate of sodium† is used.

A series of very suggestive experiments on Chesshire's bicarbonate-of-sodium and Sibson's oxalate-of-ammonium methods have been communicated

* Chem. News, Sept. 10, 1869, p. 123.

† Chem. News, Sept. 3, 1869, p. 111; Church's 'Laboratory Guide,' 3rd edition, p. 146.

to the Committee by Mr. M. J. Lansdell; and as they appear to show conclusively the valueless character of either of the above processes for determining "Reduced" Phosphates, the results are given in full. The samples were all passed through the same sieve, and the proportions employed were those recommended by the authors.

	Sample contained (equal to $Ca_3P_2O_8$).	Dissolved (equal to $Ca_3P_2O_8$). By Sibson's method.	Dissolved (equal to $Ca_3P_2O_8$). By Chesshire's method.
Cambridge coprolite	56·07 per cent.	8·32 p. c.	2·23 p. c.
Bone-ash	76·87 ,,	10·58	3·07
Navassa phosphate	65·62 ,,	7·48	5·73
German phosphate	60·74 ,,	8·04	2·09
Redonda phosphate (dried)	87·42 ,,	19·72	56·97
Redonda phosphate (lump)	86·58 ,,	19·10	64·65

By employing a solution of bicarbonate of twice the above strength, the Redonda phosphate gave equal to 84·3 of $Ca_3P_2O_8$ in solution.

Using a smaller quantity of the sample in the oxalate method, 47·76 per cent. passed into solution.

It appears, therefore, that "reduced" phosphates are indicated by each process, even in natural phosphatic materials which have never been treated with acid, and hence the methods of determination are useless*.

The same objections apply to the citrate-of-ammonium method, especially with respect to the phosphate of aluminium known as "Redonda Phosphate."

It follows, therefore, that the latter comparatively cheap material would (if introduced into a superphosphate) be mistaken for and quoted as "reduced phosphate."

From the above considerations it appears that the known methods of determining the reduced phosphates are purely arbitrary.

It is now generally admitted that the cause of the "going back" to the condition of insoluble phosphate is the presence of iron or aluminium in the manure; and many chemists are of opinion that the "reduced" phosphates actually consist of the phosphates of iron and aluminium produced by some such reaction as the following:—

$$CaH_4(PO_4)_2 + Al_2(SO_4)_3 = 2\,AlPO_4 + CaSO_4 + 2H_2SO_4.$$

At any rate it is a fact that only manures containing iron and aluminium have a tendency to form reduced phosphates; so that the manufacturer has the remedy in his own hands, to avoid using mineral phosphate containing iron or aluminium.

In the analysis of mineral phosphates the proportion of oxide of iron and alumina is usually stated, but these constituents rarely appear in the analyses of "superphosphates" made therefrom.

It is generally held that the phosphates of iron and aluminium have a very limited manurial value, and this fact is a strong argument against the reduced phosphates being calculated into and credited as phosphate of calcium. The value of a manure so largely depends on the proportion of oxide of iron and alumina present, that the Committee is very strongly of opinion that the united percentage of these two bases in a manufactured manure (superphosphate) should always be stated. By doing so the manufacturer or purchaser would be enabled to judge of the probability of a newly made manure "going back" on keeping, and he would be in a better position to form an opinion of the true value of the sample. At the same time

* Mr. John Hughes has made experiments leading to a similar conclusion. Chem. News, vol. xix. p. 229 and vol. xx. p. 111.

the estimation of the "reduced" phosphates would often be rendered superfluous.

The actual mode of occurrence of some of the constituents of manures is very uncertain, and although interesting in a strictly scientific sense, is of very limited practical importance. The Committee is of opinion that the methods of statement now generally adopted are sufficient for commercial purposes; but with the view of securing greater uniformity in the statement of results by different chemists the adoption of the following plan is recommended:—

STATEMENT OF THE RESULTS OF ANALYSIS OF COMMERCIAL PHOSPHATES.

With respect to the mode of statement of the results of analyses of manufactured phosphates the Committee holds the following opinions:—

When found in quantities greater than traces, the proportions of oxide of iron and alumina in the sample should always be stated, and also their equivalents of the corresponding phosphates ($Fe\,PO_4$ and $Al\,PO_4$) and the equivalent of the latter in tricalcic phosphate. Hence that item would appear somewhat as follows:—

Oxide of iron and alumina	A°/₀
(Equal to phosphates of iron and aluminium ..	B°/₀)
(Equal to neutral phosphate of calcium	C°/₀)

If it be proposed for any reason to state the iron and aluminium as phosphates instead of oxides the following form would be suitable:—

Phosphates of iron and aluminium..........	B°/₀
(Equal to neutral phosphate of calcium	C°/₀)
(Containing anhydrous phosphoric acid	D°/₀)

The object of stating the equivalents in phosphate of calcium and phosphoric acid is to give the manufacturer or purchaser an estimate of the tendency of the sample to "go back" owing to the formation of reduced phosphates.

The Committee is of opinion that the soluble phosphate in a manure prepared with acid is best stated as acid calcium phosphate, though in some cases it may be questioned whether it wholly exists in that form. The term "bi-phosphate" should as far as possible be abandoned; but as this cannot be done suddenly it is recommended that the equivalent of $Ca\,H_4\,(PO_4)_2$ in $Ca\,P_2\,O_6$ should also be given. It is likewise desirable to state the equivalent amount of bone phosphate ($Ca_3\,(PO_4)_2$) from which the soluble phosphate has been derived. Hence the statement of the soluble phosphate will be somewhat as follows:—

Soluble acid phosphate of calcium	E°/₀
(Equal to so-called bi-phosphate of lime	F°/₀)
(Equal to neutral phosphate of calcium (bone phosphate) made soluble	G°/₀)
(Containing anhydrous phosphoric acid	H°/₀)

The statement of the insoluble phosphate presents no difficulty.

The Committee is not prepared to make any recommendation respecting the statement of the calcium sulphate, but is of opinion that whether the anhydrous or the hydrated substance is entered as existent in the sample, the equivalent of the other should also be added in parenthesis.

The Committee believes that it has done all in its power to secure the objects for which it was appointed, and therefore presents this as its first report.

Report on the Present State of our Knowledge of the Crustacea.—Part III. *On the Homologies of the Dermal Skeleton* (*continued*). *By* C. SPENCE BATE, *F.R.S. &c.*

Correlation of Appendages.

By the term "correlation" I mean a change of form associated with functional variations, the character of which is sufficiently distinct to produce, both in appearance and application, an appendage that is essentially different from the type with which it is homologically connected.

The eyes are less subject to correlate with other forms than most other appendages. This probably arises from the circumstance that their functional properties are only liable to vary in a greater or less degree of utility. It is true that Alphonse Milne-Edwards has observed in a species of *Palinurus* the eye to become altered into an antenna-like appendage; and the author of this report contends that it is homologous with the first pair of appendages in *Nauplius*, and therefore correlates with a free-swimming appendage (Proceedings Roy. Soc. vol. xxiv. p. 377); but our knowledge of the cases is small where the eye loses its functional power; consequently we must assume that its variation in form must be limited in degree only consistent with its uses.

In *Podophthalma* and allied genera the organ is extended on a very long appendage, whereas in others the peduncle is extremely short; and in those genera that reside in dark habitats the visual organ has become so depauperized that it can only be traced through the anatomical arrangement of the nervous system. This is the case with the Cirripedia, where, from the fixed nature of the animal, sight would only be a means of inflicting pain, since the animal could not escape any object of terror it observed approaching.

The eye in the *Nauplius* form, whether in young specimens of the higher types or adult forms of Entomostracous Crustacea, is not homologous with the true organ of the higher forms of Crustacea, and therefore cannot be said to correlate with it.

The first pair of antennæ, called the antennules by some writers, is generally of a very simple character. They usually consist in their outward form of a base or peduncle made up of three separate joints, the remaining portion being broken up into numerous minute articuli, that gradually decrease in size towards the extremity, and so become long and flexible, like the lash of a whip, and consequently are named the flagellum by anatomists. It is usual for this to break into two separate branches; and it is clear that one must be of a superior character to the other, since there are certain organisms attached to it that are invariably constant, whereas they are never attached to the other. I have therefore, when desirous to distinguish the former, identified it as the primary branch of the flagellum and the other as the secondary, which in different species is again liable to be redivided at various points along the branch, but every time forming more feeble and less important branches. This appendage, when compared with its homotype, a truly formed walking-limb, differs from it in the same way as the latter changes in the lower forms of Crustacea when variated for other purposes, as in *Mysis*. A true or normally developed limb adapted for walking consists of seven separate joints. The first pair of antennæ consists of seven also; but three of these only retain their normal character, the four others being differentiated so as to comply with other conditions necessitated by distinct wants.

The first, or coxa, is the joint that is most important to the necessities of the animal; it is the part that invariably contains the functional organ with which the appendage is endowed, and is most capable of internal organic change. In the lower types of Crustacea it differs little in external form from the other less important joints of the same limb, and appears to become depreciated as it corresponds with the increasing length of the flagellum. In Amphipoda the length of this antenna is often very considerable in the deep-sea genera; whereas in those that live on the shore or on land, as *Talitrus* and *Orchestia* mostly do, not only do the flagella diminish in general proportion, but the entire organ, as an appendage, becomes enfeebled and weak, arguing strongly that its higher endowments are best capable of full development under the former than the latter conditions.

Moving upwards in the grade of animal life, in those Crustacea that pursue a wholly aquatic existence this first pair of antennæ, while decreasing in the length of the flagellum, does so apparently by diminishing its tenuity, and so condensing all its power within less extent. This also corresponds with a similar change in the coxal joint of the peduncle.

This change appears to be carried to the highest extent in the short-tailed genera, of which we may find a convenient example in the common edible Crab (*Cancer pagurus*) of the British seas. The coxa in this genus is very much larger than the other joints of the peduncle, and on being opened is found to contain an osseous chamber, attached by one extremity only to the antero-external surface of the outer walls of the joint.

In the genus *Maia* a similar chamber, but different in form, exists; and this probably will be found to be true of all the Brachyura or short-bodied forms of crabs.

In the Macrura a chamber of a similar nature, but longer in form, corresponds with the depreciated appearance of the coxal joint of the antenna, which is longer, narrower, and carries a longer and more slender flagellum than the Brachyura. But the chamber in the Macrura is certainly of a very peculiar character, for it is in some of the species, such as *Homarus*, *Astacus*, and *Palinurus*, more or less completely filled with particles of sand. This sand is thrown off with the exuviations of the animal at each successive moult, and is again replaced by the voluntary act of the crustacean itself.

In some genera, such as *Anchistia*, *Palæmon*, and *Lucifer*, there exist various forms of otolithes.

In lower orders, such as the Amphipoda, the antenna is very simple, and generally long and slender. The second filament, which in the higher groups is commonly equal in length with the primary branch, is in this order reduced to a rudimentary condition, and is frequently wanting in the adult form, although almost invariably present in the young stage. We generally find, however, that in those genera where this antenna is reduced in length the coxa increases in dimensions, while the two succeeding joints are less so in proportion.

A marked exception to this is perceptible in *Orchestia* and *Talitrus* and the terrestrial Isopods, where the appendage is short and unimportant, approximating towards a rudimentary condition. In the Hyperidians it has a tendency to become enfeebled and diminutive. The tendency to variation in these two widely separated forms is certainly the result of certain altered circumstances which interfere with the characteristic development of the organ.

Talitrus and *Orchestia* are genera that live in an intermediate position; their habits are between the aquatic and land Crustacea. They do not live in the water, and some species are found some miles inland. Their short antennæ differ from those of the truly aquatic genera of the *Lysianassidæ*, and are evidently organs in a rudimentary condition, impoverished in character and small, because they have no duties to perform. In the *Hyperidæ* they have also assumed an impoverished condition probably from a similar cause, although the habits of the creature are very distinct. In the *Orchestidæ* and *Oniscidæ* the animals live out of what might be pronounced to be their accustomed element; whereas in the *Hyperidæ* they are inhabitants of the sea, but exist if not parasitic, certainly encased within Medusæ in such a way as to lose much power of free action. Organs of sense, such as the anterior antennæ are generally considered to be, must lose their power from want of use, owing, in the one case, to altered conditions, and in the other to incapacity for action.

Talitrus and *Hyperia* are generally considered by carcinologists to rank at opposite extremities of the order; and when generalization is adopted from too narrow observation, a faulty conclusion is liable to be enunciated, such as that which identifies a short antenna as typical of an improved organization on the one hand, or as evidence of a more feeble type on the other.

Among the Entomostracous forms of Crustacea the first pair of antennæ correlates with various forms, and apparently loses its functional sense. In *Nebalia* it varies so little from the normal form, that it must be admitted as part of the evidence that this genus ranks higher in the natural order of Crustacea than the Entomostraca. In *Limnadia* these appendage appear to have degenerated into a simple flagellum, the peduncle or stalk having become impoverished to the same extent. In *Daphnia* they appear to be wanting. In *Cypris* they are flagelliform and robust. In *Pontia* they are flagelliform and long, and they are very long in *Cyclops*. In *Caligulidæ* they are reduced in size and feeble in form, and frequently support organs of adhesion of sucker-like appearance. In the Lerneans and close allies they are wanting, unless, as is probable, they homologize with the organs of insertion, in which case correlation is carried to an extreme degree.

The object or function of this pair of antennæ has by all the older carcinologists been supposed to fulfil the duties of an olfactory organ. Dr. Farre, in the 'Philosophical Transactions' for 1843, was the first who attempted to reverse this decision. In 1851 Professor Huxley communicated to the 'Annals of Natural History,' 2nd ser. vol. vii. p. 304, some "Zoological Notes and Observations made on board H.M.S. 'Rattlesnake' during the years 1846–51. I. On the Auditory Organs of Crustacea." He says that "The older authors, Fabricius, Scarpa, Brandt, and Treviranus, unanimously confer the title of auditory organs on certain sacs filled with fluid which are seated in the basal joint of the second or larger pair of antennæ;" but "by the majority of the older writers no notice is taken of the sac existing in many genera in the bases of the first or smaller pair of antennæ. Rosenthal *, however, describes this structure very carefully in *Astacus fluviatilis* and *Astacus* (*Palinurus*) *marinus*. He considers it to be an olfactory organ, while he agrees with previous writers in considering the sac in the outer antennæ as the auditory organ."

This view is supported by Professor Milne-Edwards, as I shall show when writing about the second pair of antennæ.

This distinguished carcinologist appears to have given no consideration to

* "Ueber Geruchsorgane d. Insekten," Reil's Archiv, Bd. x. (1811).

the apparatus attached to the base of the first pair of antennæ, which, with the exception of Rosenthal, appears to have been overlooked by most carcinological anatomists. Prof. Huxley, in the paper quoted, admits its presence only in *Macrurous* Crustacea; for he says, "It is universally acknowledged that in the *Macrura* there exists in the basal joint of both the first and second pair of antennæ a sac containing a liquid, and that in the *Brachyura* such a sac exists, at least in the second pair."

"Although," the same author continues, "the structure of the organ contained in the first pair of antennæ in the *Macrura* departs somewhat from the ordinary construction of an acoustic apparatus in the Invertebrata, yet the argument from structure to function, as enunciated in the paper referred to (Dr. Farre's), seems almost irresistible. Still, as it has obviously not produced general conviction, I hope that the following evidence may be considered as finally conclusive."

Mr. Huxley then describes and figures a small transparent Crustacean (taken in the South Pacific) of the genus *Palæmon*; and states that the "basal joint of the first pair of antennæ is thick, and provided with a partially detached ciliated spine at the outer part of its base. Between this and the body of the joint there is a narrow fissure. The fissure leads into a pyriform cavity contained within a membranous sac, which lies within the substance of the joint. The anterior extremity of the sac is enveloped in a mass of pigment-granules; on that side of the sac which is opposite to the fissure, a series of hairs with bulbous bases are attached along a curved line; these are in contact with, and appear to support, a large ovoid, strongly refracting otolithe.

"The antennal nerve passes internal to and below the sac, and gives off branches which terminate at the curved line of the bases of the hairs. The sac is about $\frac{1}{100}$ of an inch in length, the otolithe about $\frac{1}{225}$ in diameter. The structure is obviously very similar to the ordinary apparatus in Mollusca &c." A similar kind of formation I have observed in a species of *Anchistia* from Australia; and also Dana has figured a similar structure in the same appendage of an *Anchistia*. It may be that Huxley's *Palæmon* may be a species of Dana's *Anchistia*.

The form of the otolithe observed by myself was irregularly ovoid. It is described in the 'Proceedings of the Zoological Society' for the 24th of November, 1843, p. 5, pl. xxi. fig. 56, where I observe that it "bears a near resemblance to that which Van Beneden considers to be an otolithe, and which was found by him in the inner ramus of the posterior pair of pleopoda in some species of Stomapoda."

Huxley likewise has observed and figured the same structure as being present in the genus *Lucifer*; where he says that "we have an organ precisely similar to the auditory sacs of the Mollusca, while *Palæmon* offers a very interesting transition between this and the ordinary Crustacean form of acoustic organ as described by Farre."

M. Souleyet has also noticed the structure in *Lucifer*, but only gives it a passing notice, in Froriep's 'Notizen,' 1843, p. 83.

The second and third joints appear to possess no peculiarity of structure, but generally diminish in length and breadth, perhaps in a corresponding ratio to the increased functional development of the first or coxal joint.

A filamental appendage is almost universally attached to the extremity. In some genera the lash is consolidated to a plate, as in *Scyllarus, Ibaccus*, or rigid rod, as in *Clydonia* &c.; but, as a rule, throughout the entire list of genera in all the Podophthalmous Crustacea, whether Brachyura, Macrura, or Stomapoda, there are universally present two or more of these filamentary appendages, often subequally long, only one of which, the primary, appears to fulfil any important office.

In Amphipoda there is never more than one secondary appendage, and that is always of a rudimentary character, and frequently only determinable in the very young stage of the animal and obsolete in the adult. In the Isopoda, with the exception of the Anisopod group, it is always absent.

The secondary appendage, even in those families where it is most developed, appears to fulfil but an unimportant office.

In this it differs from the principal filament, or *tige*, as it is named by Milne-Edwards, which, in addition to the numerous simply-formed hairs with which it is covered, is furnished with a considerable number of membranous cilia, which are peculiar to this organ in Crustacea, and may be found in every form of animal in the class, except where the entire appendage has become impoverished from the peculiar nature of the animal's habits or conditions, such as in the Terrestrial Isopods or parasitic families of Crustacea.

The forms of these cilia vary a little in separate genera; but in whatever shape they are found there is, I think, no doubt but that they are actively concerned in communicating vibrations, analogous to the waves of sound, to the nerve-system in this pair of antennæ; and on this account it is that I named them, in my Report on the Sessile-eyed Crustacea to this Association in 1855, as being auditory cilia.

In 1853 M. Leuckart (Troschel's 'Archiv,' i. p. 255) stated that the organ attributed to auditory consciousness was not to be found at the base of the antennæ in the genus *Mysis* as in other Crustacea, but that a chamber containing an otolithe, similar to that found in the antennæ of Macrura, existed in the inner ramus of the caudal pleopoda, which has been confirmed by Kröyer, Van Beneden, and, I can add, my own observations. Kröyer and Van Beneden have traced the branch of a nerve to the chamber, and have no doubt but that this organ fulfils the functions of an auditory apparatus.

This small otolithe, according to Van Beneden's description, shows an extreme regularity in the arrangement of the several layers of which it is formed, as if it were a little agate or highly polished siliceous stone.

It is liable to vary somewhat in form in separate species.

In 1863 Dr. V. Hensen published his researches on the auditory organs of Decapod Crustacea (Zeitschr. f. wissensch. Zool. xiii. Bd. 3 Hft. 1863).

His observations extended to twenty-eight distinct forms, and he confirmed the assertions of Farre and others that the sand found in the auditory chamber of the Prawn &c. is but common sand, he having seen the animal introduce it after having moulted. But in those Crustacea in which the auditory chamber is closed and the otolithes are cast at every moult and again reproduced, these organisms Professor Humby, after having tested some 200, thinks to be fluate of lime.

Dr. Hensen, however, appears to attribute more of the power of hearing to the hairs of certain forms that exist, (1) attached to the otolithes; (2) attached to the auditory chamber; (3) attached to the external surface of the animal.

The first of these he finds to exist chiefly among the Macrurous Decapoda, in some cases springing from among the otolithes, in others supporting, as in the tail of *Mysis*, the otolithe in its position.

The second kind of hair exists in the auditory chamber of the Brachyurous

Crustacea, which contains no otolithe, but is a large chamber filled with a fluid in which these hairs stand in great numbers.

The third kind exists on the peduncle of the first antenna and on the second joint of the second antenna, and, in *Palæmon*, on the uropoda; in *Mysis* they exist in the same member; so that the function of hearing must be considered as established in this part of the animal. In *Palæmon squilla* the auditory hairs are replaced, as the animal increases in age, by those of the ordinary kind. Dr. Hensen classifies the several forms of auditory apparatus under separate heads:—

1. Those which have one otolithe within the auditory chamber—as *Lucifer*, *Sergestes*, *Mysis*, *Hippolyte*, and *Mastigopus*.

2. Those that have no otolithe and no auditory chamber—as *Thysanopoda* and *Pandalus*. Dr. Hensen also mentions *Alima*, *Erichthus*, and *Phyllosoma*; but these being the immature forms of known Crustacea must be excluded from his list.

3. Those that have a chamber with numerous otolithes—as *Palæmon*, *Pasiphaë*, *Crangon*, *Alphæus*, *Astacus*, *Gebia*, *Pagurus*, *Palinurus*, *Nephrops*, and *Lithodes*.

4. Those that have a closed auditory chamber but no otolithe—as *Porcellana?*, *Hippa*, *Pinnotheres*, *Myctiris*, *Ocypoda*, *Grapsus*, *Lupea*, *Sesarma*, *Nautilograpsus*, *Platycarcinus*, *Pilumnus*, *Chlorodius*, *Gelasimus*, *Trapezia*, *Carcinus*, and *Hyas*.

From the experiments which he made, Dr. Hensen found that the animals living in water took no notice of sound made in the air, and that they were only slightly affected by sounds made with a fife or bell in contact with a membrane connecting the same with the water, the only effect being that the crab would first jump and then quit the place. He has observed freshly-caught specimens of *Palæmon antennarius* on the first experiment leap out of the water when a sound was made against the side of the vessel. He performed various other experiments on distinct species, among others that of removing the auditory apparatus from the tail of *Mysis*, and was disappointed to find the powers of hearing were not interfered with as much as he had anticipated.

In experiments made with musical notes, he was induced to believe that certain hairs vibrated to certain sounds. Under these conditions, Dr. Hensen found that a certain hair, which only vibrated under one note, will, under a different one, shake to the very base so powerfully that it cannot be distinctly observed, and that as soon as the sound ceases the movement also ceases. To illustrate the extent to which Dr. Hensen believes this to be capable of being carried, he has drawn up a scale of musical notes adapted to the various hairs which he thinks belong to this sense.

As we descend in the scale of Crustacean forms the antennæ naturally become simplified; but as they lose their internal structural character they increase their external functional arrangement. Thus in Amphipoda the auditory chamber and otolithes are wanting, but in all the aquatic normal forms the filaments are long, and richly studded with those membranous organisms that I have named *auditory cilia*.

The second pair of antennæ has a tendency to vary in form to a greater degree than the first, but the functional variation is as limited.

In the higher forms, such as the Brachyura, some of the joints of which they consist are fused together, and not unfrequently ossified with the tegumentary tissues of the head or cephalon, in some instances to such an extent that their separation cannot be identified. But whether free or fused with other parts, the normal character of this pair of antennæ is that of a peduncle of five joints and a terminal flagellum, variable in length, and, with but few exceptions, consisting of a solitary branch.

The centre or third joint of the peduncle in some orders, as the Macrura, invariably carries a squamose or scale-like plate; this varies in size and a little in form, but disappears in the higher and lower orders, and again reappears in the genus *Apseudes* among the Isopoda. This squamiform plate is, I believe, homotypical with the secondary branches of the flagellum of the first pair of antennæ, therefore a correlative of the same.

In the Brachyura the first three joints of the base or peduncle of this antenna are more or less perfectly fused with the dermal tissues of the cephalon. In some, as in most of the triangular genera, as *Stenorhynchus*, *Pisa*, &c., the line of separation between the somite and the appendage is indistinguishable in the adult. This is also more or less the case in several forms of Brachyura, and makes a ready and safe key to generic distinction. In all these forms the flagellum is reduced to a feeble condition, and becomes almost rudimentary in those of terrestrial habits.

In the Macrura the genus *Scyllarus* and its near allies have the flagellum transformed into a broad plate or scale; but in Crustacea generally this appendage is multiarticulate, robust, and long. In some genera, as in *Palinurus*, it is used as a weapon of offence as well as for other requirements.

In the Amphipoda this antenna is simple and normally well defined, the five joints of the peduncle and the flagellum being separate and distinct, and the whole appendage robust and long, the two parts (*i. e.* the flagellum and peduncle) being generally subequal. But in those genera that exhibit a variation, the higher class has the peduncle the more important, as in the *Orchestidæ*, whereas in the male of *Cerapus*, as compared with the female of the same and the *Hyperidæ* in general, it is less so. Almost universally the flagellum is delicately multiarticulate, varying from a small number of articuli, as in *Corophium*, to an innumerable quantity, as in some species of *Bathyporeia*. In the genus *Clydonia* the flagellum consists of a long, rigid, non-articulate spine. Among the *Hyperidæ* the antenna is considerably impoverished, and in many genera it is rudimentary, while in *Phrosina* it appears to be absent.

In the parasitic Amphipods, such as *Cyamus*, as compared with the preceding antenna, the second is well developed and important, but not so much so as in the organs of the normal Amphipods.

In the Isopods this appendage is seldom very important, being largest in the terrestrial forms, as *Ligia, Oniscus*, &c., and in some aberrant genera, like *Arcturus* &c.

By most carcinologists this pair of antennæ is considered to be the seat of an organ of sense. It has been worked out and displayed by M. Milne-Edwards, in his 'Histoire Naturelle des Crustacés,' vol. i. p. 124, pl. 12. figs. 9, 10, both in *Homarus* and *Maia*. He argues that the structure demonstrates the auditory character of this organ, as we have shown in investigating the evidence relative to the functional properties of the preceding pair of antennæ.

As Milne-Edwards, in his 'Histoire Naturelle des Crustacés,' vol. i. p. 124, 1840, suite à Buffon, bases his opinion on the character of the structure of the organ at the base of the second pair of antennæ, it is but just that his reasons should be communicated as literally as translation will conveniently admit. He says:—" In *Maia* and other short-tailed Crustacea there is a very curious operculum. M. Audouin and I have observed that it is connected with a moderately large osseous plate, which separates from it at right angles, and is directed upwards towards the organ, and ends in a point; near its base this long plate is pierced by a great oval aperture, and over this opening is stretched a thin elastic membrane, which we call the internal auditory membrane, and near which the auditory nerve appears to terminate; some small bundles of muscles are attached to the extremity of the osseous plate, which supports also the opercular disk of the auditory tubercle, and which by its form recalls somewhat the stirrup (bone) of the human ear; moreover on the anterior border of the exterior opening, which is shut by the disk, there raises also a small plate, which is parallel to the internal auditory membrane; and when the anterior muscle of the little operculum is contracted so as to turn slightly this little apparatus forwards, the delicate membrane to which we allude becomes more and more stretched. After the researches of M. Savart on the transmission of sound, we know that an aperture closed by a thin and delicate membrane is one of the circumstances most favourable for increasing the power of an acoustic organ. . . . . It therefore may be assumed that this kind of tambourine that we have described as covering the external ear of the Crayfish serves to communicate to the auditory nerve the sensations that are transmitted to it, and affect them in the same manner as if the nerve was in direct communication with the external membrane. The mechanism by means of which the auditive membrane is alternately extended and relaxed is analogous to that which is produced in the human ear by that osseous chain which traverses the tympanum, and its effects should be the same. It must serve to augment or diminish the extent of the undulations on the vibrating membrane, and to moderate the intensity of the sounds which strike the ear.

"The existence of the long rigid lash belonging to the second pair of antennæ, which is in connexion with the auditory organ, appears to be another circumstance of a character that must facilitate the perception of sound. This opinion has already been enunciated by M. Strauss, and appears to agree well with the results of M. Savart."

In most of the Brachyura the entrance to the organ in this pair of antennæ is covered and protected by a movable operculum, and again covered by the several appendages of the mouth, a situation of much value in enabling the animal to appreciate the character of food it is about to consume, but one that cannot be available for an acoustic organ, seeing that sound could not reach it unless interfered with to an important degree. I therefore fully indorse the opinion, which I think all recent observations demonstrate as true, that the second pair of antennæ is the seat of the olfactory nerves, while the first contains the auditory apparatus. These antennæ are frequently developed with great power; and in the genera *Corophium* and *Podocerus* they are frequently used for climbing, and not improbably for clasping foe and friend.

The fourth pair of appendages is represented by the mandibles (the *protognathe* of M. Milne-Edwards's nomenclature of 1854, 'Annales des Sciences Naturelles'). The correlation that this pair of limbs undergoes is not very extreme.

We see them in the simplest form most probably in *Nebalia*, where they differ little from a truncated pair of appendages, the molar or masticating surface being represented by a pair of opposing tubercles attached to the first joint.

In the Brachyura the tubercle is increased to a maximum, while the rest of the appendage is reduced to a minimum. This exists to a greater or less degree throughout the several orders of Malacostraca, varying in shape and altering in form, but universally present with the same functional powers.

In *Anceus* the functional property is evidently lost, for the male animal ceases in the adult stage to live on substances that require mastication. In this stage it is doubtful if the animal imbibes nourishment even in the form of fluids; yet the organ retains the general form of a mandible, but is planted, both in position and arrangement, as if it were an antenna.

In the female, *Anceus* (*Praniza*) retains the general form of structure of the young animal, when it lived a parasite on fish; the mandibles are therefore delicate and slender needle-like styles, arranged with the succeeding appendages so as to act together in consort with power as a proboscis or organ of penetration.

In the genus *Cyamus* the mandibles appear to be reduced to a minimum, both in physical and functional qualification, and so also in several genera of the *Hyperidæ*.

The appendages of the fifth pair, the *deutognathe* of Milne-Edwards's latest nomenclature, are those that are called *mâchoires* by Milne-Edwards in his 'Hist. Nat. des Crust.,' *foot-jaws* by many authors, *maxillæ* in my "Report on the British Edriophthalma," and for which Professor Westwood has suggested "siagnopoda," as the Greek equivalent for this and the succeeding pair of appendages which belong to the mouth. Neither this nor the sixth pair, the *tritognathe* of Milne-Edwards, appears to undergo any change of form with a relative change of function that can be accepted within the meaning of the term correlation. They vary little in character from the larva to the adult Brachyura, and from the Edriophthalma to the Podophthalma. Their functional power is invariably connected with manducation, in which they assist in conveying food to the mouth; and from the delicacy of their structure compared with other appendages, it is probable that they may have gustatory capabilities; but of this as yet we have but small independent or structural evidence.

The seventh pair of appendages is the last that belongs to the cephalon or head. They are generally absent in the larva of the Brachyurous forms that pass through the zoëa stage, and only appear when the animal is approximating the adult condition. From the time that these appendages first appear to that of the permanent form of the adult animal there is little variation in form, but between their external shape in the various orders of Crustacea there is a considerable degree of variation.

In the Decapoda the *tetartognathe* of Milne-Edwards takes an intermediate character between the maxillæ and gnathopoda, and its functional properties probably assume the character of the former rather than the latter.

In the Edriophthalma and some Schizopoda they are modified on the type of gnathopoda in the Macrura, and they fulfil the functions of the posterior pair as they exist in the Decapoda; that is, they act as an operculum, and efficiently protect the mouth and its more delicate appendages.

The eighth pair of appendages undergoes a very considerable amount of correlation in Crustacean life. In the higher forms they are functionally employed as aiding in mastication. Passing through the Macrura they assimilate a pediform character of an imperfect type, while in *Squilla* and the Amphipods they are developed into a well-formed grasping-organ. Among the Isopoda they are formed as true walking appendages, and differ little from the succeeding pairs except in being somewhat more robust. Among the Phyllopoda they assimilate to the larval character, and possibly disappear in some of the lower types.

The correlation is equally great in the ninth pair of appendages, which, as a general rule, is formed on the same type as the preceding pair. There are many instances of variation in form, not only between these two pairs, but between the appendages of the same pair. This variation is generally estimated as of sufficient importance for generic classification; but whatever variation may exist, it is one of degree only, and not inconsistent with the same functional characters. These are so universally connected with either seizing or directing food to the mouth, that I do not think that a better term can be suggested than *gnathopoda* for the eighth and ninth pairs of appendages, which are the first two that belong to the *pereion*.

The five following pairs of appendages (that is, the true pereiopoda or perambulatory legs) correlate between organs adapted for walking, grasping, and swimming. When adapted for walking, we consider them in their normal condition; they consist then of seven simple subcylindrical joints, of which the last is formed into a simple pointed extremity.

When intended for grasping or holding any object, the anterior distal angle of either joint of the leg may be produced to a corresponding process against which the extremity of the ultimate joint impinges, and so forms a prehensile organ that represents a two-fingered hand.

The power of producing a chelate process appears to exist in the various joints of all the five pairs of pereiopoda.

This, I think, is strongly exemplified in the presence of chelæ, more or less perfect, in the young of many Crustacea, which disappear in the adult stage. Thus in the freshwater *Astacus*, while in the embryonic condition rudimentary chelæ are apparent in each pair of appendages, they are found fully developed only on the three anterior pairs of the adult. Again, we frequently see, both in this genus as well as in *Cancer*, that supplementary chelæ are developed at various parts of these appendages, not only when they are not wanted, but often when they are absolutely detrimental to the animal's requirements.

In some forms we find the chela is prominently developed in the larval or young stage, while it entirely disappears in the adult. Evidence of this exists in some genera of the Hyperine Amphipoda, such as *Vibilia* and *Brachyscelus*. In the adult *Vibilia* the leg is long, slender, and simple, not very unlike that of the same appendage in the normal character of Amphipoda; in *Brachyscelus* it has the *basis* developed to a large scale, and the remaining five joints are reduced to little more than a rudimentary limb. In these very dissimilar genera the penultimate pairs of *pereiopoda* are in the larval condition developed into chelate appendages; in the former genus by a process attached to the *carpus*, in the latter by a similar process attached to the *propodos*.

These animals probably resemble *Hyperia* in their habits, and pass most of their lives within the cavity of some Medusa-like creature, where prehensile appendages are of little use, and consequently the force of chelate production is not stimulated. It is an interesting problem, and probably true, that the not very remote ancestor of either or both these genera is to be found in a form not very distant from one like *Phronima*, where the chelate organ is large and well developed in the antepenultimate pair of pereiopoda of the adult animal.

In some genera, as *Gelasimus*, the difference in extent of development is very great between the right chela and the left, and between those of the males and females. When, in the latter case, the part varies from the type, the variation generally exists in the male animal, the chelæ of the female, and less altered appendage in the male, corresponding generally with the normal form. In *Gelasimus* the variation in the male is so great that the chief characteristic limb, which may be either of the first pair of pereiopoda, loses much of its original functional power. It may hold any object, but it cannot reach its mouth with it; consequently we may assume, finding it only in the male, that it is used chiefly as a weapon of offence and defence.

In the common Lobster (*Homarus marinus*) we find the same to a certain extent, but not to such an exaggerated degree; nor is it confined to the male, only that the large chela is developed to so great an extent that it cannot reach the mouth. In this case we have learned, from observation, that the animal feeds itself with some of the posterior chelate appendages, while it uses the first pair only for holding the food.

It is not often that any of the posterior pairs of *pereiopoda* are developed into important chelæ, but even this is the case in some genera. The most posterior pair in which we are aware of a largely developed chelate organ exists in *Stenopus* among the Macrura, and *Phronima* and *Phrosina* among the Amphipoda. In some genera, particularly among the Anomura, the two last pairs of *pereiopoda* are developed into small chelate organs. In *Dorype* they are adapted for grasping any piece of wood, shell, or foreign body that the animal may hold on its back sufficiently important to find protection under. In the genus *Homola* the posterior only is so developed, the penultimate resembling those anterior to it. In *Pagurus* and *Cenobitus* they are developed into very small chelate organs, and are used for very different purposes.

One of the most important is to supply the place of a flabellum that is wanting in the branchial chamber of this family. With this purpose the animal passes it into the gill-cavity, and there cleanses and wipes the branchial organs with the brush of hairs that is attached to it, or removes particles of dirt or objects of detriment by means of the pincers. Moreover, it has the power of feeding itself with these same organs under peculiar circumstances, as related by Mr. Darwin in his 'Naturalist's Voyage.'

He tells us that some of these animals, as *Birgus*, live chiefly on the land, that they frequently live on the cocoanuts which fall from the trees, and that they first pull off all the husk or rind from the outside, invariably selecting the end where the eyelets are. These being exposed, they, with their heavy claw, tap one repeatedly until they break it in; then, inserting one of the posterior pairs of pereiopoda into the hole, they draw up the juice of the cocoanut with the brush on the leg, and feed on the milk—as singular and unusual an adaptation of means to an end as is perhaps to be found in the history of animal instinct, being one that is highly suggestive of educational knowledge.

Where the *pereiopoda* are developed for natatory purposes, they are generally of a more feeble and less perfect type. In the Schizopoda they have the character of weakened or impoverished appendages. The secondary parts increase in importance, while the primary become depreciated. The branchial organs lose much of their internal character as well as their high structural features, while the hairs on the appendages and general surface are increased both in number and size. In fact the rigidity of the leg is lost, and the flexile nature of a fin is acquired. This would appear as if atavism, or a retrograde character, were apparent in the development of the *pereiopoda* in the Schizopod group.

In *Nebalia* and the Phyllopoda the general characteristics of the pereiopoda partake more of a larval or embryonic form, bearing, as they do, a near resemblance in character and general appearance to the oral appendages in the zoëa of Crustacea than to any retrograde or impoverished condition.

The pleopoda are very liable to undergo a considerable amount of correlation.

In the Brachyura the anterior are adapted for intromittent organs, and carry the penis within their folds.

In the females of Brachyura and Macrura they are formed for carrying and suspending the ova in the water, and for swimming purposes in both males and females in the latter order.

In the Stomapoda, while they are used for swimming purposes, in some genera, as *Squilla*, they support branchial organs also.

In the Amphipoda they are adapted for swimming only.

In the Isopoda they are constructed as foliaceous plates, and often enclosed in a chamber and adapted for respiration, though they are constantly used as natatory appendages also as a secondary condition. This generally refers to the five anterior pairs of appendages.

The sixth pair universally in Macrura and Isopoda, the fourth, fifth, and sixth in Amphipoda, are variated into leaping or pushing appendages, by which they are enabled to spring forwards or backwards to a very considerable extent, as Macrura in the water, and *Talitrus* and *Orchestia* on the land.

The last pair of appendages is seldom present; in one or two genera among the Schizopods they exist in a rudimentary state, but in so feeble a condition that they can only be considered as present in an anatomical sense, as for all functional purposes they are practically useless.

On Exuviation.

One of the most curious and interesting phenomena connected with the dermal skeleton is the power of its being cast or shed as a whole. This is exhibited in the Crustacea more perfectly than in any other group of animals.

The exuviation is not confined to the external or dermal tissue only, but extends to all that which in the higher groups of animals is known as the mucous membrane, or internal continuation of the true skin.

In all Crustacea, from the smaller Entomostracous forms to the large Podophthalmous animals, every hair and spine upon the external surface, as well as every cilium and minute organ that may exist on the walls of the various internal cavities, is detached and shed in continuous connexion with each other.

How this could be accomplished was for a long time a mystery. According to Mr. Couch, Olaus Wormeus, in the early part of the seventeenth century, speaks of it as a thing not to be doubted. The first to observe, with experimental accuracy, the process, was M. Réaumur; as long ago as 1712 and 1718 he published, in the 'Mémoires de l'Académie des Sciences,' pp. 226 and 263, his "Observations sur la mue des Ecrevisses."

He kept specimens of *Astacus fluviatilis*, or river Crayfish, in cases that he had perforated with holes, and placed in the river stream. He found, in the latter part of the summer or the commencement of the autumn, that these Crustacea change the skin. He observed that for some days previous to the commencement of this operation the animal abstains from solid food, from which circumstance he was able to anticipate the period of the operation, for he was able by the pressure of his finger on the carapace or surface of the dorsal somites to observe that the dermal tissue yielded to the touch and was less resistant than at other times.

Soon after the animal appears to be restless, and commences to rub its legs one against the other. It then turns itself over on the back, and agitates the whole of the body; then all of a sudden it bursts the membrane that unites the carapace with the body, and raises the great dorsal carapace.

The animal now rests for a while; then it recommences by agitating its legs, and moving every part of the body. The carapace is then gradually elevated along the base of the legs, and in less than half an hour the animal is disembarrassed of its old integument. It draws back it head, disengages both its eyes and antennæ, then draws out its legs from the case formed of the old integument.

This latter part of the operation appears to be performed with a great deal of pain, and sometimes in the struggle to liberate the legs from the old skin one or more are broken off. This is probably induced from some incident precluding the external case from being ruptured; for if the old skin does not split in a longitudinal direction, it is difficult to understand how the legs can be withdrawn from the old case. But as soon as the crayfish has overcome this painful portion of the moulting, it rapidly disembarrasses itself from the rest of the envelope. It withdraws its head from the carapace, presses forward, and quickly liberates itself from the posterior part, and soon frees itself entirely from the old skin.

The carapace then falls back into its old relative position, and joins itself to the percion and pleon: thus the old skeleton appears in general form exactly as it did before it was stripped from the animal; consequently it bears a perfect resemblance to that of a crayfish of the same character. The new skin which succeeds the moulting is soft and membranous; but in three or four days, or even in twenty-four hours, it becomes encrusted with calcareous matter, and becomes as hard as the old integument.

Milne-Edwards says that all the higher orders of Crustacea change their skin in nearly the same manner. If, he says, we examine a species of *Maia* some time before it has commenced moulting, we shall find between the test and the chorion a membranous mass that resembles the cellular tissue, imperfectly condensed at first, but becoming more and more solid and thick as it approaches the period of moulting.

"This new membrane is evidently," says Milne-Edwards, "secreted by the chorion, and moulds itself upon the test that covers it." We find attached to it nearly every hair that should be present at a later period; but these appendages are not enclosed within the hairs that are attached to the ancient moult, as Réaumur believed he observed them in the crayfish. Generally they project upon the surface of the new skin, and are folded like the finger of a glove which is inflected within itself.

Collinson, in the 'Phil. Trans.' 1776, art. 51, published some observations on *Cancer major*, probably the common edible crab. The account which he gives of the manner in which the animal escapes from the old shell varies from Réaumur's description of the process in the crayfish.

Instead of the carapace being raised as a whole and thrown off perfect, it divides along the lateral sutures that extend from the anterior portion of the mouth to the posterior margin of the carapace. This, according to Milne-Edwards, separates the lateral pieces (or epimera) from the dorsal piece, or somite proper; but, according to Dana and myself, the line of division separates the second antennal and mandibular somites.

Milne-Edwards contends that this splitting of the carapace in the Brachyura is a necessity demanded by the formation of the animal; and he says that in those Brachyura where this suture does not exist he is inclined to believe that exuviation takes place as described by Réaumur in the crayfish. One argument against this idea is that this suture exists in every one of the Brachyurous forms of Crustacea.

The new tegumentary structure continues in a soft condition, according to Collinson, for a longer period than described by Réaumur in the Crayfish; and the period of moulting for these animals is considered a period of sickness. They generally during this state hide themselves in sheltered places where they may be best protected from the animals to which they are most liable to become a prey. Some hide themselves beneath stones, others burrow into the mud. At this period some exotic land-crabs are most preferred for their edible properties; but the marine forms are valueless for food.

In the 'Annals of Nat. Hist.' vol. vii. p. 298, 1851, the author of this Report gave an account of the manner in which he had observed exuviation take place in the common Shore-Crab (*Carcinus mœnas*).

The manner in which it appears to free itself from the skin depends upon the internal growth of the animal.

From the period of quitting the ovum to that of old age the skin is thrown off at certain periods. When very young it is accomplished every few days; as the animal grows larger, weeks and then months intervene, until the animal arrives at an adult condition, when it is cast but once a year; and when it has become old, and ceases to increase in size, it is probable that the shell is cast off less frequently, if we are to judge from the state in which specimens have been taken on which oysters of two or three years' growth have been found attached to the animal. In old age the absence of the internal growth appears to be wanting as a stimulus for the reproduction of the new skin.

The increased bulk of the growing animal becomes compressed within limits too small. The old carapace is therefore raised out of its position by the mechanical pressure of the internal structure; and one of the first signs of the approaching change in the animal's economy is an increased thickness of the animal.

As the period of exuviation approaches the crab wanders about in search of a retired spot, and frequently exhibits a savage disposition, darting at any thing that approaches it. When it finds a suitable position, it inserts the point of one or more of its legs into some crack or crevice, and withdraws itself from the old skin by raising the carapace, and escaping between it and the pleon, in the manner described by Réaumur and Collinson.

The carapace of the new structure is at first in a very wrinkled and crumpled condition; but it almost immediately expands to its full size, thus becoming much larger than its old proportions, and continues without further increase in dimensions until its next period of exuviation.

The animal has the power for a certain period of retaining its shell at will until suitable circumstances both as to time and place occur for the casting of its shell with security. It appears also to be very shy. In several instances I have seen animals before and after the process has commenced, having patiently watched for hours at a time without success to see the actual process proceed; upon returning, after a few minutes' absence, I have found the old skins cast off, and the animal at rest by the side of it. This would indicate that it is done rapidly, if not with ease.

Réaumur described exuviation in the Crayfish (*Astacus fluviatilis*) as being one of great labour and difficulty, as well as being of long duration.

In all the cases that the Reporter has observed in the common Shore-Crab (*Carcinus mænas*), and they have been numerous, the process has been easily and quietly performed in a short time, when conditions have been favourable, and without a struggle. One condition is the capability of securing the feet in some crevice or notch; another is retirement. Unless it has the former, the duration of the period is considerably prolonged; it seems to be almost impracticable, since without it there would be no point of resistance against which the animal can act in its efforts to withdraw itself from the old structure. Neither of these conditions was probably present in Réaumur's experiment; hence the animal had the appearance of undergoing prolonged labour and struggling.

One specimen of the Common Crab the Reporter frequently took into his hands, and with a pair of scissors cut away the old carapace as it was loosened and raised from the surface of the new shell. After the whole of the integuments had been removed from the animal, it hung attached to the eyestalks reversed; here it continued for a considerable time, nor had the animal power to free itself from it without assistance—a circumstance that induced the Reporter to conclude that the anterior portion can only be removed by the assistance of the legs, which failed in this instance because the carapace being cut away, the legs had no object against which to press. The carapace, therefore, is rejected naturally in an inverse direction, and only returns to its old position by the elasticity of the membranous ligaments that have not been ruptured.

This has been interestingly exemplified by a series of Trilobites that have been found in the locality of Newton Abbot, many of which were observed with the heads reversed lying close to the bodies of the animals. There is no doubt, I think, but that all the specimens so found were the exuviations of animals then living rather than the representatives of defunct ones.

When they have thrown off the old skeleton, the Crustaceous animals are very liable to become the prey of others, both of their own and other forms. Of this they appear to be aware, and are consequently more afraid of an approaching object, and through fear are much more active and less easily caught than at any other period.

It is at this time also (that is, immediately after shedding the skin) that the female is in a state adapted for the approaches of the male. For some days previously the male may be seen running about and hiding itself under stones and in crevices of the rocks, holding the female clasped by one or more of its legs, the carapace of the female being pressed against the sternum of the male. In this position they continue until the female throws off the old calcareous shell, when the female is reverse in its position relative to the male, and connexion between the two immediately ensues, and continues for a day or two, perhaps until the shell of the female attains its hard calcareous character.

It would therefore seem to be tolerably certain that the period of the exuviation in the male must be at a separate period of the year from that of the female.

Mr. Gosse, in the 'Annals of Natural History,' 2nd series, 1852, vol. x. p. 210, gave an account of his observations of a crab (*Maia squinado*) during the period of moulting, in which he appears to confirm all that has been previously described as to the manner in which the Brachyura and Macrura get rid of the old integuments.

As to the lower forms, such as the Edriophthalma, it was long assumed, on the authority of Professor Bell, who relied on the assertion of the late Mr. J. Couch, that the animals of this order never shed their skin at all, but continue adding to and increasing it until they arrive at the adult stage. Those who have observed these animals, and seen how the old skin, in a not very long period of time, is liable to become incrusted and overgrown with foreign material, must rejoice to know that, like their higher neighbours, these animals can at certain periods of their existence eject their old skin, and swim about in a new one, fresh and clean.

This fact may easily be demonstrated by any who may like to retain a few specimens in a glass tank, when the exuviæ will be seen soon to strew the bottom as dead animals, but which, on close examination, will be found to be the remains of the cast-off skins.

I have kept these creatures long in small vessels, and watched them closely for years, and have seen them shed their exuviæ not unfrequently.

The manner of so doing appears to be upon the same plan as that of the higher forms, such variation as takes place being consistent only with the variated conditions and forms of the animals. The animal, having no carapace, escapes from the old skin by a separation immediately behind the cephalon, between it and the pereion; the pereion splits along the lateral walls just above the coxal plates of the legs. This separation corresponds with the lateral opening between the carapace and the legs in the higher orders, where, there being no dorsal arcs to the somites of the pereion, the legs appear to separate from the carapace or cephalon rather than from the pereion, of which they form an attached portion.

The little animal clings to a fragment of weed or stone, and resting there for a time, gradually liberates itself through the opening that I have described, first by removing the whole of the body posterior to the cephalon, then, after resting some short time, withdrawing the head and its appendages from the anterior portion.

In the terrestrial forms, chiefly represented by the *Ligia* and *Oniscus*, a variation in the exuviation appears to depend upon the nature of the habitat; thus, living in the air and creeping about among bushes, the worn-out old epidermal tissue appears generally to be shed in portions, a circumstance that I attribute to the animal's surface coming into contact with rough projecting bodies, so ripping off portions before the whole is ready to be cast off. In these creatures the new skin appears to have arrived at a firmer and more resisting state before being shed than in the aquatic forms.

When the Crustacea cast their old integument, and appear as renewed animals, they exhibit afresh and uninjured all the appendages that have been broken off or wounded.

On Renewal of Appendages.

It has long been known that these animals, after losing any of their appendages, have the power of reproducing them. But the manner in which this is done has been known only through the results of modern observations.

The late Mr. H. Goodsir, in the 'Annals of Nat. Hist.' 1844, vol. xiii. p. 67, writes, "That he has found that a small glandular-like body exists at the basal extremity of the first phalanx in each of the limbs, which supplies the germ of the future legs. This body completely fills up the cavity of the shell for the extent of about half an inch in length. The microscopic structure of this glandular-like body is very peculiar, consisting of a great number of large nucleated cells, which are interspersed throughout a fibro-gelatinous mass. A single branch of each of the great vessels, accompanied by a branch of nerve, runs through a small foramen near the centre of this body, but there is no vestige of either muscle or tendon, the attachments of which are at each extremity. In fact this body is perfectly defined, and can be turned out of the shell without being much injured. When the limb is thrown off, the blood-vessels and nerve retract, thus leaving a small cavity in the new-made surface. It is from this cavity that the germ of the future leg springs, and is at first seen as a nucleated cell. A cicatrix forms over the raw surface caused by the separation, which afterwards forms a sheath for the young leg."

When a part receives a hurt beyond repair, or sometimes for a less cause, such as a passing fright received by the animal or from the dread of capture by an enemy, a crab or lobster will throw off the injured limb. This appears to be known to them, for it not unfrequently forms a plan of attack on one another. I have known the common Velvet-Crab (*Carcinus puber*) attack for some purpose the common Shore-Crab (*Carcinus mœnas*), and, with a pinch from its nippers, induce the weaker animal to eject all its legs in rotation, and leave it a helpless mass, at the mercy of any passing terror. But when a limb receives a less intended injury, it appears to be removed by a violent muscular contraction, terminating with a blow given by another limb or against some foreign body. The amputation is the work of a few seconds, except when the exuvia has been recently cast; then for the few succeeding days before the external shell is hardened it has not that easy capability, and the wounded limb will sometimes remain attached to the animal for half an hour or longer before it is rejected. (Ann. Nat. Hist. 1851, vol. vii. p. 300, "Notes on Crustacea.")

The newly-formed limb is developed within the old shell, and lies folded within its case until the animal moults, when it appears as part of the newly perfected animal, the sac-like membrane in which it was folded being cast with the rest of the exuviæ. The new limb is larger or smaller in accordance with the duration of time which elapsed between the period that the limb was amputated and that at which the skin is shed. The form and condition in which the limb then is in remain to all appearance stationary until the next time of moulting, when the whole creature again advances in size, but the new or small limb more in proportion than the rest of the animal, until it equals it in relative proportion.

The size of the restored appendage is therefore dependent upon the length of time which occurs between the accident and the next succeeding moult—that is, the length of time from the commencement of repair to that when the limb is freed from the saccular membrane.

The legs during development generally lie folded upon themselves; but the long flagelliform appendage of the antennæ is adapted to a spiral case until the period of the general moult arrives, when it is withdrawn, and assumes a straight line, the old skin retaining its spiral form ("Report of Committee appointed to explore the Marine Fauna of the South Coast of Devon: No. 2," Brit. Assoc. Report, 1867, p. 283, pl. iii. fig. 4).

It may readily be supposed, after having seen the animal withdraw from the old shell, that we arrive at a full knowledge of how the act is performed. It may appear comparatively an easy natural process to withdraw the soft and yielding body from the hard and rigid case; and this may be so when the appendages are not very much larger at the extremity than they are at the points of articulation.

The late Mr. Couch, who, at his place of residence, had valuable opportunities for studying marine animals under various conditions, gave much attention to this subject.

In the Report of the Royal Polytechnic Society for Cornwall for the year 1843 is a communication on the process of exuviation in Crabs and Lobsters, by J. Couch, Esq., and again, in the Journal of the same Society, is a paper giving an account of "A particular Description of some circumstances hitherto little known connected with the process of Exuviation in the common Edible Crab," by Jonathan Couch, Esq., F.L.S. &c. (1852). This last memoir chiefly refers to the manner in which the animal withdraws the large claws from the old shell.

Bell says, in his Introduction to his 'History of the British Stalk-eyed Crustacea,' p. xxxv, that "It is impossible to imagine that the crust of the legs, especially of the great claws of the larger species, could be cast off unless it were susceptible of being longitudinally split; and Réaumur states that such is actually the case, each of the segments being composed of two longitudinal pieces, which, after separating, to allow of the passage of the soft limb, close again so accurately that it is very difficult in the last crust to discover the line of division. When the animal has disembarrassed itself of the crust, the latter is found absolutely entire, and has exactly the form which it possessed previous to the operation."

In the 'Annals of Nat. Hist.' 2nd ser. vol. x. p. 210, Mr. Gosse, in his account of the exuviation in *Maia squinado*, states that the animals withdrew the legs, first one and then another, until they were quite out, as if from boots. The joints as they came out were a great deal larger than the cases from which they proceeded. It was evident that in this instance neither were the shells split to afford a lateral passage for the limbs, nor were the limbs reduced to tenuity by emaciation.

It is this point which the late Mr. Jonathan Couch took up in his last memoir alluded to. He writes:—"That in my former studies of this process I had myself overlooked or misapprehended the mode by which the claw-legs were withdrawn from the loosened crust, is in the first place to be ascribed to the fact that my attention was chiefly occupied with what was going on in the body and its immediate organs, the eyes, antennæ, and inward frame; and in the next place to the circumstance that the portions of the legs which alone answer to Réaumur's description in any degree are by their situation hidden below the under portion of the carapace, to which they are pressed close by the principal joints of the legs themselves, so that they could not have been attended to without a greater degree of violence than I judged myself warranted in using with due regard to the other observations I was desirous of carrying out.

"It was evident, from an inspection of the proceeding in this specimen,"—a female (technically a hen crab) of the stage of growth only one degree short of the full size,—"that Mr. Gosse's statement relative to the withdrawal of the smaller legs is correct, and therefore the language quoted from Réaumur will not correctly express what takes place in the Common Crab; nor, I believe, for reasons presently to be assigned, even in the species on which his observations were made—the River Crayfish. The bony covering, where this remarkable process takes place, is not simply divided by splitting, but by a far more complicated action, which yet is beautifully expressive of the simple means to which creative wisdom has had recourse when a natural proceeding was to be regulated. But the most remarkable part of the process, and that which particularly leads me to present this communication to the Society, is what I found to take place in the larger or claw-legs.

"In these the flesh of the two outer sections is much shrunk; but the portion occupied by the third, or innermost, is, on the contrary, very much distended. This is especially seen on the inner concave surface of this portion of the limb, where, if we examine the part under ordinary circumstances, we find three lines, which meet at an angle, their diverging extremities being bounded by a curved border that is directed at its termination towards the body of the animal. As a preparation for exuviation, in the same manner as the well-marked line in front of the carapace or shell between its margin and the mouth becomes loosened by absorption, so this curved line on the claw-leg has become separated along its course, while the other lines (those which are straight and meet at an angle) are only so much changed from a firm crust as still to remain connected together by a membrane, and thus assume the nature and offices of movable joints or hinges. The hitherto firm structure of this part of the claw-leg being thus turned into a movable cover, which admits of being lifted at the curved circumference, the swollen portion of the limb is protruded through the opening; and, by the tension thus produced below, the wasted extremity is drawn downward, the greatest accommodation of space being thus afforded with the least expenditure of effort or displacement.

"In the specimen examined I found that a portion of the muscular substance of the limb had become so much distended as to be thrust out of its sheath, and partly wrapped round the outside of the loosened crust.

"But while this may be supposed to be of great mechanical use in drawing downward the remaining wasted portion of the limb occupying the more distant segments, it offers but a slight hindrance to the final passing of the whole through the final ring or coxa, where the leg is united to the body. For this last remaining space is narrow; and the distention being chiefly produced by a liquid diffused through the fleshy fibres, it offers but little positive obstruction to the passage. A dragging action, therefore, accompanied probably by a muscular contracting power, is all that is required to enable it to slip through; at the same time that a portion of the distending fluid, if not the whole, is so much thrust backward as still to occupy the opening, and thus contribute to bring down each successive part in turn.

"The extremity of the claw-leg, then, being not only smaller naturally, but more wasted in this process than the rest, finds no hindrance to its escape; and thus the imprisoned limb is set at liberty. It is a fact beyond doubt, as appears by examination of many specimens, that no splitting process takes place in the slender or walking legs.

"It is a matter of some interest to ascertain whether and to what extent this remarkable process takes place in others of the great family of Crustaceous animals; and I have exercised no small extent of effort in following the examination in species of both the sections, the long-bodied or lobster kind, and the short-tailed or crabs." Mr. Couch's results were not attended with any great success in point of number of species.

"Nothing of this kind appears," he says, "in the Norwich Crab (*Maia squinado*), *Corystes cassivellaunus*, the common Crayfish (*Palinurus vulgaris*), or various species of shrimps. We may therefore conclude that all the limbs in those instances are withdrawn from their covering in the same manner as the smaller legs of the edible crab. The River Crayfish (*Astacus fluviatilis*), the particular subject of the French naturalist's researches, as well as the common lobster, have such lines marked on the inner segment of their claw-legs as leave no doubt in my mind that an opening takes place in them when the process of exuviation proceeds, although not such a mechanical splitting as Réaumur describes; and it does not take place in any shape in the smaller, or walking legs.

"The same may be said of the common Harbour-Crab (*Carcinus mœnas*), *Xantho florida*, the Velvet-crab (*Carcinus puber* and *pusillus*), and *Atelecyclus heterodon*, all of which I have examined."

It would be interesting to know how in the male of the genus *Gelassimus*, the enormously large distal joints of the prehensile claw can be drawn through the small opening of the coxa. I am much inclined to believe that the splitting of the walls at the point alluded to by Mr. Couch may be more for the purpose of enabling the animal to withdraw the great osseous tendon, which at this joint must be extremely in the way of the passage of the rest of the limb during the withdrawal from the old case.

In a very large number of exuviæ that I have examined I have never seen the splitting process as described by M. Réaumur.

Whatever may be the period, whether it be during the larva state or that of the adult animal, the process of development under which the new shell is produced must be similar.

M. Milne-Edwards, in the introduction to his 'Histoire des Crustacés,' p. 55, says that it is evidently secreted by the chorion, and moulds itself upon the integument that covers it.

In the 'Annals of Nat. Hist.' 1851, vol. vii. p. 298, are published some observations on the development of the shell of crabs, with illustrations. I state that I found immediately above the heart a mass consisting of nucleated cells, areolar tissue (and blood-vessels?), extending to the internal surface of the old shell, from which it is separated by a layer of pigment, which gives colour to the new formation. Towards the base (that is, immediately above the heart) the cells are uniformly large and distinct, while the areolar tissue ramifies throughout the whole. As advance is made from the base, cells of a less size mix with them, which increase in number as they diminish in diameter, until they approach the layer of pigment, immediately beneath which they adapt themselves, by mutual pressure, into a polygonal form. The layer extends over the whole periphery of the crab, immediately beneath the shell, the thickness of the mass decreases with the distance from the centre, and the larger cells become fewer in number, the mass being chiefly made up of the smaller cells, which become lime-absorbing organs for the future shell, which process commences previously to, and is completed after, the removal of the exuviæ.

Third Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England, and the quantity and character of the Water supplied to various towns and districts from these formations, including Report on the South-Lancashire Wells, by T. M. Reade. *The Committee consisting of* Prof. E. Hull, Rev. H. W. Crosskey, C. E. De Rance, Captain D. Galton, Prof. A. H. Green, Prof. R. Harkness, H. H. Howell, W. Molyneux, G. H. Morton, T. Mellard Reade, Prof. Prestwich, *and* W. Whitaker. *Drawn up by* C. E. De Rance (*Secretary*).

[Plate II.]

When the Report of your Committee, presented at Glasgow, was written, it was believed that sufficient information would have been collected this year to enable them to draw up a final Report on the subject of the inquiry with which you entrusted them.

Your Committee, in the prosecution of their duties, have largely distributed the circular form of inquiry; but they feel, though a large amount of valuable information has been obtained through this source, it for the most part only gives to the general public information as to local areas already in the hands of the inhabitants of those districts, and that to collect information that may be of general value as to the probable depth and quantity of water available in adjoining areas, requires personal examination and study of a trained geologist.

As far as the time and opportunities of your Committee go, they have endeavoured to carry out such personal examination; and the results, with those obtained during the coming year, they propose to lay before you at the next Meeting of the Association, should you think fit to reappoint their Committee, which they trust will be the case, as much information is at present promised them, and facilities are more freely given as the existence of the Committee becomes more widely known.

In regard to their general fitness for drinking and cooking, the Rivers Pollution Commissioners classify waters in the order of their excellence in respect to wholesomeness and palatability as follows:—

Wholesome.	1. Spring water.	Very palatable.
	2. Deep-well water.	
	3. Upland surface water.	Moderately palatable.
Suspicious.	4. Stored rain-water.	
	5. Surface water from cultivated land.	Palatable.
Dangerous.	6. River-water which sewage gets access to.	
	7. Shallow well-water.	

The value of spring and deep-well waters is not merely due to their greater intrinsic chemical purity and palatability, but to their being peculiarly suited for domestic supply, from their almost invariable clearness, transparency, and brilliancy, and their uniformity of temperature throughout the year rendering them cool and refreshing in summer, and preventing them readily freezing in winter; and their utilization and conservation appear to be a matter not only worthy of inquiry into by the Association, but one of national importance, and to demand imperial legislation.

The average amount of hardness of the water of the deep wells of the New Red Sandstone, tabulated by the Rivers Pollution Commission, being 17°·9, and of the springs from the same formation no less than 18°·8, the relation of hardness of water to the rate of the mortality of the persons drinking it becomes a matter of great importance.

The Commissioners give three Tables of Statistics that bear directly upon this point.

From Table I. it appears that in twenty-six towns inhabited by 1,933,524 persons, supplied with water not exceeding 5° of hardness, the average death-rate was 29·1 per 1000 per annum.

From Table II. we learn that in twenty-five towns inhabited by 2,041,383 persons, drinking water of more than 5°, but not exceeding 10°, the average death-rate was 28·3 per 1000.

In Table III. we find that sixty towns, with an aggregate population of 2,687,846, drinking water of more than 10° of hardness, the average death-rate was only 24·3.

Of the towns in Table I. none are supplied from the New Red or Permian formations.

In Table II. three are so supplied.

In Table III. ten are so supplied.

From which it will be observed that the largest number of towns supplied with New Red water is found in the Table with the lowest death-rate and the hardest water.

The same result is obtained if we compare towns of corresponding populations and occupations supplied from surface-areas with soft waters, and those supplied by deep wells in the New Red Sandstone. Thus Manchester, with 351,189 inhabitants, has an average death-rate of 32·0 per 1000; while Birmingham, with 343,787, has only 24·4. And, again, Stirling, with 14,279 inhabitants, has an average of 26·1 per 1000; while Tranmere, with 16,143 inhabitants, has only 18·8.

But it may possibly be objected that the high death-rate of Manchester is not due to the softness of the water supplied to the inhabitants, but to the density of the population, the close proximity to the houses of cesspools and ashpits, and the want of care experienced by children in the manufacturing districts; and, again, that the low death-rate of Tranmere is due to the constant emigration of adults. And that these averages, being dependent on so many external causes, not due to the purity or impurity, hardness or softness, of the water supply, is borne out by the facts that Greenock and Plymouth, both supplied with soft water, with an equal number of inhabitants, have a death-rate respectively of 32·6 and 23·3 per 1000, due to difference of density of population, Greenock having only one house for every twenty-eight people. And, again, Liverpool and Birkenhead, both supplied with moderately hard water; the former an old and densely populated town, with a site saturated with what is injurious to health, has a death-rate of 34 per 1000; while Birkenhead, a new town on an open site with wide streets, has a death-rate of only 24 per 1000, though mainly inhabited by a poor and struggling class of persons.

But, at the same time, it is worthy of note that the five inland manufacturing towns with the lowest death-rate are all supplied with hard water, and all from the New Red Sandstone.

	Population 1871.	Mortality per 1000 per annum.
Birmingham	343,787	24·4
Leicester	95,220	27·0
Nottingham	86,621	24·2
Stoke-on-Trent	130,985	27·9
Wolverhampton	68,291	25·9
Average	144,981	25·5

And, again, the average death-rate of twelve inland non-manufacturing towns supplied with soft water was 26·0 per 1000; while that of twenty similar towns supplied with hard water was only 23·2.

When, however, the mortalities of the districts including the principal English watering-places are compared, there appears to be little variation in the death-rate, whether the population be supplied with soft, moderately hard, or hard water; so that it may be safely concluded that where sanitary conditions prevail with equal uniformity, the rate of mortality is practically uninfluenced by the degree of hardness of the water drank; and H.M. Rivers Pollution Commission are of opinion that "soft and hard waters, if equally free from deleterious organic substances, are equally wholesome."

Your Committee has as yet not been able to obtain much information as to the water supply to be obtained from the Permian rocks. These beds in different areas of England present so many distinct types that an analysis of them may be found useful to those inclined to work up information for your Committee.

*Its Salopian type**.

Well shown in the neighbourhood of Enville, south of Bridgnorth. In descending order:—

UPPER SERIES.	Red and purple sandstones and marls.	
MIDDLE SERIES.	Breccia in a marly base	60 to 120 feet.
	Sandstone and marl	40 to 50 ,,
	Calcareous conglomerate	30 ,,
	Sandstone and marl	30 to 40 ,,
	Calcareous conglomerate	12 ,,
LOWER SERIES.	Purple sandstones, passing various shades of red, brown, and occasionally white, often calcareous, and interstratified with red marls	850 ,,

(Coal-measures of Forest of Wyre.)

In Warwickshire the lower series occur, and the overlying calcareous breccias may be seen at Coleshill and Hurley, near Baxterly; while the higher beds have been penetrated in a boring for water at Warwick at a depth of 700 feet, and are pierced in shallow wells at Kenilworth. The whole of this triple series is believed to belong to the *Rothtodtliegende*, or Lower Permian.

* Memoirs of the Geological Survey. "The Triassic Rocks of the Midland Counties of England." By E. Hull, F.R.S. London: 1869.

Collyhurst (near Manchester) type.

These beds are believed to have been formed contemporaneously with the Enville group, but in a separate hydrographical basin, separated from that of Shropshire, Staffordshire, and Warwickshire by an east and west upheaval of Lower Carboniferous rocks across the plain of Cheshire.

The Lower Permian beds of South Lancashire have been worked out in great detail by Mr. Binney, F.R.S., who gives the following sequence in descending order :—

RED MARLS.	Red marls, with numerous bands of fossiliferous limestone, worked at Astley and Bedford. At Worsley this series attains a thickness of 131 feet, with fifty-two thin beds of limestone	131 feet.
LOWER PERMIAN SANDSTONE.	Bright red sandstone, obliquely laminated, of uniform texture, seen at Collyhurst and at Stockport	1500 feet.

On the southern edge of the Lancashire coalfield these beds are slightly unconformable to the underlying Coal-measures between Manchester and Sutton, allowing the reappearance of the "*Spirorbis* Limestone" at Whiston. North of the coal-field the unconformity is much more marked; at Skillaw Clough, near Bispham, Roach Bridge on the River Darwen, near Pleasington Station on the Blackburn Railway, the Permian rests directly on the Millstone Grit; and in the wide spread of Lower Permian Sandstone, found by your Reporter to underlie the low drift-covered plain of Garstang, between Preston and Lancaster, the underlying rocks are of Lower Yoredale age, as is also the case in the deep borings of the Furness district, on the opposite side of Morecambe Bay, carried out by the Diamond Boring Company.

There are a few wells in the Garstang Permian Sandstone, the deepest of which is at Higher Crookey.

In Cumberland the same series obtains, but is overlaid by the St.-Bees Sandstone, so finely developed in the cliffs of that name, and referred by Sir Roderick Murchison to Permian age, though formerly referred to the Trias. The Collyhurst Sandstones are described by Prof. Harkness in the Vale of Eden, under the name of "Penrith Sandstones," as attaining a thickness of nearly 3000 feet.

Durham type.

In Durham and the north-east of England the sequence is widely different. That at Durham is described by Prof. King as follows :—

6. Crystalline and Concretionary limestone.
5. Brecciated limestone.
4. Fossiliferous limestone.
3. Magnesian limestone.
2. Marl slate.
1. Lower Red Sandstone (with Coal-plants).

The Lower Red Sandstone lies irregularly and unconformably on the Coal-measures in hollows eroded in its surface, but contains many species of Coal-measure plants. Large quantities of water are pumped from these sandstones, and from the Magnesian Limestone of this county, for the supply of Sunderland, South Shields, Jarrow, Seaham, and several villages—the quantity pumped from an area of 50 square miles overlying the Coal-measures being, according to Messrs. Daglish and Forster*, no less than 5,000,000 gallons per day, which abstraction has not in the least altered or lowered the permanent water-level in the rock of this district, which occurs along the coast at mean-tide level, rising to 180 feet above it inland.

The following analysis of the Sunderland water is given by the Rivers Pollution Commission:—

Total solid impurity		44·18
Organic Carbon		·035
Organic Nitrogen		·030
Ammonia		0·0
Nitrogen as nitrates and nitrites		·416
Nitrogen, total combined		·446
Previous sewage contamination		3·840
Chlorine		4·17
Hardness	Temporary	·8
	Permanent	13·9
	Total	14·7

The Commissioners comment on the fact that spring water, Waterham's Field, Pontefract, is not only excessively hard, but differs from the Sunderland well-water in having a large amount of temporary hardness (24·9); but it is important to notice that the water of Sunderland, unlike that of Pontefract, is obtained from the Sandstone beneath the Magnesian Limestone, and not from the Dolomite itself.

These limestones, as stated by the Commissioners, are rarely used as a source of water-supply; dolomite being a double carbonate of lime and magnesia imparts both these substances to the water. 100,000 lbs. of the Sunderland water contained 5·89 lbs. of lime and 3·96 lbs. of magnesia, which must be due to the percolation of the water through the porous limestone before it reached the underlying sandstone.

These limestones of Durham gradually thin away to the south, through Yorkshire and Derbyshire, and die out near Nottingham. The thin limestones of Lancashire, already described, may be considered their debased and argillaceous equivalents, the fossils occurring at Astley and Bedford being the well-known magnesian limestone genera *Tragos*, *Schizodus*, *Bakevellia*, and *Turbo*.

The less crystalline limestones hold 3·45, 6·0, 13·13, 14·87, and even 17·0 lbs. of water to the cubic foot. The Sandstones vary less, 10 lbs. of water (a gallon) being the average point of saturation. The more crystalline limestones absorb very little.

Of these Yorkshire and Nottinghamshire Limestones, the Commissioners give the following analysis:—

* Report Brit. Assoc. 1863, Newcastle Meeting, p. 726.

	Pontefract, Yorkshire.	Mansfield, Well, 75 feet deep, Water-works.	Mansfield, Mr. Peat's Well.
Total solid impurity	84·92	25·24	54·32
Organic carbon	·054	·053	·139
Organic nitrogen	·021	·014	·039
Ammonia	0	0	0
Nitrogen as nitrates and nitrites	2·673	·599	1·888
Total combined nitrogen	2·694	·613	1·227
Previous sewerage contamination	26,410	5,670	11,560
Chlorine	5·55	1·40	3·20
Hardness: Temporary	26·5	6·0	23·4
Hardness: Permanent	40·8	16·4	26·0
Hardness: Total	67·3	22·4	49·4

From Somerset and Devon your Committee has received no returns; but they would wish to call attention to the classification of the Triassic rocks of the South-Devon coast, recently published by Mr. Ussher*, of the Geological Survey, in which he gives the following sequence:—

1. Upper Marls	1350	feet.
2. Upper Sandstone	530	,,
3. Conglomerates	100	,,
4. Lower Marls	600	,,
5. Lower Sandstone and Breccias	1000	,,
	3580	,,

But he states that this maximum total thickness is probably 1000 feet greater than the actual vertical distance, but from various causes an estimate is very difficult.

In Leicestershire, Mr. Plant reports that for many years water good in quality and abundant in quantity has been known to exist at the base of the great gypsum bed which lies in the Upper Keuper Marls. This supply has been proved wherever the marls have been penetrated in wells from 30 to 80 feet in depth, and in excavations for brick-making &c.

In one of these excavations near the town of Leicester, on the base of the gypsum being reached at a depth of 40 feet and the last layer cut through, a copious supply of clear water burst through in such abundance as to require special arrangements to carry it to an adjacent brook. The water was found to have worn a deep channel in the red marl lying immediately beneath the gypsum. The stream remains constant in dry and wet weather.

The marls above and below this gypsum bed are quite dry and free from water, and the water occurring in it must be derived from the various outcrops of this bed in Nottinghamshire, Derbyshire, and Leicestershire.

Mr. Plant has been led to conclude that this water, running constantly at the base of the gypsum bed, must be the source of supply of sulphate of lime found in the underground waters of the Midland Counties; and he has always found it difficult to account for the water obtained in deep wells (pump and draw wells) in the Upper Red Marls of this county whenever the gypsum bed was penetrated; he is now of opinion that, as far as domestic and farming requirements are concerned, in the Upper Red Marl district, this horizon affords the most abundant and valuable source of supply.

* Quart. Journ. Geol. Soc. vol. xxxii. p. 392.

And though this gypseous bed does not strictly come under the head of an inquiry into the Permian and New Red Sandstones formations, yet it is important as affording another and undescribed source of underground water-supply in the Midland Counties.

The various sources of supply he tabulates thus in descending order:—

1. Great Gypsum bed.
2. Upper Keuper Sandstone.
3. Lower Keuper Sandstone.
4. Bunter Sandstone.
5. Permian Sandstone.

Mr. Plant states that he trusts to have some further information about deep borings now in operation in Leicestershire in addition to those he has already obtained, and which are published in the previous Reports.

In Staffordshire, Mr. Molyneux reports that he has obtained a large amount of information; but as important borings for water are still in progress, he would prefer waiting until they are completed, so that he may be able to present the Committee with a connected Report on the area he has taken charge of, which shall include the resources of the Bunters of the Cannock-Chase district, where the South-Staffordshire Waterworks are erecting two large pumping stations, and also the results of mining operations through the so-called Permian beds south of Walsall and elsewhere.

Mineral Waters of St. Clement's, Oxford.

It has lately been suggested by Prof. Prestwich that some of the saline springs occurring in the Oolites may derive their supply from deep-seated underlying New Red rocks.

In a paper read before the Ashmolean Society he describes the character of the water now issuing from an artesian bore-hole carried 420 feet through the Oxford Clay and Oolitic strata in 1832. An analysis by Mr. Donkin proves this water to contain 1277 grains per gallon, a quantity not exceeded by many of the continental saline waters. In the large proportion of *sulphates*, this water more nearly resembles some of the German mineral waters, such as Friederickshall and Rehme, than those of England; for that of Cheltenham only contains 694 grains of saline ingredients, of which 104 grains per gallon consist of *sulphate of soda*, which, at St. Clement's, amounts to 357 grains.

As stated in your Committee's second Report, not less than 10,000 square miles of area are occupied in England and Wales by the New Red Sandstone and Permian formations, which absorb not less than 10 inches of rainfall annually, and probably more in districts where the overlying drift is porous, or absent altogether, and the sandstone is of an exceedingly open and permeable character and is traversed by joints and fissures.

This area is a fertile source of shallow wells, and both the sandstone and the overlying drift sand and gravel form an excellent water-bearing stratum; but unfortunately these shallow wells, though yielding clear and palatable water, from the numerous and potent sources of pollution surrounding them, are almost all valueless as a source of domestic supply, being charged with organic matter derived from animal refuse matters, the total solid impurity amounting to 240 parts per 100,000, or 168 grains per gallon, in the water

Results of Analysis expressed in Parts per 100,000.

(The numbers in the table can be converted into grains per imperial gallon, by multiplying them by 7, and then moving the decimal point one place to the left. The same process transforms the hardness into degrees of hardness on Clark's scale).	Depth.	Previous Sewerage Contamination.	Hardness.			Remarks.
			Temporary.	Permanent.	Total.	
BIRMINGHAM.	ft.					
Pump, No. 5 Court	...	151,960	27·5	99·6	127·1	Palatable.
Pump, 30 Ravenhurst Street	...	31,830	13·6	30·6	44·3	
CONGLETON, CHESHIRE.						
Town pump at Star Inn	...	10,456	4·0	13·1	17·1	
COVENTRY.						
Well in Cow Lane	...	32,620	37·0	35·7	72·7	Slightly turbid.
CRATHORNE, YORKSHIRE.						
Orchard well	5	16,270	6·4	36·2	42·6	
Pump in well	20	490	22·3	19·6	41·9	
DARLINGTON, DURHAM.						
Blackwell pump	...	66,920	36·9	41·7	78·6	Clear and palatable.
DAWLISH, DEVONSHIRE.						
Well at Marine Terrace	...	70,940	0	30·6	30·6	Slightly turbid.
GREASELEY, NOTTS.						
Morley's pump	45	59,600	22·2	40·7	62·9	
HUGGLESCOTE, LEICESTERSHIRE.						
Mr. Moore's pump	...	29,330	0	37·1	37·1	Clear and palatable.
HURWORTH, NEAR DARLINGTON.						
Well at Rectory	...	25,880	32·3	3·8	36·1	
KIDDERMINSTER.						
Well in "Three Tuns" Yard	...	52,900	11·3	17·3	28·6	
LEAMINGTON.						
Mr. Jones's well	...	60,540	35·6	28·3	63·9	
MALPAS, CHESHIRE.						
Town well	...	3,790	12·0	10·7	22·7	Slightly turbid.
NEWARK, NOTTS.						
Well near Trent	...	560	13·0	18·9	31·9	
NEWENT, GLOUCESTERSHIRE.						
Well	...	113,620	25·3	31·1	56·4	
NEWNHAM, GLOUCESTERSHIRE.						
Mr. Everett's well	...	35,930	42·2	40·7	82·9	
RETFORD, WEST NOTTS.						
Well in Mermaid Yard	...	73,240	14·1	43·3	57·4	Clear and palatable.
STAFFORD.						
Pump in Station-Master's Yard	...	5,020	17·0	12·4	29·4	
STOCKTON-ON-TEES.						
Mr. Trotter's well	...	18,930	52·0	35·1	87·1	Slightly turbid.
WILNECOTE, NEAR TAMWORTH.						
Public pump at head of village	...	78,510	0	57·5	57·5	
WORKSOP, NOTTS.						
Park-Street well	...	20,940	15·7	28·5	44·2	Turbid. Palatable.

of one of the shallow wells of Birmingham. An examination of the analyses of eighty-seven samples of these waters made by the Rivers Pollution Commission shows, in the high figures of the column of previous sewerage or animal contamination, how largely sewers and cesspools contribute to the contents of these wells.

The preceding Table of the composition of waters from shallow wells in the New Red Sandstone is compiled from the sixth Report of the Rivers Pollution Commission.

The pollution of these wells is easily understood when it is remembered that in most of the villages and in many of the smaller towns the water-supply is obtained, and the sewerage disposed, by digging two holes in the cottage garden, often within a few feet of each other, into the shallower of which the refuse of the cottage is discharged, and out of the deeper of which the water-supply is pumped from a porous soil, which soon gets replenished from the soakage of the soil lying beneath and around the shallower cesspool. The dangerous and disgusting liquids making their way into the well, after passing through a foot of porous soil, are sufficiently deodorized as to not impair the palatability of the water; and such polluted waters are drank for years, until an outbreak of epidemic disease calls attention to them.

At least 12 millions of the British population obtain their water-supply from shallow wells of this class.

In regard to village water-supply, the evidence of Mr. James Caird, C.B., one of the Inclosure Commissioners, examined by the Chairman of the Select Committee of the House of Lords on Improvement of Land (Minutes of Evidence, 2nd May and 24th June, 1873, pp. 42 and 348), is of importance, as he states that both he and his colleagues, Messrs. Darby and Ridley, consider "that in the case of charges for the supply of water to a village for sanitary purposes it would be very advantageous, where the village belongs to an estate, that it should be included in the objects of the loan, the improvement being one that is for the convenience of the agricultural labourers resident on the estate;" and Mr. Ridley further suggests "that in any Sanitary Act that may be passed, a provision of that kind should be inserted, making the providing of water an improvement under the Act of 1864."

It was suggested in 1865 to the Rivers Pollution Commissioners by the late Sir George Grey, then Secretary of State, that they should endeavour, if possible, to carry out the suggestions of Mr. Charles Neate, M.P., that they should inquire "how far the general level of springs in the country has been lowered" by agricultural drainage; "how far it depends upon the height at which water is maintained in the neighbouring river, and what is the number of springs that have altogether failed, or at least that fail during the summer." This inquiry they do not appear to have been able to carry out, possibly from a belief that springs that would be affected by local drainage would be subject to surface-pollution, and consequently be of no value as a source of water-supply. But when it is remembered that many deep-seated springs derive their supply from distant outcrops, often of an exceedingly porous and permeable character, the question of cutting off the available rainfall by means of intercepting drains becomes one of great importance; and your Committee intend inserting a clause in their forms of inquiry in the hope of elicitating information on this point.

Through increase of population and manufacturing requirements, the quantity of water annually consumed in England is steadily increasing, while the number of available sources of supply being necessarily limited, the competition for the possession of suitable water-bearing areas, especially those adjoining the more densely crowded centres, becomes keener and keener, and the parliamentary and other preliminary expenses larger and larger. Rival townships after severe competition obtain the whole of the water rights of a district to the exclusion of those who, from apathy, ignorance, or want of funds, neglected to claim a portion of the supply naturally belonging to them.

The Local Government Board and Parliamentary inquiries at the best only endeavour to ascertain whether any water-scheme laid before them is likely to fulfil the particular objects proposed; and they have no means of judging whether it is the best scheme, or whether it will interfere with the interests of other districts who may not be represented. To take two cases in point:—

The urban sanitary district of Pemberton, near Wigan, with 10,374 inhabitants, situated on the Coal-measures, has suffered much from an inadequate supply of water. After much opposition in Parliament, an Act has been obtained to construct reservoirs to impound waters flowing off cultivated land, and consequently belonging to that class considered *suspicious* by the Rivers Pollution Commission.

In the adjoining urban sanitary district of Ashton-in-Makerfield, with a population of 7463, situated on the Pebble Beds of the New Red Sandstone, which at present gives a very inefficient supply of water from shallow and dangerous wells, an Act of Parliament has been obtained, after much cost, opposition, and litigation, to construct works to obtain surface-water from adjoining cultivated land on the Coal-measures, which will, moreover, necessitate constant pumping.

Colliery-shafts sunk in the New Red Sandstone and Permian formations south of this district yield an almost inexhaustible supply of pure water; and your Committee cannot but feel it a matter of regret that this source of supply should be so systematically disregarded, which could not be the case were the Local Government Board empowered to see that districts choose the purest water and cheapest scheme available in a given area.

The supply of New Red water just referred to, east of Ashton and Golborne &c., may possibly be made available for the additional supply of Liverpool, the water-pipes of which borough pass through the district in question from Rivington.

Your Committee are of opinion that it is desirable that they should continue to inquire into areas where New Red and Permian water may be obtained by means of deep wells.

That, looking to the national importance of utilizing the underground waters of England, it is desirable that the sphere of their inquiry should be extended so as to include the Oolites, which the results obtained by the Rivers Pollution Committee prove contain an almost inexhaustible supply of pure water, which is not made available for the supply of the population living upon it until it is hopelessly contaminated with sewerage.

That the result of their labours since the formation of the Commission has been to prove that there is an available daily supply of water from the New Red Sandstone and Permian of England of not less than 3600 million gallons of water, the quality of which is remarkably free from organic impurity, and the hardness of which does not in the least appear to affect the health of the population at present taking their supply from it, the death-rate of this area comparing well with the best soft-water district.

On the South-Lancashire Wells. *By* T. Mellard Reade, C.E., F.G.S.

As a member of the Committee I have devoted considerable time to obtaining information on the subject we are engaged in investigating, especially as regards South Lancashire ; I have exhausted the information available to me through the means of your printed forms of inquiry. Much more ought to be obtainable ; but companies undertaking the supply of districts are, perhaps naturally, jealous of giving answers which they imagine may be used to their detriment at some future time.

Having collected all the answers to the queries of the Committee, I next attempted to analyze them, with a view of ascertaining whether I could help the Committee further by a digest of the, to some extent, crude facts and statements relative to the district I am more immediately acquainted with.

In doing this I was met by the difficulty of reducing the replies to one common datum for comparison. With existing wells there are only a few in which the quantity pumped, the variations in the supply, and correct analyses of the water from time to time are taken and recorded with the scientific exactness which would enable me to draw deductions having the force of demonstration.

So far as I am able I purpose now to present for your consideration the facts and my deductions therefrom, arranged with the object of enabling you to test for yourselves their relative importance.

The area of the country over which my information extends (and here I must acknowledge my indebtedness to Mr. G. H. Morton, F.G.S., who has kindly placed at my disposal all the valuable facts in his possession relating to Liverpool and Cheshire wells) includes in Lancashire the Triassic rocks lying between the south and south-western borders of the Lancashire coalfield, and the shores of the Mersey and of the Irish Sea as far north as Southport. In Cheshire the area occupied by the wells of which I have any reliable information lies within a radius of 5 miles from Liverpool.

For the purposes of comparison, however, although there are outlying wells which I shall have to refer to, there are three nuclei or centres about which the most important systems of wells are grouped, viz. Liverpool, Birkenhead, and Widnes. These "systems" I have shown on two sheets of vertical sections annexed to this report (Plate II.), reduced with as much accuracy as was available to a common datum, on which I have shown the extreme variation of level of water in each well produced by pumping. As regards *seasonal* variation it will have to be treated separately.

I have also shown on the 6-inch Ordnance Surveys, coloured geologically, the position of each well in the Liverpool and Widnes Systems, and in other cases have shown the position of the wells in the 1-inch scale Geological Survey sheets.

Widnes Wells.—With the exception of the town supply, these wells have been sunk for manufacturing purposes. As a great chemical manufacturing town, Widnes has been entirely created within the last 30 years *, and a large supply of water is a necessity.

Widnes occupies what I have shown to be the site of the old course of the river Mersey †, a rock valley having a depth of 141 feet below Ordnance datum, now filled up with glacial-marine drift. It is through this drift, of

* The first works were established by Mr. John McClellan in 1846, the second by Mr John Hutchinson in 1847.

† Buried valley of the Mersey, Proc. of Liverpool Geol. Soc., Sess. 1871–2.

varying thickness according to the position of the well, that the well-sinkers and borers had to penetrate to get to the water-bearing rock below. This portion has of course in each case been tubed. The succession of these strata is shown on the sections, and consists first of Marsh Clay or Silt (Postglacial), Quicksand (Glacial), and a great depth of a tenacious, unctuous, fine clay of a brown colour, evidently recomposed to a considerable extent from the Triassic Marls, but being itself of glacial marine origin, as shown by the shell-fragments and occasional erratic boulders and pebbles it contains. This reposes on a red sand often containing erratic pebbles, the top sand of the red rock below. According to the Geological Survey the bed-rock belongs to the Pebble Beds, or middle division of the Bunter.

It is pretty certain from the consensus of evidence on the subject that when this retentive bed of brown marl was first pierced the water rose above the surface of the ground. A reference to the section will show that the water-level has been permanently lowered by pumping to an average of about 8 feet below the surface; when the pumps are at work, of course the level of the water in the well is entirely dependent upon the power of the pumps. I have not been able to obtain returns from all the well-owners, but the amount of water of which I have returns, if we include the Local-Board well at Cronton, is 1,670,000 gallons per diem; I should think, however, there must be a million more gallons pumped*. The form of the printed questions, however, creates a difficulty, as the "Quantity capable of being pumped up in gallons per day" is not necessarily the same thing as the *actual* yield.

There can be no doubt, however, that a very considerable quantity of water in this area is tapped and utilized. It will be seen from the sections that the extreme height the water rises above ordnance datum is 18 feet.

Stocks Well, Cronton.—This is a well belonging to the Widnes Local Board. It is situated about $2\frac{1}{4}$ miles from Widnes, and is 70 feet above O.D. (not 45 as stated in the return); but as it does not lie in the Preglacial valley of the Mersey, I mention it separately. It yields 800,000 gallons per day. Before pumping the water flows over at the surface, and therefore rises 52 feet above the water-level at Widnes. The Widnes Board are sinking a well at Netherley Bridge, and, I understand, get a yield now of about 350,000 gallons per day.

Garston Iron Works.—The yield of this well is 240,000 gallons per day. It is situated on the margin of the river Mersey, and the water-level appears to be approximately the same as at Widnes. As it is nearly 7 miles from Widnes and 4 from Liverpool the water-level appears to be governed by proximity to the river. The water-level is stated to have diminished.

At Whiston the St.-Helen's Corporation have established a well; but further than that the yield is 1,000,000 gallons per day I have no reliable information.

Ince Waterworks, Golbourne.—In a direct line this well is over 10 miles from Widnes. The surface-level is 125 feet above O.D.; the yield 240,000 gallons per diem. The water-level before pumping is stated to be 80 feet below the surface, or 45 feet above O.D.

The Sankey White-lead Works, Well, Sankey Bridges.—The peculiarity of this well is its being all in the drift, finishing in a bed of gravel about 100 feet below the surface. The water, rising to within 3 feet 6 inches of the

* Mr. Boult, who has collected a great amount of information on the subject, gives 480,000 as the yield of the Ditton Iron Company's well, Pilkington's 240,000, and the Tharsus Copper Works 192,000, or a total of 912,000, all of which will be additional to my returns.

surface, is, as I reckon it, about 16 feet 6 inches above O.D. It is evident the river governs the height to which the water rises. It is stated not to be perceptibly affected by the seasons.

Ormskirk Local Board Well.—This is a well lying out of the special area I have marked out for further investigation. It is remarkable as being affected by local rains within 24 hours. The water-level is stated to vary slightly in summer and winter, but has not diminished during the last 10 years. The water is pronounced to be remarkably good and soft. There is a very large fault on the west side of the well.

Borings through the New Red Marls.—In two cases I know of, these marls have been pierced; the one at Alsager within 300 yards of the railway-station, in which 553 feet of the marls were pierced, and water tapped which rises in an iron tube 10 or 12 feet above the surface. The level of the surface is 310 feet above O.D. The water is very pure and soft, and suitable for brewing-purposes. Though the bore was continued to a depth of 1000 feet, the water was not increased thereby. The second case is at Preston Brook, at which the water was tapped after piercing 400 feet of marls.

An attempt was made to pierce the marls at the Palace Hotel, Birkdale, near Southport, but was given up at a depth of 558 feet.

I have now recapitulated the leading features of the wells outside of Liverpool and Birkenhead of which I have information. As the answers are already printed *in extenso* in the two Reports of the Committee, any one wishing for more detailed information can there obtain it.

Inferences.—Though the information is any thing but of a scientifically exact character, it appears to me that some useful inferences can be drawn from it. They are these:—

As to the present Water-level.—It is quite clear that, when a well or a system of wells is established in a district, the permanent water-level is lowered to the extent of the draw upon the supply. Though I call this the permanent water-level, I merely do so to distinguish it from the temporary level of water in the well produced by, say, 12 hours' pumping. It is not naturally, but becomes *artificially*, the permanent water-level of the country; and in any case, were the pumping-operations to cease entirely, I should expect to see the natural water-level restored in 12 months.

As to the effect of local Rains.—In only a few instances have the observers stated that they could distinguish the effect of rain on the wells. Even in the one in the drift at Sankey Bridges my informants say they can distinguish no seasonal changes. It is quite possible, however, that this bottom-drift gravel may be supplied from springs in the rock below. The Ormskirk well is a comparatively shallow one, and the local rains affect it, I should say, by immediate local percolation. It will be seen that the Liverpool wells are not altogether exempt from this local percolation; at all events the Bootle well is not. This, however, is only in accordance with what we would expect inferentially from a consideration of hydraulic principles; the larger the area from which the supply of water is drawn, the less likely is the well to be affected by local rains. The nature of the top rock, the dip of the beds, the number and position of the fissures in the rock, the proximity of a fault, will all assist to determine the extent of local percolation. If, however, the well and the bore is made watertight by tubbing and tubing to a considerable depth, local rains cannot influence the yield to any perceptible extent. When a great thickness of clay or marl is penetrated I know of no recorded instance of seasonal variation in the supply from the Triassic rocks.

As to the Mode of Circulation of Underground Waters.—A few minutes' consideration will show that the supply to a well or bore cannot arise through general percolation through the pores of the walls or internal surfaces of the well or bore. According to Mr. Isaac Roberts's experiments, quoted in your 1st Report of 1875, a pressure of 10 lbs. to the square inch, which I suspect exceeds any hydraulic pressure acting on the pores of the rocks in any of the wells of which I have returns, gives 4½ gallons of water per hour per square foot of sandstone 10 inches thick, or 108 gallons per foot per diem. If we take the total area of the surface of the three wells and bore-holes of Messrs. Gaskell, Deacon, and Co., at Widnes, which is the largest well-surface, compared with the yield of water, that I have recorded, it amounts to 4428 superficial feet, which, with 500,000 gallons per diem, gives 113 gallons per superficial foot per diem, assuming the water to ooze out at the same rate from top to bottom, which is manifestly absurd; if, on the contrary, we take the Green Lane one recorded in your Report of 1875, p. 123, we find it has an area of only 95 superficial feet of surface and a yield of 817,000 gallons per diem, or 8600 gallons per foot per diem.

It is thus evident to me that the rain-water is absorbed generally by the rock at the surface, and that it percolates very gradually to underground fissures, traverses planes of bedding and jointing, and so circulates and is drawn off at the well. It is, in fact, a large rock-filter, with veins and ramifications extending in various directions, which enable us to tap and draw off the supply; and it is this freer circulation than what would take place through homogeneous rock that enables us to draw in some cases those immense supplies, such as is obtained at Green Lane, of 3,243,549 gallons per diem as a maximum, the average quantity for 1876 being 2,903,712 gallons per diem.

Source of the Supply: Rainfall.—The enormous aggregate yield of wells in a given area of the New Red has set many speculating as to the *source* of the underground water, some being unwilling to admit rainfall as a sufficient source of supply for the wells; consequently ingenious theories have been devised to account for it. Mr. Joseph Boult, to whom I am indebted for much information, does not believe the supply is from surface-percolation; and Mr. Robert Bostock, an excellent practical geologist, of Birkenhead, believes that sea-water is decomposed by filtration through the rock, and that the water of the sea is the main source of the supply. Unfortunately, when tested, none of these theories will themselves "hold water;" and whatever difficulties there may be in "surface-percolation," there are, in my opinion, tenfold greater difficulties in any other theories. Again, many Cassandra-like water-prophets cry out that because the water-level is reduced in Liverpool, therefore we are drawing on capital, and are gradually exhausting Nature's storehouse, or rather "store-cistern." A little calculation would show this latter fear to be groundless.

According to information supplied me by Mr. G. J. Symons, which I append, the maximum rainfall taken by Mr. Briggs at Sandfield Park, near Liverpool, for 10 years ending 1874, was 34·90, and the minimum 22·64, the average for the 10 years being 30·14. Roughly, 25 inches of rain over a square mile of surface gives a supply of 1,000,000 gallons per diem; therefore if we assume that 10 inches are absorbed independently of evaporation (and I think this is not an unreasonable assumption in a flat absorbent district like Lancashire), it would take a contributing area of 7·5 square miles to supply 3 million gallons per diem. It must also not be lost sight of that rivers having their sources in other strata—the carboniferous system for instance, where the rainfall is much greater from the district being hilly*—meander through the low-lying Triassic country and supply their quota. Many of these rivers have loose sandy beds, favourable for percolation; and with fissures, however contracted, to convey the water to a distance, a constant circulation must necessarily be kept up. If we assume the absorption to be as much as 10 inches, a circle having a radius of just over $1\frac{1}{2}$ mile from the well would be sufficient to keep up the supply to 3 million gallons per diem. I am not by any means suggesting that nature acts in this uniform sort of way; on the contrary the water may travel by faults and fissures a long distance in one direction and a short one in another†; but of this I am assured, that a good well depends upon these underground ramifications, and that their existence or absence constitutes the main distinction between a well being a good yielder or a bad one, more than on the actual constitution of the rock itself, as, according to my experience, all the New Red Sandstone is sufficiently porous, looked at as a filter. As regards a greater yield being obtained by boring or not will be dependent upon the source of the deeper yield and the depths to which the well is pumped down. At Alsager no additional water was obtained by boring deeply into the rock.

If the tube was well supplied by the rock first penetrated, and the fissures (if any) intersected by the bore lower down had the same "head" or source, the supply would not be greater; but if the water were to be pumped down below its natural level instead of flowing out of an artesian tube, it is quite possible the deep bore might begin to yield.

As exhibiting the nature of the underground circulation I have made a calculation from materials supplied me by the borough engineer of Liverpool, Mr. Deacon.

The Dudlow-Lane well is about 2 miles in a direct line from the Green-Lane well, and while the engine stopped in November 1875, the water rose to 95 feet above the bottom of the well. This would give a difference of level at the time between the water in the Dudlow-Lane well and the Green-Lane well of about 80 feet. The velocity of discharge in the 6-inch bore-hole of Green-Lane well when delivering 817,000 gallons (see Report of Committee, 1875, p. 123) per diem would be 459 feet per minute; a 9-inch pipe, with the difference of level of 80 feet, would carry water from one well to the other at a rate sufficient to supply the bore with the quantity of water it is stated to have yielded. Or, to state it in another way, a 6-inch pipe 4000 feet long and 170 feet head would supply, roughly speaking, the same quantity of water at the same velocity as that which passes through the bore.

It is therefore evident that there must be fissures, having a large aggregate area, to enable nature's rocky filter to supply water at the rate of 459 feet per minute to the 6-inch bore-hole when we consider the smallness of the available head, for the friction through rocky fissures would be excessive as compared with smooth pipes.

Quality of the Water: Hardness.—So few analyses having been given in the papers returned to me, and wishing to further investigate some of the questions flowing out of the inquiry, I was under the necessity of applying to Dr. Campbell Brown, the public analyst of Liverpool, who has kindly

* For the distribution of rainfall in England on the various groups of strata, see my presidential address on "Geological Time," Proc. Liverpool Geol. Soc., session 1876–7.

† I am informed the Green-Lane Well has been proved to "draw" at a distance of $2\frac{1}{2}$ miles in a direct line. A reference to Mr. Robert Stephenson's report of 1850 shows, according to the evidence of Mr. Bold, that a well at Moseley Hill, distant 5000 yards, was affected by the pumping-operations at Green-Lane well.

supplied me with information respecting the Liverpool wells in the form which I thought desirable for my purpose.

I append his statement of the analyses of the water of Bootle, Green-Lane, Windsor, and Dudlow-Lane wells from 1868 to 1876, together with very valuable information kindly given me by Mr. Deacon, the borough engineer, as to the nature of the wells and the level of the water in the wells on the dates of the analyses. At my request he was also good enough to supplement it by a table showing the average daily yield of the several wells from 1868 to 1876.

To make the information more complete, Dr. Brown has also, for purpose of comparison, recalculated the analyses of several Liverpool wells given in Robert Stephenson's Report of 1850 into the terms of his own analyses; I also append these.

Having vainly endeavoured to discover some connexion between the rainfall and the yield of the wells by comparing Mr. Deacon's table with the rainfall table supplied by Mr. Symons, which I also append, it suggested itself to me that relative hardness might be a test of surface-percolation; but Dr. Brown states that "I do not find that there is any regular difference between the hardness in summer and winter. Differences can be traced to heavy rainfall and the rate of pumping." It is also clear, from a perusal of what Dr. Brown says of the Bootle well, that heavy rainfall does affect its hardness; but that the effect is only a local one is clear from the resumption of hardness which took place after 7 days' pumping. As local percolation means greater danger of organic contamination, it is open to question whether it should not be to a great extent prevented.

A perusal of Dr. Brown's statements seems to show that the hardness has increased from 15° in 1868 to 22°·28 in 1876 in the Bootle well; in the Green-Lane well from 13° in 1868 to 18° in 1876; in the Windsor well from 15° in 1868 to $21\frac{1}{2}$° in 1876; and in Dudlow-Lane well from $6\frac{1}{2}$° in 1868 to $7\frac{1}{2}$° in 1876. In some cases the deep-bore water is softer than the well-water, in others harder.

On comparing these analyses with those recalculated from Robert Stephenson's report by Dr. Brown and his remarks thereon, it is impossible not to be struck with the fact that the Corporation wells at Bootle and Windsor are now yielding water of almost identical quality with that supplied in 1850, although there have been many intermediate fluctuations. Taken together with the steady increase of hardness since 1868, it seems to show that the deepening and boring done since 1850 must have had the effect of softening the water, but that now it is, through greater pumping strain, returning to its original hardness; in fact, the old conditions are reintroduced on a larger scale.

It is consolatory as showing that the hardness is not due to the depth or extent of the contributing area, but to the actual drain on the rocks. This is a point that demands more consideration than I have yet been able to give it, pressure of professional work having driven me to the last day almost for preparing this Report. I quite agree with Dr. Brown also that there is very little, if any, percolation of sea-water into the Corporation wells, and consider his arguments are conclusive on that point; there is no doubt, however, that sea-water does enter wells in some cases. It is naturally what we would expect; but each case must be taken by its own evidences, and the fact remains that though the mean level of the water in the Bootle well was about 20 feet below low-water mark in 1876 and its distance from the sea is under a mile, with the dip of the rocks from the sea towards it, yet no sea-water enters the well. Whether this is due to the great north and south faults, by which it is cut off from the sea, is a subject for speculation; if so it is easy to understand how those wells belonging to private firms on the margin of the river are affected by sea-water, while the wells more inland are not.

On the Cheshire side the Wallasey well is on the margin of the great float, and is pumped down to below low water, yet it is not affected by the sea; but here, again, the well itself is tubbed, and there is a great covering of drift over the rock, which may be impervious. In some cases, on the other hand, the bare rock is exposed in the river without any drift covering. It appears to me that no general rule can be drawn on the subject, local circumstances alone determining what will take place.

In presenting you with this Report I must apologise for its shortcomings, as there are many points touched upon which require more mature consideration than I yet have had time to give them. As, however, local observers who win the facts are necessarily the best able to arrange them in a form to be understood and digested, I trust I may have contributed something towards a knowledge of the circulation of underground waters.

APPENDIX.

I. Various Returns.

Name of Member of Committee asking for information, A. H. Green.
Name of Individual or Company applied to:—

The Selby Waterworks Co. James Wetherill, Surveyor and Manager of Waterworks.

1*. There are 7 wells in the town of Selby, obtaining water from the New Red Sandstone. **2.** 20′ 6″ above mean water-level at Liverpool. **3.** Depth of well 12′ 0″×6′ 0″; cast-iron pipe to top of rock; diameter of bore in rock 6 inches; 330 ft. from surface. **4.** Water rises to within 4 ft. of natural surface; when pumping we have to take the water as the bore yields it; it flows to the above height in 2 hours. **5.** About 250,000 gallons, more if the bore was larger. **6.** Yes; about August, September, and October. **7.** No; below the streams, but not affected by them. **8.** About 8° of hardness, which you will find from the report of Mr. Homersham on the Wakefield Water Bill last session; the water is well adapted for domestic purposes. **9.** Alluvial soil 5 ft.; clay, 24′ 0″; sand charged with water one man can pump, 1′ 0″; clay, 24′ 0″; quicksand, 21′ 0″; strong spring of water and the bottom of pipes, Red Sandstone, 18′ 0″; marl resembling Fuller's earth, 0′ 1″; Red Sandstone, 10′ 3″; Grey Sandstone, 0′ 1″; Red Sandstone, 64′ 9″; ditto, harder, 118′ 6″; very hard rock, 10′ 6″; Red Sandstone, 6′ 9″; very hard rock, 4′ 9″; ditto, 22′ 0″: total 330 ft. 8 in. to bottom of bore-hole. **10.** Yes. **11.** They are kept out. **12.** None. **13.** None whatever. **14.** None. **15.** From inquiry none have been given up; plenty of good water can be obtained.

Name of Member of Committee asking for information, C. E. de Rance, per Mr. Aveline, F.G.S.
Name of Individual or Company applied to:—

Mr. John Vivian, C.E., 23 King Street, Whitehaven, for the Furness Diamond Boring Company.

1. About 500 yards from the village of Glaston-in-Furness. **2.** About 30 ft. **3.** Bore-hole 2108 ft. deep; 8″ diameter at top, 2½ at bottom. **4.** About 10 ft. the water will rise, always flowing out of the hole. **5.** A flow of about 104,760 galls. per day. **6.** No; only open during the past 12 to 18 months. **7.** Not perceptibly;

* For nature of questions, see first report of the Committee, Bristol.

about 4 ft. above their level. **8.** Nothing peculiar; good pure water. **9.** 23 ft. of drift or boulder-clay, Red Sandstone and shales, greenstone or Laver Dyke, Magnesian Limestone, grits and shales, mountain Limestone; there were four springs:—1st cut at 120 ft. from surface in Red Sandstone; 2nd cut at 244 ft. from surface in Red Sandstone; 3rd cut at 1061 ft. from surface in the Greenstone Dyke; 4th cut at 2080 ft. from surface in dark blue shale at junction of Limestone. **10.** No springs, but a little drainage. **11.** The drainage was tubed back. **12.** There is a dyke, but no known fault. **13.** No. **14.** No. **15.** Not known; I think not.

Name of Member of Committee asking for information, C. E. De Rance.

At Southport Palace Hotel, Birkdale Park, a boring was made without success for water, which reached a depth of 186 yards without finding the base of the Keuper Marls. At Scarisbrook Park, east of Southport, the Red Marls were penetrated and found to rest on chert, limestone, and grit, which may possibly belong to the Yoredale series.

At Poulton-le-Fylde a fruitless boring for coal, after passing through Upper Boulder-clay, Middle Sand, and Lower Boulder-clay, penetrated the Keuper Marls to a depth of 179 yards without reaching their base, pseudomorphic crystals of salt and pieces of gyysum occurring as at Southport.

At the North-Eastern Hotel, Fleetwood, a boring was made for water by the War Office without success, a bed of grit being reached at 179 yards.

Name of Member of Committee asking for information, C. E. De Rance.
Name of Individual or Company applied to:—

Mr. Boult, from Mr. Beloe, C.E.

1. Neston: (*a*) Waterworks; (*b*) Village well. **2.** (*a*) 176 feet; (*b*) 103 feet. **3.** (*a*) 119 feet×7×5½, 178 feet×5″; (*b*) 75 feet×25×9, 332 feet×3″. **4.** (*a*) 59 feet above O.D.L. normal level. **5.** (*a*) 191,000. **8.** The water is tasteless nd pure.

Mr. Boult, from Messrs. Macfie and Sons.

1. Sugar Works: (*a*) Bachelor Street; (*b*) Vernon Street, Liverpool. **2.** (*a*) 56 feet; (*b*) 56 feet. **3.** (*a*) 127 feet, 504×7 feet; (*b*) 126 feet×11 feet, 603×18 feet. **4.** (*a*) 4 feet below Ordnance datum line; (*b*) 4 feet below O.D.L. **5.** (*a*) 830,000; (*b*) 660,000.

	Grains per gallon.
8. Total hardness	22
Solid matter	744
Albumenoid ammonia	0·21
Ammonia	0·33
Chlorine	406·5
Water, salt, and acid.	

9. (*a*) Drift 38 feet, Upper Mottled Sandstone 466 feet.

Mr. Boult, from Mr. E. Tate.

1. Love Lane Sugar Refinery, Liverpool. **2.** 51 feet. **3.** 109 feet×9 feet, 369 feet×4″ and 8″. **4.** Normal height 19 feet below O.D.L. **5.** 840,000. **8.** Water has a strong taste of salt.

Mr. T. Boult, from Mr. Dresser, Edmond Street, Liverpool.

1. Edmond Street Rice Mills, Liverpool. **2.** 60 feet. **3.** 79 feet by 4½; bores 379 feet; 3 bore-holes, 12″, 6″, and 4″. **4.** 15 feet below Ordnance datum in normal condition. **5.** 230,000.

	Grains per gallon.
8. Total hardness	19
Solid matter	1157·8
Albumenoid ammonia	0·27
Ammonia	0·6
Chlorine	588·4

9. Drift 18 feet, Upper Mottled Sandstone 361 feet. **13.** The water is very bitter and saline.

II. Details of Liverpool Wells collected by Mr. Mellard Reade.

Bootle Well.

On 5th Dec. 1868 the hardness of Bootle-well water was					15°
On 8th Feb. 1870	„	„	„	„	15·3
On „ „	„	„	deep bore	„	16
On 26th June, 1872	„	„	well water	„	$16\frac{1}{2}$
On 24th Sept., 1872	„	„	„	„	$16\frac{1}{2}$
On 1st April, 1873	„	„	„	„	$17\frac{1}{2}$
On 28th May, 1875	„	„	„	„	22·7
On 4th June, 1875	„	east side of well		„	22·4
On „ „ „	„	west	„	„	27·25
On 20th May „	„	deep bore		„	22
On 1st Sept., 1876	„	„		„	22·28

In 1876 the hardness varied from 22° to $24\frac{1}{2}$°, and on 7th Dec., 1876, it was $25\frac{1}{2}$°.

I do not find that there is any regular difference between the hardness in summer and winter. Differences can be traced to heavy rainfall and the rate of pumping: *e. g.* the hardness of Bootle-well water was taken weekly for a year; it was generally about 23°, but after heavy rains it fell to 22° and 21°·8, and in very dry weather it rose to 24°. On 1st October, 1875, the hardness was 23°, and on 6th October, when the level of the water was 12 feet 6 inches above the bottom of the well, the pump was stopped for repairs. On the 8th October the water rose to 34 feet, and there was no unusual variation in the hardness; at that time heavy rains began to fall, and on 15th October, the level of the water being 48 feet, its hardness fell to 18°. The hardness due to magnesium salts was almost the same at this time as before the change, the difference being due to calcium salts. Pumping was then resumed on 15th October after the sample was taken, and in 7 days, viz. on 22nd October, the level was reduced to 17 feet and the hardness rose again to 23°.

On 31st January, 1877,	the water of well was..............	24°·56
„ „ „	the average water of the deep bore ..	23·44
„ „ „	the water near the bottom of bore....	20·56

Green-Lane Well.

On 2nd Dec., 1868, the hardness of Green Lane well was					13°
On 26th June, 1872	„	„	deep bore	„	$14\frac{1}{2}$
On 28th March, 1873	„	„	well	„	$13\frac{1}{2}$
On 25th May, 1875	„	„	deep bore	„	16
„ „	„	„	well	„	$14\frac{1}{2}$

In 1875 the percolating water from the upper strata at 40 feet above the bottom of the well was 10°, while the mixed water of the well taken at the same time was from 16° to $16\frac{1}{2}$°.

On 5th Sept., 1876, the water of the deep bore was	....	18°·28
„ „ „ „ well itself „	....	18

In 1876 the average was from 18° to $19\frac{1}{2}$°.
In 1877, Jan. „ „ „ 20°·6.

Windsor Well.

On 5th Dec., 1868, the hardness of Windsor Well				was	15°
On 26th June, 1872	,,	,,	,,	,,	18
On 30th Sept., 1872	,,	,,	,,	,,	17
On 20th Oct. 1873	,,	,,	,,	,,	16½
On 24th May, 1875,	,,	,,	,,	,,	19¾
,, ,, ,,	,,	,,	deep bore	,,	19
On 13th March, 1876	,,	,,	well	,,	21½
On 8th June and Sept. 8th	,,	,,	,,	,,	23½
On 7th Dec.	,,	,,	,,	,,	24½
On 1st Sept.	,,	,,	deep bore	,,	21·16

Dudlow-Lane Well.

On 2nd Dec. 1868, the hardness of Dudlow Lane well				was	6½°
On 24th Sept., 1872	,,	,,	,,	,,	6
On 30th Sept., 1872	,,	,,	,,	,,	7½
On 20th Oct., 1873	,,	,,	,,	,,	7½

In 1874, when the pumps were frequently stopped, the average was 5¾° ; the highest was 7°.

On 1st June, 1875, the deep-bore was 7°·86.
,, ,, ,, well itself was 8°.
On 4th Sept., 1876, the deep-bore was 8°·88.
,, ,, ,, well was 8°.
The average at present is 7½°.

The hardness was taken weekly in 1874, and there was no regular difference between the hardness in summer and winter.

The hardness of Flaybrick-Hill well in Birkenhead was 4¼° in 1870, and 5° in 1874.

J. Campbell Brown, D.Sc.

Liverpool Royal Infirmary, School of Medicine,
March 4, 1877.

Liverpool Corporation Waterworks.

Particulars of Wells in the New Red Sandstone belonging to the Liverpool Corporation.

Bootle Well.—The depth of this well from the surface of the ground is 104 feet. The bottom of the well is 49 feet below Ordnance datum. In connexion with the well there are 15 bore-holes, one of which (4 inches in diameter) is sunk to 571 feet below O.D., one to 273 feet 5 inches below O.D., and one to 268 feet 5 inches below O.D. The other bore-holes are shallow.

Green-Lane Well.—The depth of this well from the surface of the ground is 185 feet. The bottom of the well is 49 feet below O.D. There are two bore-holes: one, of 9″ diam. at the top and 6″ diam. at the bottom, is sunk to a depth of 248 feet 6 inches below O.D.; the other, of 18″ diameter, is sunk to a depth of 359 feet below O.D.

Windsor Well.—Depth from surface of ground 210 feet. Bottom of well below Ordnance datum 24 feet 2 inches. There is one bore-hole of 6 inches diam. at the top and 4 inches diam. at the bottom. The total depth of the bore-hole is 269 feet below O.D.

Dudlow-Lane Well.—Depth from surface of ground 247 feet 3 inches. Bottom of well below Ordnance datum 49 feet. Bore-hole 18″ diam. sunk to a depth of 245 feet below O.D.

The following is a tabulated statement of the levels of the water in the several wells in relation to the Ordnance datum on the dates referred to by Dr. J. C. Brown in his report on the hardness of the water:—

Bootle.			Green Lane.			Windsor.			Dudlow Lane.		
Year.	Date.	Level of Water below O.D.	Year.	Date.	Level of Water below O.D.	Year.	Date.	Level of Water below O.D.	Year.	Date.	Level of Water below O.D.
		ft. in.			ft. in.			ft. in.			ft. in.
1868.	December 5.	37 2½	1868.	December 2.	38 4	1868.	December 5.	19 1½	1868.	December 2.	33 7
1870.	February 8.	38 4	1872.	June 26.	36 1½	1872.	June 26.	17 1	1872.	September 24.	38 11
1872.	June 26.	38 0½	1873.	March 28.	35 0	1872.	Sept. 30.	16 6½	1872.	September 30.	7 0
1872.	September 24.	37 3½	1875.	May 25.	38 6	1873.	October 20.		1873.	April 1.	11 9
1873.	April 1.	37 4½	1875.	Mean level during the Year.	36 0	1875.	May 24.	17 9	1873.	October 20.	Above O.D. 3 0
1875.	May 20.	40 10	1876.	September 5.	35 9	1876.	March 13.	17 11	1874.	Mean level during the Year.	1 1
1875.	May 28.	38 0	1876.	Mean level during the Year.	32 4	1876.	June.	20 0	1875.	June 1.	Below O.D. 34 9
1875.	June 4.	40 4	1877.?	January.	31 1	1876.	September 1.	19 11	1876.	September 4.	40 6
1876.	September 1.	42 8	1877.	February.	17 11	1876.	September 8.	20 2½	Pumping stopped during a considerable part of Years 1872, 1873, and 1874.		
1876.	December 7.	42 3				1876.	December 7.	20 0			
1876.	Mean level during the Year.	34 7									

Average daily quantity of Water pumped from Wells, 1868 to 1876.

Year.	Green Lane.	Bootle.	Windsor.	Dudlow Lane.
1868 ...	2,726,426	1,405,304	969,622	277,626
1869 ...	2,661,314	1,490,745	844,912	328,568
1870 ...	2,770,167	1,475,526	933,515	1,062,405
1871 ...	2,828,032	1,399,049	864,000	1,247,403
1872 ...	2,833,639	1,433,747	869,761	184,184
1873 ...	2,779,059	1,469,293	827,655	810,590
1874 ...	2,517,680	1,291,189	899,379	1,011,260
1875 ...	2,533,050	1,399,791	821,182	1,103,307
1876 ...	2,903,712	1,293,772	830,694	1,169,494

Operations in connexion with the Wells during the above period.

Green Lane.—In 1868 a new well, 12 ft. × 9 ft., sunk 185 ft. In 1869 a bore-hole, 18″ diameter, sunk in new well to 310 ft. below bottom. Engine power not increased.

Dudlow Lane.—Finished sinking well 1868. In 1870 a bore-hole, 18″ diameter, sunk to 196 ft. below bottom of well. Pumping stopped during most of year 1872 and part of 1873.

The Green-Lane, Bootle, and Dudlow-Lane bore-holes are provided with plugs, which are occasionally raised or lowered to regulate the depth of water in the wells according to the speed at which the engines are worked.

G. F. Deacon,
Boro' and Water Engineer.

Municipal Office,
Liverpool, May 9, 1877.

Constituents of Water expressed in parts per 100,000, *recalculated from the Analyses quoted in R. Stephenson's Report of* 1850.

No. 2, Bootle, No. 1 Lodgment. January 30, 1850.

Chlorine	2·777
Sodium	1·894
Magnesia	4·714
Lime	7·627
Sulphuric acid	2·781
Silica	·686
Carbonic acid	9·649
Organic matter, trace of potash, water of crystallization, and loss	4·014
	34·142

Hardness .... 25°·3

The water has undergone a great many variations in composition since 1850, and has now returned to almost the same composition as it had then. After the deep bores were sunk, the hardness was not much more than half as great as it was in 1850, owing to the fact that there are extensive alkali-waste deposits, which yield a large quantity of lime-salts to the water of the upper strata. By continual pumping since the existing bores were sunk, the hardness has gradually risen until it is now slightly higher than it was in 1850. The deeper water is still less hard than the upper water. The following are reasons for believing that no appreciable quantity of sea-water reaches the well:—If sea-water entered the well one would expect more chloride of sodium and magnesium salts when the well is hard pumped and when there is a less strong flow of underground water from the interior towards the sea, that is in dry weather. But

1. The proportion of chloride of sodium is almost exactly the same now as in 1850.

2. The proportion of chloride of sodium does not vary beyond very narrow limits, and is very nearly the same in Bootle well as in wells further inland, such as Dudlow-Lane, Windsor, and Green-Lane wells.

3. In October 1875, when the hardness was reduced by the simultaneous stoppage of the pumping and fall of heavy rains, the proportion of magnesium salts was not altered, the change in the hardness having been due almost entirely to an alteration in the proportion of lime salts.

No. 6, Windsor well, 2 feet from the bottom lodgment. January 29, 1850.

Chlorine	2·964
Sodium	1·921
Magnesia	5·055
Lime	7·250
Sulphuric acid	·414
Silica	1·714
Carbonic acid	11·185
Organic matter, traces of potash, water of crystallization, and loss	2·829
	33·332

Hardness .... 25°·6

This water has undergone several changes, having deteriorated as the population around it increased; but since the sewering of the district and the paving of the streets were completed it has very much improved and the composition is now almost the same as it was in 1850. The hardness appears to be less now than it was then; but this may be due to a difference in the test-solution employed, as two experimenters seldom get precisely the same figures for hardness. The same standard soap-solution has been used for several years, and the hardness is found to be slowly increasing. It is less in the deep water than in the upper water.

No. 11, Green-Lane Well, 50 feet from bottom of well. January 30, 1850.

Chlorine	2·306
Sodium (in combination with chlorine)	1·495
Soda (as sodium sulphate)	1·391

Magnesia	0·000
Lime	4·209
Sulphuric acid	1·795
Silica	·914
Carbonic acid	3·302
Organic matter and loss	4·015
	19·427
Hardness 7°·5	

The proportion of mineral salts, and especially of the hardening salts, carbonate of lime and sulphate of magnesia, has increased very much since 1850, and is still increasing as the well is pumped to a lower level. The deep water is rather harder than the upper water.

No. 1, Bevington Bush, water out of the lodgment at bottom of well. January 31, 1850.

Chlorine	19·526
Sodium	12·660
Magnesia	6·911
Lime	11·386
Sulphuric acid	10·084
Silica	·571
Carbonic acid	11·004
	72·142
Hardness 40°·86.	

Note.—The nitrates seem to have been overlooked in this analysis.

The well has long ago been closed.

I analyzed this well for the Water Committee in 1868, when it contained—total solids 70, nitric acid 12, hardness 36°. The well must have contained nitrates in 1850, which have been overlooked; these salts, as well as the chlorides, undoubtedly come chiefly from urine and other sewage matter with which the ground around the well is saturated. Some of the chlorides might formerly have come from the sea, but there is no evidence whatever to show that they do.

No. 3, Copperas Hill, water from lodgment at bottom of well. January 21, 1850.

Chlorine	6·153
Sodium	3·990
Magnesia	4·965
Lime	8·887
Sulphuric acid	6·355
Silica	1·371
Carbonic acid	8·951
Organic matter, traces of potash, water of crystallization, and loss	5·843
	46·515

The chlorides and other salts in this well undoubtedly come from sewage matter in the ground in the neighbourhood. In 1868, when it was not pumped but contained condensation water from the engines, it yielded total solids 14 and nitrates ·142.

No. 5, Soho water, from lodgment at bottom of well. January 21, 1850.

Chlorine	3·308
Sodium	3·083
Magnesia	6·054
Lime	5·471
Sulphuric acid	4·571
Silica	1·600
Carbonic acid	8·460
Organic matter, water of crystallization, and loss	2·886
	35·233

Hardness .... 24°·86.

Note.—The nitrates seem to have been overlooked in this analysis.

In 1868, after the well was disused, the water yielded—total solids 65·1, nitrates 6·43, hardness 20°. It must have contained nitrates in 1850. The nitrates and chlorides undoubtedly come from sewage matter in the neighbouring soil. The carbonates of magnesia and lime could not have come from sea-water; there is no trace whatever of sea-water in the well.

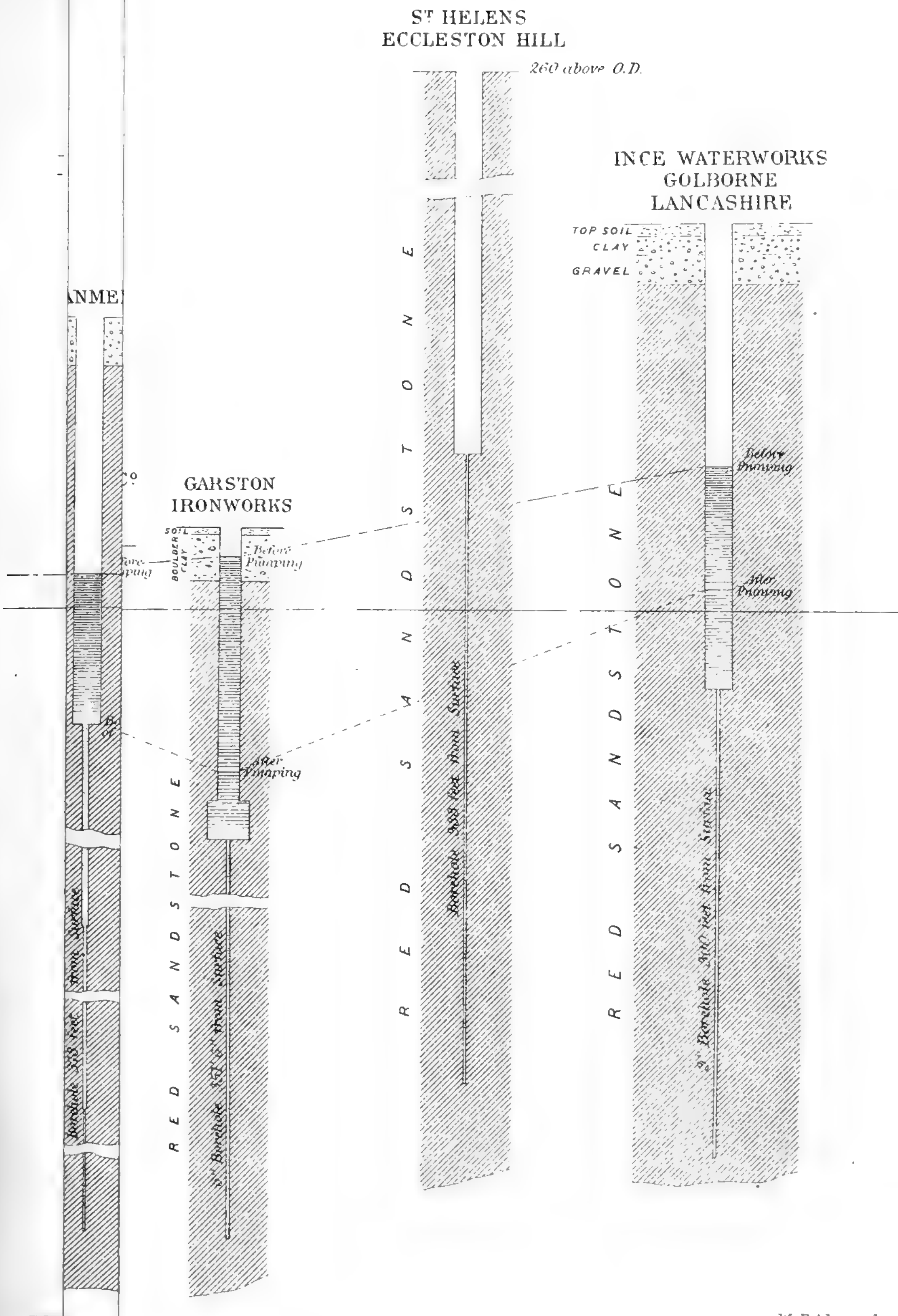
No. 12, well No. 6. Mr. Jack, boilermaker. January 31, 1850.

Chlorine	683·304
Sodium	298·396
Magnesia	75·443
Lime	107·666
Sulphuric acid	121·000
Silica	·457
Carbonic acid	18·040
Organic matter, traces of potash and iron, and loss	1·857
	1306·163

Hardness .... 503°·29

The salts in this water come either from the sea or from the marine beds in which the well is sunk; a small quantity of the lime salts also comes from other sources. Although I do not believe that any of the corporation wells contain any serious proportion of sea-water, there are private wells on both sides of the Mersey which do contain appreciable quantities of sea-water.

Plate II.



T. Me

W. Faithorn, fc


LIVERPOOL WELLS
CHESHIRE WELLS
WIDNES WELLS
WALLASEY

Rainfall at Liverpool, Sandfield Park, Lancashire.

Observer, Mr. Briggs.

Rain-Gauge, height above ground 1 ft. 2 in., above mean sea-level 147 ft.

	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.
January	1·94	3·20	1·94	1·90	2·84	2·00	·20	4·30	1·00	2·42
February	2·10	2·90	1·18	1·84	2·70	·56	·80	2·70	1·20	1·00
March	·80	1·70	1·08	2·80	1·54	·75	·20	2·80	1·50	1·40
April	·76	1·10	3·26	1·64	2·90	1·50	1·30	2·75	·40	·92
May	3·50	1·46	1·36	·95	4·90	·90	1·10	1·50	1·20	1·80
June	·70	3·90	·95	·42	1·30	1·40	2·80	6·20	1·70	·56
July	3·10	2·51	4·80	·46	1·00	·80	3·70	7·00	3·20	3·50
August	4·40	3·80	1·64	3·62	2·50	2·00	1·30	2·30	3·10	3·75
September	·63	5·50	2·14	2·14	6·54	2·30	4·70	6·30	2·70	2·60
October	3·00	2·10	4·10	4·42	2·94	6·00	5·90	6·42	3·84	3·90
November	2·50	4·50	1·92	2·28	3·70	3·30	1·75	2·94	2·00	5·00
December	1·00	2·23	3·05	6·56	2·16	2·70	2·00	4·36	·80	1·60
Totals	24·43	34·90	27·42	29·03	35·02	24·21	25·75	49·57	22·64	28·45

Fifth Report of the Committee, consisting of Professor Prestwich, Prof. Harkness, Prof. Hughes, Prof. W. Boyd Dawkins, *the* Rev. H. W. Crosskey, Messrs. L. C. Miall, G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, T. Plant, W. Pengelly, *and* Dr. Deane, *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. Drawn up by the* Rev. H. W. Crosskey, *Secretary.*

The Committee during the past year has continued to pursue the method described in previous Reports. The schedule printed in the British Association Report for 1873 (p. 189) has been circulated, and replies of considerable interest have been received. The problems involved are so vast (covering as they do the whole history of the glacial epoch), and the facts are as yet so imperfectly recorded, while the destruction of erratic blocks is going on throughout the country with such rapidity, that the work of the Committee increases in importance.

Denbighshire—Cheshire.

Mr. D. Mackintosh records a boulder in a brick-pit a short distance S. of Wrexham. Its length is 9 ft.; breadth 4½ ft.; depth unknown; and it is associated with Eskdale granite. Prof. Hull recognizes it as Lower Keuper (calcareous conglomerate) in all probability from some part of the escarpments of the Delamere or Peckforton hills, the former about 20 miles N.E., and the latter about 12 miles E. of Wrexham. The boulder is imbedded in Upper Boulder-clay, with its characteristic whitish-grey fractures. It furnishes an important instance of the intercrossing of the directions in which boulders have been transported, as it must have come at nearly right angles to the course of the Eskdale granite boulders, with which it is associated. The transporting agent was probably floating ice. Mr. Mackintosh has made further observations on the derivation of some boulders already known.

In the neighbourhood of the Dee and the Mersey the most conspicuous erratic in the Boulder-clay consists of a rock which has been called "greenstone," but to which the name of hornblendic felstone may be applied. At Dawpool, near Parkgate (where an immense number of boulders have been left on the sea-beach by the encroachments of the waves on the clay cliffs), the two largest of these hornblendic felstone erratics measure 7 × 5 × 4 ft. and 6 × 4 × 4 ft. Their most conspicuous companion erratic is Criffel granite, from the S. of Scotland. In the new dock excavation at Bootle, near Liverpool, boulders of the same character predominate, though the principal granite with which they are associated is Eskdale granite, from near Ravenglass, Cumberland.

Repeated observations failed to discover any streams of these boulders in the Lake-district, either by themselves, or in company with the great exodus of Eskdale granite, which is still represented by thousands of blocks scattered between the Eskdale fells and the sea-coast. Mr. J. Geikie and Mr. Horne pronounced specimens sent to them to be from the outskirts of the Criffel-granite area; and also regarded a few specimens of associated Silurian-grit boulders to be derived from the S. of Scotland. Lake-district Silurian-grit erratics, however, are associated with granite at Dawpool, as well as Ennerdale syenite (streams of which may be seen between the mouth of Ennerdale and the sea), Wastdale scree-rock, Dudden felspathic breccia, &c.

The extent to which these different assemblages of erratics from different points of the compass have become mixed up and interwoven is one of the most unexpected results at which an observer could have arrived.

Warwickshire—Staffordshire.

The Rev. J. Caswell, St. Mary's College, Oscott, has examined the district in the neighbourhood of the college, and supplies the following list of boulders met with (p. 83). The numbers (thus, 50–43) refer to square miles of country, as described in the Report of the Geological Section of the Birmingham Natural-History Society (British Association Report, 1873, p. 191).

Staffordshire.

Mr. F. C. Woodforde reports a number of boulders in the neighbourhood of Stoke-on-Trent and Newcastle. Most of the small ones, which were exceedingly abundant, have been moved by man, and are used on some roads as marks along the sides of ditches. Great quantities have been used to

Index No. to square mile.	Principal place marked on Ordnance Maps occurring in square.	Rock.	Size in inches.	Position.
50–43	Osborn's Barn.	Felstone.	36×27× ?	Bank under tree.
"	"	"	28×12×12	Heaps of stones on road to Barr Beacon.
49–44	Old Hall.	"	23×12×18	Road under Great Barr Park wall.
"	"	"	"	" "
51–44	Thornhill.	"	12×10× ?	Road-side.
"	"	"	34×15× ?	"
"	"	"	12×12×12	"
"	"	"	"	"
"	"	"	"	"
49–45	Barr Hall.	Brown Felstone.	18×18	Imbedded in bank.
"	"	Felstone.	56×24×18	Lying in stream.
"	"	"	12×12×12	Imbedded in road.
50–45	Queenslet.	Granite.	12× 6× ?	In a wall.
51–45	King's Vale.	Felstone.	12×12×12	Imbedded in road.
"	"	"	"	" "
50–46	Paper-mill End.	"	24×24×24	Lying in ditch.
"	"	"	18×18×18	Road-side.
52–46	Old Chester Road.	"	12×10× ?	In garden-bank.
53–46	Old Bell & Cuckoo.	Granite.	12×12×12	Road-side.
51–47	Wilton Hall.	Felstone.	"	Brook running into Wilton Pool.
52–47	Stockland Green.	"	12×12×12	In road.
"	"	"	"	"
55–47	Castle Bromwich.	"	"	At Castle Bromwich.
50–47	Perry.	No boulders found in these squares.		
51–43	Streetly Hill.			
52–43	Pool Hollies.			
52–44	Holly Hurst.			
52–45	Powel's Pool.			
53–43	Doe Bank.			
53–44	Sutton Coalfields.			
53–45	Maney.			
54–44	New House.			
54–45	New Hall.			
54–46	Jones Rough.			
54–47	Tyburn.			

pave the streets of Newcastle. One of the most remarkable is on the grounds of the High School in that town, and is used as a parish boundary. Its size is 5×3 ft.; and it formerly stood about 2 ft. 6 in. above the surface, but part is now buried. It is rather rounded, but not striated, and consists of a compact felstone. It is about 400 feet above the sea, and indicates the boundary between Stoke and Newcastle. It is quite isolated, and rests on Boulder-clay, containing glacially striated subangular boulders of a different mineral character.

The dimensions of groups of boulders in the neighbourhood of Henley farm and Beech Dale are 3 ft. 8 in. × 2 ft., 4 ft. × 3 ft., with others smaller. Some are slightly subangular, some more rounded, and all much weathered. The direction, by compass, of the longest axis of one of the group is N.E.E.—S.W.W., of another S.S.—N.W., and of another N.—S. The height of the group is 450 ft. above the sea. Larger boulders have their bases covered by soil and grass, smaller ones are almost completely covered by soil. They rest on the Keuper, very near the outcrop of the Bunter sandstone. The group lies on the side of a hill facing nearly E. They are visible in one field, but the upper part of the slope is covered with dense underwood and timber, in which others may possibly be concealed. Some of these boulders are of compact felstone, and others of granite.

Shropshire.

Mr. C. J. Woodward, of Birmingham, reports that he has walked over a considerable portion of the district having St. George's, Shropshire, as a centre, and a three or four miles radius. In the whole district boulders occur, though at times one may walk for a mile or so and not meet with them. Their apparent absence, Mr. Woodward believes, is frequently from accidental circumstances; for, as mentioned by him in the Report of this Committee for 1873 (British Association Report, 1873, p. 192), many boulders are buried as soon as met with by farmers, many, too, get broken up for road purposes. The most likely place to meet with boulders is about the buildings of a farm or at the corners of streets in villages, for in these places the stones serve a useful purpose, and consequently are not destroyed. The size of the boulders in this district is from 2 to 3 feet in length, by about the same in width and thickness; but besides these, which are boulders proper, there are stones of various sizes down to pebbles, composed of the same kind of rocks, and indistinguishable from what are commonly called boulders, except by their size. The number of boulders per square mile in the district is probably from 0 to 200 or so. The boulders consist mainly of granite and felstone. In the neighbourhood of Lilleshall Hill are several boulders, which consist of compact felstone, containing iron pyrites and garnets. Boulders of similar rock, containing garnets, have been met with at Wightwick, near Wolverhampton, and in a lane near Wroxeter, Salop.

Hertfordshire.

Boulders are found at Royston and Ashwell, upon which Mr. H. G. Fordham, of Royston, reports. The characteristic materials are a millstone-grit and a fine compact sandstone, the latter being the most prevalent. In the village of Ashwell there are as many as forty boulders, the largest of which is $3 \times 2{\cdot}6 \times 1{\cdot}6$ ft. It is much worn and rounded by exposure to the wheels of carts. Another smaller cubical boulder measures about a foot in each direction, and is of fine yellowish sandstone. Other boulders of this material occur of larger size, up to about 2 ft. 6 in. in the longest diameter. There are patches of Boulder-clay and gravel on most of the neighbouring hills, and probably these boulders have been derived from them. These gravels are mostly composed of flints, but they also furnish fossils and fragments from the Oolite and Lias.

In Royston is a boulder remarkable for its size and history. It is of millstone-grit, and measures 4 ft. 8 in. × 3 ft. 6 in. × 2 ft. 2 in. The history of this boulder, so far as known, is given in the notes to 'Royston Winter Recreations in the Days of Queen Ann'—a translation from a Latin poem printed in 1710. It has been used as the footstone of a cross of considerable antiquity, and is now preserved in the garden of the Royston Institute.

Two boulders, one of millstone-grit, $3 \times 2 \times 1$ ft., with rounded angles, and another of sandstone, smaller, occur in the garden of a house in Melbourn Street.

In the district the boulders are used for paving, marking the sides of roads, and protecting the corners of buildings.

South Devon.

Mr. Pengelly reports as follows respecting boulders and scratched stones in South Devon:—

In 1875 Mr. P. F. S. Amery wrote me respecting boulders of "greenstone" on his father's estate of Druid, near the town, and within the parish, of Ashburton; and during a visit there, in July 1876, he kindly accompanied me to inspect them.

The boulders occur about ·5 mile north-west from Ashburton, in two adjacent fields, the easternmost being known as *Longbottom*, whilst that on the west of it is termed *Cole's Bottom.* In the southern corner of Longbottom there is a boulder measuring $24 \times 18 \times 11$ inches, having rudely quadrilateral faces, with the angles well rounded off. It contains no marks or scratches, and it is known that it does not now occupy the place in which it was found, which, however, was, no doubt, in the same field and not far off. It is now near the bottom of the field, and about 30 feet above the level of Ashburton, which is itself about 200 feet above mean tide.

A similar but smaller stone occurs on the opposite side of the same field. The soil on which both specimens lie, and in which they were found, is a clay, sometimes yellowish and sometimes bluish, in which stones of the same character as the boulders, but of much smaller dimensions, are numerous. The labourers term them "water-stones."

Near the top of Cole's Bottom there are the fragments of a boulder, which must have been considerably larger than either of those already mentioned, which it resembles in lithological character. It was encountered by the plough in 1875, and unfortunately broken in pieces and dislodged by the workmen who found it. The fragments, which are themselves of considerable size, are now lying by the hedge in the same field. The boulder appears to have had all its angles rounded off, like those already mentioned; but on what was probably its lower surface there are several grooves, sensibly straight, about 6 inches long, from 2 to 3 inches broad, and parallel to one another. These grooves are crossed and partially effaced by two others of greater breadth. This specimen is about 70 feet above the level of those in Longbottom, and rather further from Ashburton. It must be confessed that the grooves it bears do not impress one with the conviction that they are of glacial origin; and were it not that they occur on what was apparently the lower surface of the mass, they might rather, perhaps, be ascribed to the plough.

The only greenstone formations known to exist in the immediate neighbourhood are those forming Roborough Hill, on the eastern side of North Street, Ashburton, and Sparnham Hill, on its western side; but to have travelled from either of them, the largest boulder must have ascended an acclivity to the height of 200 feet above the valley separating the spot in which it was found from the hills just named; whilst the smaller specimens must have performed a similar journey, but failed to attain so great a height.

In July 1876, Mr. Paige-Browne, of Great Englebourne, Harberton, South Devon, was so good as to inform me of the existence of a large number of boulders in his neighbourhood, and to invite me to make him a visit for the purpose of a joint inspection of them. I availed myself of this invitation on the 28th of the following September, and on the next day we proceeded to the hamlet of East Leigh, also in Harberton parish. On our way thither Mr. Paige-Browne directed my attention to the frequent occurrence of large stones, of a reddish colour, in the foundation courses of hedges and other rough walls, and all differing strikingly from the slate or "shillet" of the district. These were the outposts, so to speak, of the boulders we were to examine; and whilst they were considerably smaller than most of the specimens to be visited, they were so large as to render it probable that they had not been transported by man from any great distance, but had been found near at hand and utilized.

At East Leigh, about a mile north-westerly from Englebourne House, and nearly as far in a south-westerly direction from the village of Harberton, boulders are very numerous and of great size. They are generally angular and subangular, but with one face more or less rounded, and even polished, but without any scratches or striæ. They are all of a red colour and jaspideous aspect, and so siliceous as to scratch glass readily. One of them, probably the largest of the group—so near a cottage-door that we felt called on to apologize to the inmates for our seeming intrusiveness when engaged in examining it—measures $17 \times 10 \times 5$ feet, and, taking its specific gravity at 2·5, its weight can be little less than 60 tons. It lies on the common soft shillet of the district, and is certainly a travelled block. This is, no doubt, the history of all the numerous blocks near it.

A short distance towards the north-west there is in a field a large mass of the same kind of rock, rising above the soil, and probably *in situ*, having on it a loose, but in all likelihood untravelled, block of the same character. Both of them, and especially the upper one, are smoothed and rounded on certain parts of the surface. Indeed one portion of the upper stone has a polish a lapidary might envy; but it was no doubt produced by the rubbing of cattle. Neither of the stones is scratched or striated.

East of these blocks, in the adjoining field, is the striking and abrupt pile known as *Berry-Stone Rock*. It is distinctly stratified and jointed, and is, I have no doubt, the undisturbed remnant of a much larger mass—the parent of all the numerous boulders covering the district immediately on the south; and it seems more than probable that some of the isolated masses rising above the greensward, not far from the Rock, as well as in the adjacent field on the west, are untravelled, undisturbed prolongations of the same mass.

In the south face of the pile, which is almost vertical, Mr. Paige-Browne detected fragments of crinoidal stems, and we found subsequently obscure casts of Brachiopods, all of which we left untouched. Information has reached me that Mr. Champernowne, F.G.S., of Darlington Hall, has since found several corals in the same mass, but none of them sufficiently perfect for specific identification.

Mr. Paige-Browne informed me that a common mode of freeing cultivated ground from boulders was to dig deep adjacent pits, into which, by undermining, they were caused to fall, and were then buried. The process, however, being attended with risk, is not now much resorted to, as the workmen object to it.

Whilst descending to Leigh Bridge, on the east of Berry-Stone Rock, we entered a very small field, in which the boulders were very numerous, and many of them of great size. Here we found an intelligent villager named Heath, who stated that all the blocks of which he had had experience lay either in the common soil, or on rock utterly unlike themselves; that unsuspected boulders of precisely the same character were frequently encountered in the district by men engaged in cutting deep gutters and drains, and that they were sometimes of such dimensions as to render it much the wisest course to leave them undisturbed and to deviate from the proposed line of excavation.

From the observations I was able to make, and the information furnished to me, it appears that the boulders occupy a zone, about ·75 mile long and ·5 mile broad, south of an east-and-west line from Leigh Bridge on the east, through and a little beyond the Berry-Stone Rock on the west, and that none have been detected north of that line.

The Berry-Stone Rock occupies a place in the map of the Geological Survey of Great Britain, but it does not appear that Sir H. De la Beche, or any other writer, has directed attention to its remarkable character, or to the multitude of boulders lying in its vicinity and undoubtedly connected with it.

Having learnt that, on account of the proximity of the numerous and very large boulders, its limited extension, its supposed metamorphic character, its dissimilarity to all the other rocks of the district, and its resemblance to certain metamorphic rocks surrounding Dartmoor, it had been suggested that the Berry-Stone Rock was itself an erratic block, and derived probably from *Auswell Rock*, about 8·5 miles due north, I decided on making it a second visit, and requested that, as a preliminary step, an excavation should be made immediately adjacent to its southern or precipitous side. Having secured the ready consent of Mr. Helyar, of Coker Court, Somerset, who is the proprietor of the land, and of Messrs. E. and E. Whiteway, the tenants, this was done; and on the 25th May, 1877, I proceeded, with Mr. J. S. Amery, to the spot, where we found Mr. Paige-Browne and Mr. E. Whiteway. Two pits had been dug, one five feet deep and the other somewhat less, the work having been stopped in each case by the occurrence of a mass of rock, which was either a large boulder or a subterranean prolongation of the Berry Stone *in situ*. In short, there was no indication that the base of the pile had even been approached.

The entire mass is rudely rectangular in form, measuring 145 feet long in an east and west direction, 56 feet high from the top of the southern face to the bottom of the deepest pit at its base, 11 feet high on the northern side (the difference in height being due, not to the form of the pile, but to inequalities in the level of the ground), and 32 feet broad at the top. The beds dip at about 26° towards the north, and are of considerable thickness, one of them measuring 7·5 feet; and the numerous well-defined joints are sensibly vertical, in no instance "open," and have a north-and-south direction.

It will be seen from the foregoing data that the portion of the pile which has been actually examined contains upwards of 250,000 cubic feet, and, at a specific gravity of 2·5, weighs upwards of 18,000 tons—facts sufficient of themselves to show that the Berry-Stone Rock is certainly not a travelled mass, but is distinctly *in situ*. According to Professor Heer (see his 'Primæval World of Switzerland,' edited by James Heywood, M.A., F.R.S., 1876, vol. ii. p. 181), the largest block in Switzerland—the "Monster Block" on the hill of Montet near Devent—contains no more than 161,000 cubic feet, that is, less than two thirds of the volume of the Devonshire pile; and we learn from the First Report by the Committee on Scotch Boulders (1872, p. 24), that the largest block they have detected—that at Kemnay, in Aberdeenshire—measures $38 \times 30 \times 10{\cdot}5$ feet, $=11{,}970$ cubic feet at most; *i. e.*, less than one twentieth of the bulk of the Berry Stone.

If these are the measures of the greatest efforts of Switzerland and Scotland respectively—countries possessed of mountains entitled to look with scorn on our Dartmoor, and which we know were the scenes of glacial labours on a most magnificent scale, whilst we have done no more than, if we have done so much as, to show that Devonshire was glaciated at all—we can scarcely hesitate to dismiss the hypothesis of the Berry-Stone Rock being a travelled block.

Again, to have travelled from Auswell Rock, or any spot in that neighbourhood, the blocks must have bid defiance to at least many of the hills and valleys of the interjacent country. True, their route for a part of the way might have been the Dart valley; but they must have left this as high up as at Staverton, and been regardless of the contour of the country throughout the residue of their journey; and since they abound at the level of the River Harber, at Leigh Bridge, that contour must have closely resembled that which obtains at present. Of those at a distance from it, there are none at so high a level as the base of the Berry Stone itself.

Further, had the Berry-Stone Rock, or any of the undoubted boulders south of it, travelled from Auswell Rock, we might surely have expected that, here and there, and at by no means wide intervals, blocks of the same character would have presented themselves in the intervening country; but it is admitted, even by those who have diligently sought them, that, so far from any thing of the kind being met with, the boulders of East Leigh, as already stated, are confined to a narrow zone, having the Berry-Stone Rock on its northern margin, and without a single block to the north of that pile.

Finally, it is difficult to believe that such a mass could have fallen on a glacier without being divided along some of its numerous joints; in other words, that a pile traversed by so many divisional planes could, after such a fall, have remained so large.

The foregoing reasons, as well as the general aspect of the rock, forbid the acceptance of the notion that it is a travelled block, and compel me to hold that it occupies the place it always did, and that it is the parent of the numerous blocks scattered over the district immediately on the south.

With regard to the characters which distinguish it so strikingly from the surrounding formations, if it has undergone metamorphosis at all, the fossils it yields show that it has not been to an extent sufficient to obliterate them. Unfortunately they are too ill-preserved for specific identification, so that they fail to tell us whether they belong, like the Auswell Rock, to the Carboniferous period, or, like the adjacent "shillet" and slate, to the Devonian era. If, however, the Rock has been metamorphosed, it is not inconceivable that subterranean granitoid rocks may exist in various directions very far from Dartmoor, and, without reaching the surface anywhere, may in certain places rise very near it in sharp conical masses, and that such metamorphosis as the Berry Stone has undergone may be due to such a subterranean boss. Such an explanation of the highly metamorphosed condition of the rocks extending from the Start Point to the Boll Tail, in the southern angle of Devonshire—the cause of which is no more exposed to view than in the case now under notice—has been suggested by Dr. Harvey Holl, F.G.S., and the late Mr. Beete Jukes, F.R.S. &c. (see Quart. Journ. Geol. Soc. Lond. vol. xxiv. pp. 439, 440, 1868, and 'Notes on Parts of South Devon and Cornwall,' 1868, p. 15), and a glance at the known distribution of the granitoid rocks in Cornwall, Devonshire, and Lundy Island will show that it has at least an air of probability.

The extension of the Berry-Stone pile, though now confessedly very limited, was of necessity considerably greater before the crowd of huge boulders was severed from the mass; and, as already stated, there can be little doubt that at least some of the so-called boulders rising through the greensward in a line with the Berry-Stone, and on the west of it, are indications of its subsoil prolongation in that direction.

A degree of resemblance to the Auswell Rock may be the result of similarity of composition and of exposure to corresponding treatment. It may be sufficient, perhaps, to justify the question, "Has the southern been derived from the northern mass?" but not sufficient to justify an affirmative reply.

I cannot conclude this note without expressing my gratitude to Mr. Paige-Browne for having directed my attention to phenomena so unexpected and so striking as the Leigh boulders, and which are certainly amongst the most pronounced indications of ice-transportation known to me in Devonshire.

Leicestershire.

Mr. J. Plant, of Leicester, reports as follows:—

Isolated Boulders.

Loseby, Leicestershire, about 9 miles from Leicester. Gravel-pit, in map under letter *o* in Loseby. $4\frac{1}{2}$ feet long, 3 feet wide, $3\frac{1}{2}$ feet deep. Sharp angles and edges on one side, the other side rounded off. Long shape; never moved by man; S.E. by S. No groovings can be seen. Granite. About 650 feet above the sea at mean tide Liverpool.

The erratic is in a gravel-pit of "drift," flint, rounded pebbles of liver-quartz, &c.; this gravel-bed forms part of a long "ridge" of drift-gravel; the pit opened is 20 feet deep, and rests upon gravel, which again lies upon the upper clays of "Lower Lias."

This "erratic" is 10 miles distant from its nearest possible source, and is the largest of this kind that I have found at that distance. It is reported to me that when working (some years ago) this gravel-pit, a large block of pure coal (as large as this "erratic") was found, but it was speedily utilized for domestic purposes.

I was informed of another block of coal (large size) found in a gravel-pit at Beeby, 4 miles west of Loseby. These blocks of coal must have travelled in ice, as they would certainly have been broken up by any other means of transport, such as water. Both blocks were buried many feet in the gravel.

I have never met with any "erratics" of any kind on the "marlstone," and, in fact, there is very little "drift" upon any of it, the red rock being nearly at the surface; and hence the name of these marlstone-districts, "the red lands." The mean height of the marlstone is 680 feet, all lying south, south-east, and east of Leicester, and the mean height of Charnwood Forest (the presumed source of these erratic blocks of granite, syenite, greenstone) is about 700 feet; there are a few peaks 840 feet, and one, Bardon Hill, 902 feet.

Groups of Boulders.

Group No. 1.—At Evington, about 1 mile east of the town of Leicester. The size of the boulders is from 3 feet $\times 2\frac{1}{4} \times 1\frac{1}{2}$ down to cubic blocks about 1 foot on each side. The greater part have sharp angles and edges, and when free of clay and sand the rock-surface is very fresh, not at all weathered; the grits and sandstone are rounded and worn.

Many of the limestone blocks are covered with grooves and scratches. Rocks at *south end* of Charnwood Forest would supply the granite, syenite, and greenstone, and *north end* of the same district would furnish the grits, sandstone, and limestone. Nearly half are granites, others millstone-grit, with limestone, chert, Triassic sandstone, and coal-measure sandstones. About 280 feet above sea-level.

The group extends over an area of about $1\frac{1}{2}$ mile by $\frac{1}{2}$ a mile wide. At depths of from 1 foot up to 20 feet in "drift," these boulders are found in heaps; the "drift" has been penetrated (for a deep sewer) 30 feet, and bottom not reached.

Group No. 2.—At Thurnby, 5 miles south-east of Leicester. Size of boulders from 2 feet $\times 1\frac{1}{2} \times 1\frac{1}{2}$ down to cubic blocks about 9 inches on each face. All edges sharp and angular. Rocks of the same nature occur at the south end of Charnwood Forest. All seen are granites, syenites, greenstones. Height above the sea is about 500 feet mean tide Liverpool.

The area occupied is a mile square, but they are scattered in groups and patches. The boulders occur at depths of 1 to 2 feet in "drift." Great numbers of them have been collected and utilized for roads, others are now seen for many miles along the turnpike, supporting the footpath at intervals about 12 feet apart: this is a very common way of utilizing these boulders in modern times; formerly they were all used up in foundations of houses, churches, abbeys, walls, barns, &c.

Fourth Report of a Committee, consisting of Prof. A. S. Herschel, *M.A., F.R.A.S., and* G. A. Lebour, *F.G.S., on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*

Having been led during the past year, by a renewal of their appointment (with the provision of a grant amply sufficient to enable them to recommence it), to pursue, and if possible to complete the experimental investigation in which they have now for the fourth year been engaged, of the Thermal Conductivities of certain Rocks, the Committee have attempted to complete this research as far as the different kinds of rocks within their reach appeared to offer geologically the most practical inducements to fix their places exactly in a thermal-resistance scale, and to verify as certainly as possible the results of the observations which they have obtained in former years.

The same form and size of rock-plates, the same steam-heater and cooler, and exactly the same form of thermopile as that described in the account of the experiments presented in last year's Report were resorted to in order to extend, and in part also to repeat, some of the former experiments in this year's series of similar determinations. The apparatus was, however, modified in some essential points, in order, by changing entirely the circumstances of the experiments, to leave no doubt of the reality of the observed thermal conductivities, and of the extent to which their values can be trusted as representing correctly the true conductivities of the rock-specimens examined. For this purpose a new thermopile was constructed, having as one of its elements iridio-platinum instead of iron wire (German silver being, as before, the other element), which, with the fine gauge (0·4 mm., rolled to 0·2 mm.) of the wires used, was not so destructible as iron, while it yielded with German silver a thermoelectric current whose electromotive force was scarcely less considerable than that obtained with a combination of iron and German silver. The series of twenty-four junctions of dissimilar wires contained in the continuous circuit which enclosed the rock, while opposite to each other (above and below the rock-plate) in twelve pairs, were so distributed equally over its area as to indicate by their total action an average difference of temperature between its faces for all the different points of the area of the plate *. The wires, where not used to touch the plate, were secured to a band of thin leather 4 or 5 inches wide, two similar bands of thin silk above and below the rock-plate forming the rest of their support, so that the rock-plate could be placed between the two silk bands in a flexible loop of a twelve-fold coil of wires, the right half of which consisted of German silver and the left of iridio-platinum half-turns of the coil. The latter were cut through, and being joined to twenty-four ends of German-silver wire in a water-bath, which proceeded from as many teeth of a commutator, it was easy (as described by a sketch of the arrangement in last year's Report) to note the actual mean temperature of either the upper or the lower set of junctions touching the rock-plate, by varying the temperature of the water in the bath until no current passing through the galvanometer indicated that the water in the bath had reached the same temperature as that of the set of junctions above or below the rock-plate with which the junctions in the water-bath had been connected up.

Several independent proofs having already been obtained that water, without convection, possesses a thermal conductivity which is not only high among liquids, but is actually not inferior to that of some solid rocks whose place is low in the conducting-scale, no difficulty was anticipated in making the wire junctions assume identically the existing temperatures of the rock-faces touching them, nor was the bibulous or porous stratum of thin silk upon which they rested, when soaked with water, expected to vitiate the observations by any inequality of temperature in a water-film of such exceeding thinness, touching the rock, in which the thermopile wires were placed. In order to press them close, smooth sheets of unvulcanized india rubber were placed outside of the wet silk; and the wires being thus effectually squeezed against the rock with a simple luting of pure water (which, under the pressure of 4 lb. per square inch on every part of the surface, could nowhere well attain half a millimetre in thickness), the equality of their temperature with that of the rock-face contiguous to them might be regarded as assured. In some of the most porous rocks, as chalk and firestone, the water laid on the silk was nearly absorbed by the stone, leaving the silk damp, but steaming; and as equally steady and satisfactory observations were yet obtained in these cases when air and water-vapour must to a great extent have replaced the water-film, it deserves a future trial if steam (and it may be even air) in such an extremely thin film as contained the wires in these experiments may not be as effective a medium of heat-conduction with which to surround the wires as water; but, beyond the evidence that air saturated with water-

* The thickness of the plate was also similarly gauged with steel calipers at several points, so as to obtain the average thickness, the exact value of which as thus obtained was used in all the experiments described in these Reports to calculate the conductivity of the plate.

vapour (at a tension of a few inches of mercury, and at a temperature of 110° F. to 130° F.) is as efficacious as water itself, no special experiment with the thin wire thermopile to solve the question as regards dry air alone was made in further trial of what would be, if found to be successful, a practically very valuable simplification.

The other variations introduced in this year's series of experiments were to increase the temperature differences and the heat-flow through the tested plates by removing all but the most necessary sheets of caoutchouc lining between them and the heater or cooler, and by raising a more rapid supply of steam in the heater with a stronger flame. The actual temperature of the plates was also raised in some experiments by shifting all the movable linings from underneath to above the plates so as to bring the latter further from the cooler and nearer to the source of heat. The success of these experiments was only partial, because, in the strong temperature differences which prevailed (when temperatures between 130° F. and 160° F. were noted in the water-bath), false currents arising from want of homogeneity in the heated wires presented themselves in the thermopile, which, in spite of the number of its coils, did not neutralize each other entirely; and it was found necessary to test it very carefully (as described in the last Report) by introducing a hot paper-covered thick plate of iron between the lappets of the thermopile in place of a rock-specimen, and observing the temperatures of its two faces at the water-bath. Errors of indication of the thermopile were thus discovered, and were noted at different temperatures of the iron plate, arising from the abrupt changes of temperature along the wires. The way in which the temperature of the water in the bath was changed, quickly or slowly, from hot to cold, or *vice versâ*, seemed especially to influence these considerably; and it was finally resolved to abandon the attempt to obtain new results, by these means, of the thermal conductivities of the rock-plates at higher temperatures and under very different circumstances of the heat-flow through them from those which had been employed before, although the known allowances for the small erratic deportment of the thermopile always gave under these entirely new conditions results which did not differ appreciably from those which were previously observed, and which have been recorded in the earlier tables of these Reports. Temperatures of the rock-faces between 100° F. and 120° F. were found by trials with the iron plate to be easy to observe correctly in the water-bath, with proper care in its management, with errors not exceeding two or three tenths of a degree, while the temperature differences requiring to be thus observed varied from between 3° and 4° with quartz to between 30° and 40° with shale and sand. About this range of temperature of the rock-faces was accordingly adopted, by properly thickening the lining between them and the heater, in the experiments which afforded the following table of results (p. 94). While it would be necessary, in order to deliver the individual wires of the thermopile from strong effects of temperature-differences, and to obtain scientifically accurate results, to discard steam-heating and the use of temperatures much above those of the outer air altogether, resorting for, example, rather to cold water from a main to produce the temperature difference necessary to transmit heat through the rocks, or using water otherwise cooled artificially in the cooler, and exposing the under surface of the rock with a lining and a metal plate to the ordinary temperature of a room, yet with the small uncertainties which, without doubt, remain in the indications of the thermopile from the cause here pointed out, in this and in all the earlier tables of absolute conductivities and resistances which the Committee has appended to its Reports, it can furnish some additional support from these provisional experiments to the assurance which it has already gained in former years, that the values assigned to them will not be found to differ, except in some rare accidental cases, more than 10, or, in the least satisfactory cases, it may be 15 or 20 per cent. from the real thermal conductivities of the rock-plates examined. The heat-capacity of the cooler and the rate of loss of heat through it to the outer air were reobserved, and were used independently in the preparation of this Table, although they differed slightly (perhaps from setting and tightening of its jacket with time) from similar measures of them which were used last year.

The conductivities observed this year are, for the most part, a little higher than those found formerly, perhaps by reason of the new determinations used of the heat-capacity and heat-loss of the cooler; but some exceptions to this rule are also found; and it must be remembered that no allowance is made in these or in the earlier results for the small quantity of heat absorbed by the rock-plate itself during the progress of an experiment, nor, again, for the fact that the rate of absorption of heat and of its emission to the outer air by the jacketed vessel of the cooler is dependent on the rate of rise of water temperature inside it. The specific heats of the materials of the rocks themselves and of the apparatus are not sufficiently known to determine these corrections surely; but at the common specific heat (0·2) of a great number of rocks it appears that about one thirtieth of their values may have to be added to the observed conductivities for the first of these considerations. Whether an additive or subtractive correction is required for the second cause cannot be decided, because it is an uncertainty already occurring in the determination of the heat-capacity and rate of heat-loss of the cooler, the judgment necessary in assigning which must be regarded as providing sufficiently for this correction. Thus a correction for heat-capacity of the cooler vessel and its jacket of one tenth was added to the conductivities before observed directly, while one eighth was added in the experiments of the present year, allowing a rather longer time (of three or four minutes) for the heat to penetrate the vessel and its jacket. At the slow rate (about 1° F. in the same time) that the temperature of the water rises in the cooler during an experiment no higher correction than this could well be admitted; for after this length of time the loss of heat from the water depends sensibly upon its escape to the outer air, and no longer perceptibly upon the absorption or capacity for heat of the vessel and its jacket, when an experiment is made to find the amount of this heat-loss by absorption. The uncertainty of this correction must therefore range between one tenth and one eighth of the observed conductivities, which have been used as its extreme values in different cases. The apparatus may fairly be regarded in other respects as perfectly heat-tight in its connexions by the thick belts of caoutchouc which surround the tested plate of rock and the meeting ends of the boiler and cooler pressed against it by great pressure; and a thick wooden table (through which the padded boiler top just reaches the level of its upper surface) prevents any extraneous heat from the source below it from reaching the testing apparatus. The discrepancies which are observed can therefore only be ascribed directly to two disturbing causes. These are, the imperfect closeness of contact of the thermopile wire junctions with the tested rocks, and the want of absolute freedom of the wires from extraneous currents arising from other actions than those of the temperatures at their points of junction. It is impossible to prevent entirely the operation of these dis-

Absolute Thermal Conductivities of certain Rocks observed in 1877, compared with those observed in former years.

Rock-specimens tested. (Plates described here as "parallel to" or "across the cleavage" have *their flat faces* cut in those directions. The direction of the heat-flow tested is from one flat face to the other, through the thickness of the plate.)	Absolute values observed in 1877. Conductivity.	Absolute values observed in 1877. Resistance.	Observations of previous years. Absolute Conductivity.	Observations of previous years. Rock-specimen tested; and Remarks.
Fluor spar	about ·01000	100	·00926	1876 (the same plate). (1877. The thermopile in these three observations was perhaps overrating?)
White crystalline quartz (semitransparent, from a vein; Schiehallion).	·00920	109	....	
Quartzites (Schiehallion): Pink, compact from summit	·00912	110	....	
Quartzites (Schiehallion): Rough-grained, yellow (N. slope)	·00856	117		
Opaque white quartz (Killarney)	·00853	117	·00880	1875 (the same plate: Killarney).
			·00800	1876 (the same plate: Killarney).
			·00753	1876 Opaque white quartz (Morthoe, Devon).
Peterhead red granite	·00690	145	....	The thermopile was (?) overrating.
Fine-grained grey granite (Loch Rannoch)	·00600	167	....	Two observations. (Action of the thermopile apparently unsteady.)
	·00435	230	....	
Coarse-grained grey granite (ibid., Perthshire)	·00502	199		
Aberdeen grey granite	·00485	206	·00600	1874 (the same plate).
			·00514	1875 (the same plate).
Micaceous sandstone (Flagstone-quarries, N. side of Loch Rannoch, Perthshire). Plate *a*, perpendicular to cleavage	·00577	173	....	(Average of four observations, *a*, *α*, and *β*, all nearly across the cleavage, 0·00632).
Plate *α*, do. do.	·00588	170	....	
Plate *β*, cleavage inclined 65° to face of plate	·00710	141	....	Two observations with high average conductivity (·00681); perhaps somewhat overrated by error of the thermopile (?).
	·00653	153	....	
Plate *b*, cleavage 45° inclined to face of plate	·00532	188		
Cleavage parallel to face of plate: Finest grain. Plate (1)	·00482	207	....	Average of five observations on plates parallel to the cleavage, 0·00441.
Cleavage parallel to face of plate: Finest grain. Plate I.	·00453	221	....	
Cleavage parallel to face of plate: Medium fine grain. Plate II.	·00445	225	....	
Cleavage parallel to face of plate: Coarsest mica foliation. Plate (2)	·00424	236	....	
Cleavage parallel to face of plate: Coarsest mica foliation. Plate III.	·00400	250	....	

Mica schist: compact, with irregular contorted foliation (Loch Rannoch, Perthshire).	·00463	216	·00366	1875; Whinstone.
Blue Porphyritic Trap-rock (Loch Rannoch)	·00481	208		
White Sicilian marble (two observations)	·00607 ·00542	165 184	·00559 ·00462	1874 1875 (the same plate).
White Italian vein marble	·00511	196		
Irish fossil marble	·00506	198	·00559 ·00488	1874 1875 (the same plate).
Devonshire red marble	·00493	203	·00525 ·00469	1874 1875 (the same plate).
Blue limestone, white-veined (Loch Kinardochy, near Schiehallion). Plate A	·00594	168	....	Conductivity(?) too high by fault of the thermopile.
Blue limestone, white-veined (Loch Kinardochy, near Schiehallion). Plate B	·00606	165	....	
Dolomite, hard, compact (South Shields)	·00509	196		
Do., hard, very magnesiferous (Castle Eden, Durham)	·00533	188		
Building Limestone, magnesian (Mansfield, Notts)	·00605	165	....	Thermopile probably overrating.
Do. (Caen, Normandy)	·00471	212	·00395	1874 (the same plate).
Nummulitic Limestone (Great Pyramid)	·00365	274	·00433	1874 (the same plate).
White Chalk (pure white)	·00279	358	·00384	1874 (the same plate).
Grey Chalk (Godstone, Surrey)	·00200	500		
Firestone (Godstone, Surrey). Parallel to plane of the bedding	·00221	452	....	No certain difference of conductivity in the two directions.
Firestone (Godstone, Surrey). Perpendicular to ditto	·00202	495	....	
English Plate Glass (flint glass)	·00234	427	·00204	1876 (similar flint glass; another plate).
Altered Shale (Ratheugh Whin-crags, Northumberland). Across the planes of bedding	·00409	244	....	Two separate specimens, not from the same piece.
Altered Shale (Ratheugh Whin-crags, Northumberland). Parallel to ditto	·00314	318	....	
Grey shale (Newcastle)	·00267	375		
Black shale (Newcastle)	·00118	847		
Tough clay (dry and hard)	·00223	448		
The same (soft, wetted with one fourth of its weight of water)	·00310	323		
White siliceous ("silver") sand; dry	·00093	1075		
The same, saturated with one half of its weight of water	·00726	138	....	Conductivity very high; perhaps a little overrated by the thermopile, but certainly as high as ·006.

turbing causes; and the best endeavours of the Committee have therefore been used to obviate and to diminish the effects of their action as much as possible. This they have, they believe, accomplished in the main successfully; but instances yet frequently occur which show that without special and very close attention to them the most unequivocal experiment, apparently, may yet mislead; and it is not without this recognition and probable explanation of some of the obvious discrepancies in the accompanying Table that they venture to produce the values which it contains as probably exhibiting very approximately the true absolute thermal conductivities of the various rock-specimens which they have tested.

The quartzites (compact siliceous rocks) from Schiehallion agree in their conductivities with crystalline and opaque white quartz. Another class of rocks from the neighbourhood of Schiehallion experimented on is the class of micaceous sandstones, or flagstones, which cover a large area in the interior of Scotland. The mica, which is abundant in these sandstones, appears to have imparted to them a slaty cleavage, the plane of which in their actual positions is seldom horizontal, and is more often 30° or 40° inclined to the horizon. Like other sandstones they may be readily broken across, as well as in the direction of their cleavage-planes, and no difficulty occurred in obtaining some trial sections of them in these different directions. The result shows that the conductivity increases (on the average of the samples tried) continuously from that of heat transmission across to that of its transmission along the direction of the cleavage-planes in the proportion of 2 : 3, not quite so great as that observed in slate *, apparently from the less perfect ease and liability to cleavage which these stones present. A kind of firestone kindly supplied to the Committee by Mr. Baldwin Latham, C.E., from quarries at Godstone, in Surrey, where it is largely extracted on account of its unalterable qualities under the action of certain furnace-heats, which exhibits very regular bedding in the quarries, but of which the cleavage is yet either insensible or exceedingly imperfect, exhibits no signs of increase of conductivity for heat-transmission in the direction of the bedding-planes. But some specimens of altered shale compacted apparently to perfect uniformity and hardness by contiguity to the once molten intruder of whin rock under which they lay, so as to break with the same facility in all directions excepting where shrinkage-cracks in and across its plane of bedding (apparently like those in whin rocks) have parted it by the heat to which it has been exposed, still exhibits a tendency of heat to traverse it more freely in the direction of its original bedding-planes than in the transverse direction, in the proportion of about 3 : 4 †. The conductivity is, at the same time, raised considerably by the semifusion of the materials above that of ordinary shales, of which some new trials which were made this year are also included in the present Table.

The specimens of granite, of porphyritic trap rock, and of mica schist obtained from Loch Rannoch in Perthshire, present conductivities which resemble very nearly that of the grey Aberdeen granite with which they are here compared; and some new trials of varieties of limestone, chalk, and marble have been made, which may be regarded as in satisfactory accordance with what have been previously observed.

In order to establish and confirm the good conductivity of water which was revealed in some of the experiments made with it last year, dry clay

* About 3 : 5. See these Reports, vol. for 1876, p. 24.

† The experiment having been made on two specimens only, which were not cut from the same block, very great weight cannot be claimed at present for this preliminary trial.

and sand were saturated with it after their conductivities in a dry state had been tested, the soft materials being placed for this purpose in one of the thick caoutchouc belts, which was closed at the top and bottom with sheets of thin paper and gutta-percha tissue (used to keep water of the thermopile lappets from the *dry* sand, and roughened to make it touch the sand perfectly inside, like sandpaper, with a coat of sand attached to it with shell-lac). The water was added to the sand in its cell (by a pipette introduced below, until it overflowed from an opening in the top), so as to effect its thorough saturation; whilst the pressure (of 60 lbs. or 80 lbs.) upon it in the apparatus would prevent any water from remaining in the cell, except such as was contained in the interstices of the sand. The low conductivities of dry sand and of dry clay are (for their weights) remarkable; and the effect of adding water to them is to increase their low conductivities very considerably. But the effect is much more evident in sand than in wet clay, where the possibility of any convection-currents of the enclosed water assisting the heat-transfer is effectually excluded; in the interstices of the sand, on the contrary, however feeble they must be, it is yet possible that they may materially assist the process of transmission of the heat. It indeed appears probable that the fluid freedom of the water in the interspaces which it fills in the sand may in this case enable gravity to have some share in carrying through the open channels some ascending currents of warm water and some descending currents of cold water, in spite of the effects of friction. If this explanation can be conceded, it may be fairly granted from the great increase of conductivity imparted to loose sand by water in its passages, which will be noticed in the Table, not less than what is found in some rocks notable for their good conducting qualities, that the presence of the water used to saturate the lappets of the thermopile, easily percolating their silk tissues, must place the thermoscopic wires as thoroughly in contact with the rock as if they were cemented to it with a thin film of rock at least as good in its capacities of conduction as some of the best conductors of the ordinary varieties of rocks which have been examined. The Committee has recorded this observation of the good conducting-power of water contained in such a vehicle as sand or other freely permeable substance with considerable satisfaction, from the renewed confidence which it enables it to place in the method of experimenting which was adopted, and from the fresh assurance that it gives of the correctness of the results which have thereby been obtained.

In presenting the results arrived at by these means of experiment during the past year, the Committee feel very certainly persuaded that the lists of absolute thermal conductivities and resistances which accompany this Report, and which are appended in three previous Tables to the earlier Reports of the Committee during the last three years, are near approximations (although they differ by fluctuating and insidious faults of observation from a constant mean) to those expressions for the thermal conductivities of the most important and abundant kinds of rocks which it has been one of the Committee's principal objects in the present investigation, by the best and most conclusive possible processes of experiment, to ascertain.

Report on Observations of Luminous Meteors during the year 1876–77, *by a Committee, consisting of* James Glaisher, *F.R.S.*, R. P. Greg, *F.G.S., F.R.A.S.*, C. Brooke, *F.R.S.*, Prof. G. Forbes, *F.R.S.E., F.R.A.S.*, Walter Flight, *D.Sc., F.G.S., and* Prof. A. S. Herschel, *M.A., F.R.A.S.* *Drawn up by* Professor Herschel (*Secretary*).

The meteoric occurrences and the results of observation and research relating to luminous meteors during the past year have presented many points of interest and importance, and, as will be seen in the present Report, they have occasionally furnished materials for discussion, of which the results must be regarded as possessing considerable scientific value.

A large part of the Committee's time and attention since the presentation of the last Report has been bestowed on discussing and comparing together the summaries and reductions of meteor-registers supplied to them by a few active observers of shooting-stars at monthly and even at more frequent intervals from their own and from more extensively recorded meteor observations, from which a large store of additional information on special and ordinary showers of shooting-stars has been derived. The object at first intended to be pursued by the Committee, of providing observers with a full review of the existing lists of meteor-showers and of the radiant-points of comets and meteors, with commentaries and instructions how to observe and project the apparent paths of shooting-stars so as to note their horary numbers and to recognize their radiant-points, has, for this reason, not been carried out. But the large accessions to the known orbits or directions of individual meteors and of meteor-streams which the past year's observations have contributed exceeds what the Committee has been able to report in any previous year, and affords ground for the assumption that the brief delay in its compilation which has thus arisen will not materially affect the utility of a complete synopsis of meteor-showers, and of instructions to assist observers in tracing and identifying them, which, with more leisure in another year to bestow upon it, the Committee hopes to provide regular and occasional observers of shooting-stars with at no very distant period.

A few stone-falls have taken place, or their occurrences have been announced, during the past year; but none of these were remarkable for the size or weight of the discovered meteoric fragments. On the 16th of August, 1875, a small aërolite, weighing about 14 oz., fell in the district of La Calle and Constantine, in Algeria. On the 25th of June, 18th of July, and 19th of October, 1876, aërolites are said to have descended in America, the first in Kansas city, Missouri, about as large as and of the shape of a small oyster-shell, which struck and nearly penetrated a tin roof, where it rebounded and lay too hot to be touched immediately. Of these three aërolites little more than the brief announcements of their falls has yet been published. A small meteoric fragment weighing about three quarters of a pound fell from the prodigious fireball of December 21st, 1876, near Rochester, in the northern part of Indiana, U.S.; and aërolites in Missouri, Georgia, and Kentucky, U.S., are stated to have been discovered, and to be now in Dr. Lawrence Smith's possession, which fell from detonating meteors seen in the United States on the 3rd, 20th, and 23rd of January, 1877.

Particulars of these stone-falls and of recently discovered iron masses and meteorites, together with a review of recent progress in the special examination and investigation of certain meteoric stones and irons, are included in the last Appendix of this Report.

Of the detonating fireballs visible in 1876–77, two appear to have been of unusual magnificence, that which passed over the northern States of America on the 21st of December last having traversed a distance of about 1000 miles, from near the river Kansas to near the town of Erie and the western boundary of New York state, appearing in a great part of this prodigious flight to consist of a multitude of fireballs pursuing each other in a cluster of great length and breadth, produced apparently by a disruption of the meteor attended with very loud explosions about the middle of its course. Another surpassingly bright detonating fireball was seen in Cape Colony, South Africa, on the evening of the 16th of March, 1877, the light and the violence of whose explosion, like those of the last meteor, were quite unusual. A detonating fireball passed over the southern counties of Ireland on the 6th of April last, from Wicklow to Cork, off the coast of which latter county it burst with a very loud explosion. In the Appendix, where these large meteors are described a notice of some recent memoirs by Professor von Niessl, of Brünn, in Moravia, will also be found, showing that two detonating fireballs seen in Bohemia and Hungary on the 10th of April, 1874, and 9th of April, 1876, were directed from a common radiant-point in Cassiopeia, and must without doubt have been pursuing almost identical orbits round the sun, which Professor von Niessl considers there is evidence enough to show were of a hyperbolic form.

Descriptions of various large meteors seen in England are given in a fireball list, and also in the first Appendix of this Report with more detail, where sufficient data were collected to enable the meteors' real heights and the lengths, directions, and velocities of their real courses to be ascertained. For such determinations more or less complete materials were afforded by the meteors of July 25th, August 11th, 13th, 15th, September 24th, and November 8th, 1876, and January 7th, March 17th, and April 6th, 1877, permitting the heights, the radiant-points, and in some cases the velocities of these meteors to be assigned. Notwithstanding very conflicting statements which even professedly exact descriptions of these meteors' paths contain, an impartial discussion of all the observations allows of their combination and comparison together, so as to produce the most accordant representations of the real courses along which these meteors passed over England or the adjacent coasts. A table in the first Appendix contains the most reliable of these deductions; and sufficiently distinct descriptions of the eight fine meteors which it records were secured by observations to make the real paths here assigned to them free from any greater uncertainties than those which naturally attach to and interfere with exact vision and perfectly correct descriptions of such unexpected and startling celestial phenomena. The light emitted by the large fireball of September 24th, 1876, was unusually vivid and intense, and many remarkable instances of deception as to the real direction and nature of its source, as well as in the views of the fireball's appearance as modified by clouds and otherwise, occurred among the descriptions, some instances of which are cited in the general account given of this meteor in the first Appendix. The same Appendix also contains a list of ordinary shooting-stars doubly observed in England during the past year, a large proportion of which accordances were obtained from a comparison of the meteor-register kept by Mr. Denning at Bristol with the published list of meteors seen and recorded by Professor Main's assistants in the Radcliffe

Observatory, Oxford, the remainder being extracted from this or other published lists and from occasional records of meteor-tracks furnished to the Committee by various observers.

No very important occurrences of star-showers during the past year have been recorded. The Leonids and Andromedes of November 1876, the meteors of the 1st to 3rd of January, and the Lyrids in April 1877 were either very scarce or quite absent on the annual dates of maximum of those showers, as far as a watch for their appearance could be kept successfully; but clouds prevented observations on the Leonid meteor-nights of November 13th to 15th. Some meteors of this shower were seen on the mornings of November 19th and 20th by Mr. Denning, who also observed a conspicuous shower of shooting-stars very similar to the Leonids on the mornings of November 26th to 29th, with a radiant-point in Leo Minor. The existence of this meteor-stream in close proximity to that of the Leonids, with which its meteors may occasionally happen to be confused, deserves attention, and, if possible, exact verification by future observations. A considerable abundance of meteors, amounting apparently to an active star-shower, and including several bright ones, was noticed in America during the night of October 18th to 19th, 1876, the radiant-point being approximately between Taurus and Auriga. Scarcely any Orionids were seen on the preceding and following nights by Mr. Denning during the annual period of this well-defined October shower. A similar fitful shooting-star shower (unconnected with the Perseïds, since the radiant-point of that shower was far below the horizon at the time of apparition) took place in New Zealand on the night of August 13th; and Mr. Corder described a very accurately defined shower of small meteors from a radiant-point in Pegasus, in about two hours, on the night of September 21st, 1876, when at an earlier hour of the evening no such frequency of shooting-stars had been observed elsewhere. Collection together in such brief and sometimes abundant flights or swarms is a marked and significant peculiarity of shower-meteors, and it is very desirable to determine the position of the radiant-point of the meteor-swarm in such cases with as much accuracy as possible. In the stormy weather and full-moon light at the beginning of this year nothing could be seen of the annual January star-shower; and on one night at least (that of the 20th to 21st) of the April meteor-period, with perfectly clear sky, Mr. Denning observed only four Lyrids during five hours of uninterrupted watch. Although certainly a shower of very brief duration, this is a very remarkable scarcity of its meteors to be observed on either the first night following or on the very night itself of this meteor-shower's expected maximum display in the year 1877.

With the exception of the Perseïds of August 1876 and 1877, the Geminids on the nights of the 11th and 12th of December, 1876, furnished the most abundant annual or periodic star-shower of the year. In point of numbers (about twenty or thirty meteors per hour for one observer) the Geminid display occupied a middle place between the above two August showers, including, like those showers, several meteors as bright as Jupiter or Venus, only less attractive in appearance than the well-known Perseïds, from their somewhat smaller speed and from the less frequent occurrence of enduring light-streaks on their courses. The shower was observed in France as well as in England, and the position of its radiant-point in the north-eastern part of Gemini was well determined. Of its two nights of chief intensity the maximum of the shower appears to have been somewhat more strongly marked on the 11th than on the 12th of December. Of the two August showers, while that of 1876 was extremely meagre, it was not much surpassed by this year's display, these having both been (as will be gathered from descriptions of them and of other recently observed meteor-showers in the third Appendix of this Report) the scantiest returns of the Perseïds that have been observed for several years.

A numerous collection of newly recorded meteor-showers is contained in the same Appendix of this Report—partly obtained by Mr. Corder's and Mr. Denning's observations between the autumn of the last and the summer of the present year, and partly by a systematic projection and reduction by Mr. Denning of long lists of shooting-star observations recently published in this country and abroad. Inclusive of upwards of 1000 of his and Mr. Corder's original observations, about 4000 meteor-tracks from these various sources have been projected and were more or less completely reduced to their radiant-points by Mr. Denning, with results of which the particulars are collected, and have here been arranged together in comparative tables by Mr. Greg. About thirty of the meteor-showers thus observed and extracted appear to be new to former lists, while about one hundred other previously known meteor-shower positions are more or less exactly corroborated and confirmed. The newly recorded showers are also in many cases in better agreement with cometary shower-dates and positions than any formerly assigned individual showers had been, and several new examples of cometary coincidences are offered by them, of which, with fuller details of these new vigorously and successfully conducted investigations, the third Appendix of this Report contains a complete description.

The Committee has now to record with profound regret, at the close of its Report, the death, on the 30th of June, 1877, of Professor Heis. The first astronomer who systematically devoted his attention to observing shooting-stars in order to record their radiant-points, and who published in the year 1849 an original list of radiant-points of all the then known meteor-showers, he began in the year 1842, and continued to superintend without interruption until quite recently, the simultaneous observations of shooting-stars which he instituted in the Rhenish and neighbouring towns of Germany and Belgium amongst the best observers and most eminent astronomers of those countries, and which he also collected from observers and astronomers in more distant lands. With the thoughtful care of preserving to posterity the fruits of his long-continued records, he undertook, in the last years of his life, the compilation of all the results of his prolonged researches, from the first recorded observation in the year 1833 to the present time; and his work * "On the Results of Forty-three Years' Observations of Shooting-stars" was on the point of publication, and lacked but little final revision from his hands, before his sudden and unexpected death. To the watchful and unwearying labours of Professor Heis, which supported its cultivation during the period of indifference into which it had fallen after the disappearance of the great November showers of 1832–36, the present high position which the theory and observation of luminous meteors has reached among astronomers as an important addition to the popular branches of their science must be regarded as being greatly due; and the direction given by his earliest and latest works to the formation and promotion of the new science during its rapid stages of development will always be accounted by astronomers as one of the foremost of the great achievements by which he won distinguished and honourable titles to their grateful recollection.

* Now published as vol. ii., 1877, of the 'Publications of the Royal Observatory of Münster,' under the joint editorship of his daughters and of one of his pupils.

OBSERVATIONS

SEEN IN RECENT YEARS,

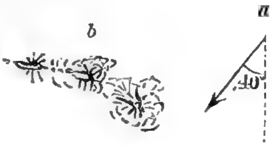
Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1847. Feb. 25	h m (Afternoon)	Twenty miles north of Iowa City, U. S.	Seen in full sunshine.	....	....	....
1861. Nov. 15	About 10 30 p.m. (local time).	From about 50 miles S. to about 50 miles N.W. of Iowa City, U. S. [Real course on map: Mr. Irish. Heights not stated.]	Apparent size somewhat greater than that of the full moon.	....	Not more than 7 seconds.	Seen in the east at an altitude of about 40°.
1872. Sept. 5	8 0 p.m. (local time).	Iowa city, U. S. Course on map from over Sioux City to Iowa City, Chicago, and Pittsburgh, U. S., and thence to the Atlantic Ocean, out of sight.	Very large	Red (blood-red).	15 seconds while in sight.	Appeared in the N.W. and passed across β Ursæ Minoris, the S. part of Cassiopeia, and the S. part of Aries, to the very horizon eastwards.
1874. Sept. 2	10 53 p.m.	Highfield House Observatory, Beeston (Notts).	From a mere point at first to $\frac{2}{3}$ of the apparent size of the moon.	Intense blue. Train of yellow sparks.	2 seconds; rapid.	$\alpha=$ $\delta=$ From 44° +38° to 101 +56·5, or from below γ Andromedæ across α Persei.
1875. Sep. 14	8 25 p.m.	Two miles north of Chelmsford, Essex.	= Venus	Greenish blue, with train of crimson sparks.	About 6 secs.	From near Polaris to 4° east of the "Pointers," and thence to within about 2° of the horizon, N.N.W., where it was perhaps lost in mists.

OF LARGE METEORS

ESPECIALLY IN THE YEAR 1876–77.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	....	The flash of light seen all over Iowa State. Several detonations, shaking the houses, at Iowa. A stone of 48 lb. fell and penetrated the earth three feet.	Communicated by C. W. Irish.
Long course; length of train 40°.	....	Several pieces detached from the nucleus, which gradually enlarged and disappeared with a most brilliant flash, leaving a long streak visible for several minutes. Reports as of a powder-mill explosion followed in 31 seconds. Seven stones fell.	C. W. Irish.
Fully 100° ...	Course on map from about 15° N. of W. to 15° S. of E. (horizontal).	Flight majestic and grand, with a spiral or wavy motion. Passed clean across the United States, from the Missouri to the Atlantic.	C. W. Irish and J. E. Blunt.
....	[In Pisces, near ζ, 15°, +7°, or 17°, +9°. Schmidt, Sept. 3–10, 17°, +9°.]	Increased rapidly. The moon was conveniently situated for comparison of its size. Followed by a comet-like train or continuous streak of separate sparks, very bright at first and visible afterwards as a conspicuous object for fully two minutes.	E. J. Lowe. The 'Times,' Sept. 4th, 1874.
....	....	The meteor not seen at first, but was said to have begun near Polaris. Not so bright a meteor quite as that of September 7th (1875), at Chelmsford. [See these Reports, Vol. for 1876, p. 139.]	H. Corder.

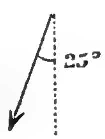
Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1875. Dec. 27	h m s 9 20 p.m. (local time).	Iowa City, U. S. [and Kingston, U. S.; 10 or 15 miles south of its point of disappearance].	At first small. Illuminated the whole heavens at disappearance with a quivering flash of light.	White. Fragments and train of sparks red.	Not more than 12 or 15 seconds. Moved very swiftly. Smoke-clouds on the meteor's track visible for 15 minutes.	Appeared in the west and was lost behind houses at an altitude of about 40° (middle point of path, over Missouri River, at junction of Kansas and Nebraska).
1876. Jan. 5	10 30 p.m. (local time).	Point of disappearance over the middle point of the boundary line between Iowa and Missouri.	Light as bright as noonday.	....	Not more than 5 seconds.	....
May 8	8 45 p.m.	Melrose (Scotland).	Brilliant meteor ...	....	....	....
June 10	10 44 p.m.	Writtle, near Chelmsford, Essex.	= ♃	Green	5 seconds......	In Leo; between γ and δ Leonis (?).
July 25	10 0 p.m.	Ibid.	= ♃	Green	4 seconds......	Shot from Ophiuchus through Boötes.
25	10 2 40 p.m.	Brighton	At first much less than, but at length about 2 × ♃, with a visible pear-shaped disk.	Pale sapphire-blue; contrasting remarkably in hue with the colour of Jupiter.	About 7 secs. Unusually slow motion.	Commencing about the middle of Taurus Poniatovii, it passed near ι Ophiuchi and β Serpentis, midway between ο and α Boötis, near Cor Caroli, and ended slightly north of ψ Ursæ Majoris.
25	About 10 0 p.m.	Richmond Park (Surrey).	About = ♃	Violet at first, then green (in front), and red (behind) at last.	About 2 secs. Slower than meteors usually move.	Moved straight from S. to N. between the directions S.S.W. and W.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	Descending thus (*a*)—  [(*b*) Final appearance at Kingston.]	Disappeared over Bilacothe, Grand River, Missouri. Length of path 200 miles, descending from W. by N. to E. by S. (along the junction line of Kansas and Nebraska), and entering Missouri. Slope of real path not far from horizontal. Seen in a circle of 200 to 400 miles, and sounds audible in a circle of 30 to 50 miles radius.	C. W. Irish.
....	Descended almost vertically (or from about altitude 70°, N.W.); real course.	Sounds of many heavy explosions followed its appearance, which was brief but dazzling in its flashes.	Communicated by C. W. Irish.
....	Going S.W.	....	Communicated by G. J. Symons.
15°	From direction of ι or θ Ursæ Majoris.	Exact position not recorded. Left a short streak.	H. Corder.
45° ?	From direction of Pegasus [?]...	Nucleus followed by a train of yellow sparks.	Id.
About 105° ...	[The apparent course described consists of two nearly equal straight parts with a strong deflection of about 45° between them, at ο, α Boötis !]	Increased continually until its disappearance. Accompanied at intervals, especially near its disappearance, by a slight train which was not persistent.	H. Pratt. The 'English Mechanic,' vol. xxiii. p. 564. (Aug. 11th, 1876.)
Long course...	S. to N.	Nucleus pear-shaped, followed at last by numerous globules which broke off it. Left no visible light-streak on its track. First appearance, behind trees, not seen.	F. A. R. Russell.

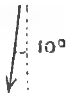
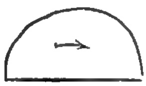
Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. July 25	h m A few minutes after 10 p.m.	Downham, Norfolk.	Very bright and large.	Sea-green; a "lovely" colour.	Moved slowly and majestically.	First seen while looking at Jupiter with a telescope; passed from the S. meridian, N. Decl. 20°, due westwards, right over Jupiter, disappearing 15° west of that planet.
Aug. 8	10 28 p.m.	West Hendon, Sunderland (Durham).	= ♃	Yellow	0·8 second; very quick.	Crossed γ Cygni (exactly) and disappeared at a point about ½ (ζ, γ) Aquilæ.
10	10 52 p.m.	Radcliffe Observatory, Oxford.	> ♃	White	1 second	Began over and shot to just past β Persei.
11	A little after 11 0 p.m.	Ringweston, Somerton.	A very bright meteor.	....	....	Approximate position by descriptions, from near λ Draconis to ζ and η Ursæ Majoris.
11	11 21 p.m.	Radcliffe Observatory, Oxford.	3 × ♃	Red, blue, and green.	1 second	From β Ursæ Minoris to α Serpentis.
15	9 28 p.m.	Burnham, near Bridgewater (Somerset).	Large meteor	Yellow to red and green.	....	α= δ= From 223° +29° to 141 +26* From due W. to N.W. [*This point of disappearance was a little below the N.W. horizon at the time recorded.]
15	About 9 35 p.m.	Douglas, Isle of Man.	> ♃ when first seen; then increasing its brilliancy as if approaching.	Yellowish, changing to greenish blue before disappearing.	Moved slower than meteors usually do.	Appeared about alt. 30°, S.S.E., and moved westward, disappearing by a steep curve to N.N.W.
22	About 8 40 p.m.	Scarborough (Yorkshire).	A most brilliant meteor.	....	....	Appeared from behind a cloud, about S.E., altitude 60°, and fell, apparently, into the sea, in the E.S.E.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	Apparent course very nearly horizontal. [The altitude at starting (57°) is irreconcilable with the rest of this description, unless for north we read south declination 20° at the commencement.]	[A. E. S., at Brompton, describes the meteor as brilliant blue, pear-shaped, followed by a train of red sparks; time $10^h\ 5^m$. Mr. F. Dennett, London, says that it there appeared "greenish purple," about 10 o'clock, shooting across the sky from E. to W.] Another large meteor was observed about 12^h P.M.	St. Vincent Beechey. 'English Mechanic,' vol. xxiii. p. 536, Aug. 4th, 1876.
)°	[Perseïd]	Bright streak; remaining visible across γ Cygni, where it was brightest, for 1 second.	T. W. Backhouse.
....	Fell vertically	Seemed to burst behind a cloud..	J. Lucas.
....	....	The nucleus died away, leaving a bright streak for some seconds between those stars and in a line with them.	Communicated by F. H. Dickinson.
....	....	Left a fine train visible at α Coronæ for about 20 seconds.	J. Lucas.
-45°	....	Ended in a train of sparks like a rocket. [The apparent course at Bristol, observed by Mr. Denning, was from 208°, +25° to 186°, +23°. For other observations of this and of the last meteor, see these Reports, vol. for 1876, pp. 132–136.]	Joseph Clark and others. Communicated by J. E. Clark.
....	Moved nearly horizontally at first, then gradually declining. [The point of disappearance is not compatible with the direction of the course, as described, near its commencement.]	Disappeared without bursting. Left no light-streak on its course. [For further observations of the meteor, at Douglas and in Ireland, see Appendix I., p. 133.]	E. W. Binney. Proceedings of the Manchester Lit. and Phil. Society, vol. xvi. p. 12; Oct. 17th, 1876.
....	....	Direction and altitude at first appearance from recollection. The general position from a memorandum at the time.	James P. Joule.

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Sept. 5	h m s 11 50 p.m.	Writtle, near Chelmsford (Essex).	= ♃	Green	3 seconds ..	α= δ= From 330° C° to 345 −15
18	6 43 45 p.m.	West Hendon, Sunderland (Durham).	About = ♃ at disappearance. As bright as a street gas-lamp 150 or 250 yards off.	Pure green ...	2·8 seconds ...	α= δ= From 212° +24° to 187 +15 Beginning of its course perhaps not seen.
19	10 14 p.m.	Bristol	= ♃	....	2·5 seconds; very slow motion.	α= δ= From 11° +1° to 8·5 −2·5
24	A few minutes after 6 30 p.m. (Paris time).	Between Marck and St. Pierre (Dunkirk to Calais Railway Stations).	Light like that of a lime-light close at hand.	Colour of the streak (and of the meteor's light) white.	....	The perpendicula streak of ligh like a chalk mark on the sk remained visibl in the N.N.W.
24	6 26 or 6 27 p.m.	Kempley, Dymock, between Ledbury and Ross (Herefordshire).	Very brilliant	....	....	Fell in the S.E. by E., at no grea distance fron the horizon.
24	6 30 p.m.	Hurley, near Great Marlow (Bucks).	....	....	....	Fell in an easterly direction from an altitude of about 25°.
24	6 30 p.m.	Two miles W. of Cowes, Isle of Wight.	....	Nucleus clear white; the tail rather more red.	Duration while in sight 2 or 3 seconds; continuing with a red flash behind the lower cloud for about 3 seconds.	Appeared from behind a cloud-belt at alt. 60°, and passed behind a lower one at alt 20°. The direction of its fall would clea Selsey Bill and Brighton nearly towards Beechey Head.

...ength of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
°	From the direction of ε Pegasi	Burst into small sparks	H. Corder.
....	....	Point of disappearance exact. Grew smaller in last third part of its course, as if receding in the distance.	T. W. Backhouse.
; very short path, almost stationary.	Radiant (near Aries) in Pisces	Left a bright phosphorescent streak visible for 3 minutes, and drifting thus—  while in sight.	W. F. Denning.
...ngth of the streak about 10° or 15°.	Direction and appearance of the streak a straight, thin, perpendicular white line.	Illuminated the carriage from behind the observer, who noted the appearance and position of the streak on turning round. This was white, sharp, and unbroken for several minutes, then slowly curling up and seeming to ascend as smoke does.	"M." The 'Times,' Sept. 26th, 1876.
....	Fell almost vertically, thus— 	It was mistaken by some persons who saw its flight for lightning.	Communicated by W. F. Denning.
...bout 12° ...	Fell quite vertically; or in the cloudy sky no slope of its path could be observed.	....	W. A. Cockburn. Communicated by W. F. Denning.
....	Fell very perpendicularly, thus— 	Nucleus well defined; barbed or spiked, with a tail following it 6° in length. Observer well-practised in quickly estimating altitudes at sea. A dark and cloudy evening.	John Thompson. Communicated by W. F. Denning.

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Sep. 24	h m s 6 30 p.m.	Hull	....	....	....	Like a rocket, immediately over Grimsby, at about the height that a rocket might attain.
24	6 31 15 p.m.	Orwell Park Observatory, near Ipswich (Suffolk).	The disk at maximum probably not more than 2′ in diameter; but its light was fully equal to that of full moon.	White, like a flash of lightning.	About 3 secs.	Point of disappearance at altitude 14° 6′, azimuth 54° 16′ E. from S.; by comparison of lowest point of the streak with Saturn at altitude 10° 56′, azimuth 53° 15′ E. from S.
Oct. 14	11 19 p.m.	Bristol	= ♃	....	Rather swift...	α= δ= From 43° +22° to 30 − 2
19	2 0 a.m.	Newburyport, Massachusetts, U.S. Numerous meteoric stones at Ledyard (Conn.) are supposed to have fallen from it.	Half the apparent size of and nearly as bright as the full moon.	White	About 2 secs.	Shot from the constellation Taurus, near the zenith, to the south-west.
22	About 11 30 p.m.	Manchester	Fully $\frac{1}{4}$ or $\frac{1}{3}$ the apparent size of full moon.	....	About 1 or 2 seconds.	Moved nearly horizontally from N.E. to E., about 50° above the horizon.
Nov. 1	8 35 p.m.	Bristol	= ♃	....	Slow motion...	α= δ= From 347° +18° to 348 − 9
5	Between 8 40 and 9 0 p.m. (Paristime.)	Choisi le Roy, France. (A detonation is said to have followed its appearance at Clerey, Aube. 'Nature,' vol. xv. p. 69.	Large fireball. Its flash was brighter than moonlight.	Bluish	....	From α Aurigæ to α Ursæ Majoris; (Course indicated by the light-streak.)

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	....	The explosion only, like that of an unusually brilliant rocket, seen through clouds.	T. M. Fallow. Communicated by W. F. Denning.
About 25° ...	Nearly vertical, thus— 	In first third part of its course rather brighter than a first-magnitude star. In the second it grew to many times the brightness of Venus, and collapsed suddenly to its first appearance. In the last third of its course it expanded again to the brightness of the full moon, when it disappeared suddenly without explosion and without sound, leaving a streak visible in this part of its course for 16 minutes. [See other descriptions of this meteor in Appendix I., pp. 135 and 138.]	J. J. Plummer.
27°	From the direction of ε Persei	A very fine meteor, leaving a bright streak for two seconds across ζ Ceti. Very accurately noted.	W. F. Denning.
....	....	The smallest objects were visible in its light. Left a streak 10° long and ¼° wide visible for more than 15 minutes; at first straight, and soon becoming Z-shaped.	The 'New York Observer,' Nov. 9th, 1876.
About 15° ...		Nucleus elongated. Left a light-streak on its course which remained visible 5^m or 10^m after the meteor had disappeared.	Communicated by R. P. Greg.
28°	Fell vertically, N. to S.	A bright meteor, even in full-moon light.	Communicated by W. F. Denning.
....	The momentary light-streak left on its whole course pointed out its track from S. to N. [? A Taurid.]	Globular nucleus; the reflected light from which drew the observer's attention to it, so as to note its explosion near α Ursæ, and the streak of light broader than the meteor, which vanished quite slowly.	S. Meunier. 'Comptes Rendus,' vol. lxxxiii. p. 862.

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Nov. 6	h m 5 45 p.m. (Paristime.)	Orsay, near Paris	Bright, but smaller than the moon's disk.	....	Moved slowly. 50 or 60 seconds [!].	About 20° or 25° above the E.N.E. horizon; appeared from behind clouds, and disappeared behind a house.
6	Between 8 0 and 9 0 p.m.	Clitheroe (Lancashire).	A large but not very bright meteor.	Red	....	Shot about 40° from near the zenith to a point in W.S.W., where it divided, one part disappearing due W., at altitude 10°, the other, which moved northwestwards, at a little higher altitude.
6	Between 8 0 and 9 0 p.m.	Pulborough (Kent).	A large meteor ...	... .	....	Fell from a little below the zenith in the northern sky, within a point or two due north.
7	7 19 p.m.	Writtle, near Chelmsford (Essex).	Lit up the clouds and sky.	....	About 3 seconds (?).	Disappeared about 6° under β Capricorni.
8	Two or three minutes after 5 0 p.m.	New Cross railway station (Kent); (and near Slough, Bucks).	At first=3rd mag.*; afterwards >1st mag.*	....	(About 4 or 6 seconds. Stoke Poges, Slough.)	First observed at about alt. 30° due north.
8	About 5 5 p.m.	Wimbledon (Surrey).	Unusually large meteor.	Bluish white...	Moved rather deliberately.	Passed at a low altitude from N.N.E. to nearly west (or 5° north of west, alt. 9°), where it disappeared at $\alpha=215°$, $\delta=+10°$, very near Arcturus.
8	About 5 6 p.m.	Hay, near Hereford, S. Wales.	Very bright meteor. Would have been splendid on a dark background.	Yellowish......	....	Traversed a cloudless place in the sky about 20° or 25° above the W. horizon.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
Short course only seen.	Moving horizontally southwards. [? A Taurid, near its radiant-point.]	Globular nucleus, leaving a slight streak on its course.	Described by A. Guillemin in 'Comptes Rendus,' vol. lxxxiii. p. 922.
....	The course before the meteor divided was sinuous. [Not a Taurid.]	Divided into two parts in mid-path, one falling to W., the other towards N.W. [? Another meteor starting from the path of the first. W. F. Denning.]	F. Nostro. 'Nature,' vol. xv. p. 59 (Nov. 16, 1876).
....	....	Burst twice, emitting bluish sparks the last time at its disappearance. (Seen also near Buntingford, Herts; in the east, moving towards the north.—R. P. Greg.)	Cecil H. C. Percival. 'Nature,' vol. xv. p 79. (Nov. 23rd, 1876.)
About 10° (?)..	Directed from Saturn (334°, −13°).	Probably burst, as there was a brilliant flash. The meteor's course imperfectly seen.	H. Corder.
About 20° ...	Travelled horizontally towards the south [?] or south-west. (So also described at Slough, moving over a long arc of the sky.)	Burst into fragments, of which five or six were counted while disappearing behind a dark cloud, and left a streak visible after the fragments disappeared. Seen in fading daylight. [See Appendix I., p. 141, for further observations of this meteor.]	S. March (and "J.A.G.") The 'Times,' Nov. 10, 1876.
....	....	The path curved downwards, near extinction, like that of a projectile, and the meteor separated into several distinct globules of light following in the same train.	F. C. Penrose. Ibid.
About 10° of its path visible.	Passed slanting downwards. [Position at Bristol by description, from 236°, +50° to 241°, +35° (?).—W. F. Denning.]	Nucleus with a great tail which threw off sparks on both sides. Twilight still very strong in the western sky. The night afterwards was clear; but few shooting-stars were visible.	Communicated by T. W. Webb, in the 'English Mechanic.'

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Nov. 8	h m About 5 6 p.m.	Manchester	Large; > Venus in its whole course, and brilliant at bursting.	....	3 or 4 seconds, not more.	From alt. about 38° due south, to alt. about 20° or 25° nearly S.W. (Twilight too bright for any stars to be visible in the sky.)
11	8 30 p.m.	Leeds	=1st mag.*........	....	Very quick ...	Crossed a point at $\frac{3}{7}$ (ϵ Delphini, Altair).
17	About 7 20 p.m.	Sutton, near Mitcham (Surrey).	Meteor of unusual brilliancy.	....	5 or 6 seconds	Shot from the great square of Pegasus to Aquila.
29	9 53 p.m.	Newcastle-on-Tyne.	At first=1st mag.*; then rather brighter than ♃.	White	Moved slowly at first, more quickly afterwards. 3·5 seconds.	$\alpha=$ $\delta=$ From 47°+20° to 7 +14 Began close to the lower edge of the moon.
Dec. 4	About 8 0 p.m.	Cardiff...........	Fully=Venus at its greatest brightness.	Bright green...	....	....
13	A little before 4 30 p.m.	Cricklewood (London).	Fireball; very large	Bright flame-colour; train of fiery appearance.	....	While walking northward the meteor crossed the observer's view from W. to E.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
30° or 40° in view, by a good estimation.	Almost horizontal, like the sketch,  towards due west.	Very beautiful effect when bursting; left a light streak for a perceptible time on the whole course which it traversed. The position measured by house-roofs and objects.	A. Brothers.
15° or 20° ...	Directed from δ Cygni. Evidently a Leonid from its appearance. [? A Leominorid.]	A beautiful meteor; left a bright green streak for 1 second on its course.	T. W. Backhouse.
Long course...	[A Taurid.]	First waned, and then came out much brighter, finally bursting in Aquila. Left a magnificent trail of fire behind it. Immediately afterwards another shot out nearer to, and passed completely through Aquila, followed by a third nearer to the horizon.	Arthur W. Mitchell. [Newspaper paragraph from J. E. Clark.]
About 35° ...	Radiant in Taurus; either 60°, +20°, or 80°, +22°; but very probably from the last of these two radiants (Taurids II., W. F. Denning), between β and ζ Tauri.	Small, and moved slowly (6° in the first second) in the first half of its course. Bright as Jupiter in the last half, dying out gradually at last; no sparks; nearly globular; no train or streak left on its course.	A. S. Herschel. The 'Astronomical Register,' vol. xv. p. 16. (Jan. 1877.)
....	Passed obliquely across the line between α and β Aurigæ, as in the sketch. 	A bright moon, foggy atmosphere, and cirrus-clouded sky dimmed the meteor, which was yet a beautiful one. It finally exploded, noiselessly, with a shower of coloured sparks.	F. G. Evans. Communicated by W. F. Denning.
....	....	In full twilight. (At Eastsheen. "E. Z.," proceeding from Kew to Mortlake by the river, saw the meteor in the N.E., of unusual brightness.)	"X." The 'Times,' Dec. 15, 1876.

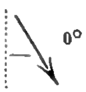
Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Dec. 13	h m 4 45 p.m.	St. James's Square, London.	About equal to, or rather brighter than ♃.	....	....	To an observer walking down the Square it passed from north to south until it disappeared behind the houses.
13	About 4 50 p.m.	Blackwater, near Yorktown (Hants).	A small fireball ...	Pale yellow, changing to bluish green; at last red, with tail of the same colour.	....	Fell from the heavens and approached but did not reach the earth before it disappeared.
13	7 28 p.m.	Bristol	= 2nd mag.* in brightness, but large and dull, with a sensible disk.	White	....	From the forepart of Ursa Major (near the N.E.) to a point near Saturn (near the south horizon).
21	8 40 p.m.	Illinois and surrounding States, U. S. America.	Meteor of the largest size; aërolitic.	Nucleus and following meteors white.	Fully a minute	From 75 miles over Kansas, to 25 miles over western Nw York.
1877. Jan. 7	About 10 30 p.m.	Putney Hill, London.	Meteor of great brightness.	....	Some 10 secs.	Its course began between α and β Geminorum, and passed across λ and ψ Ursæ Majoris, ending a little beyond the latter star.
7	10 31 p.m.	Birmingham ...	Increased from a mere point to the brightness of Venus, near α Leonis, with a brighter flash at disappearance.	Deep yellow, merging into ruby-red towards the tail.	5 or 6 secs.; very slow speed.	From a point near η Hydræ to a point below β Leonis at 182°, +16°. From near α Leonis a vaporous tail followed the meteor about 8° in length.
7	10 32 p.m.	Near London ...	....	....	Motion unusually slow.	From λ, μ Ursæ Majoris to a point 3° below α Canum Venaticorum; proceeding thence several degrees further.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	....	....	'Nature,' vol. xv. p. 278.
....	Direction from N. to S.	Twilight and thin clouds prevented any stars from yet appearing.	'Nature,' vol. xv. p. 170, Dec. 21, 1876.
122°, extremely long course.	Radiant in Leo Minor, then on the N.E. horizon. (Position, in degrees, from 135°, +66° to 334°, +10°.)	Grew alternately slow and faint, and again brighter and more rapid, until it was spent in a thin wreath of white sparks, lasting about 1·5 second.	W. F. Denning.
About 1000 miles.	Radiant in the south, or east part of Capricornus, a little south of the ecliptic.	Broke, in midcourse, into 20 or 100 lesser fireballs; detonating. A stonefall.	[See the Appendices on Large and Aërolitic Meteors in this Report, pp. 150 and 192.]
46°	[Radiant, from this and the next two observations, near γ Eridani, at 58°, −12°. See further notes regarding it, by Mr. Denning, in Appendix II., pp. 135, 142.]	Bright nucleus, with a tail of fire in its wake about 2° in length.	"J. L. McC." (W. F. Denning; 'Nature,' vol. xv. p. 346).
52°	Radiant-point in Fluvius Eridanus; 96, Tupman, or 161 of the B.A. Catalogue, 1874.	Motion unsteady with a slight undulation, as if forcing its way with difficulty. Matter apparently projected from the head formed a long train behind it. Part of the course at last hidden by houses. The meteor reappearing, burst with a flash at extinction.	W. H. Wood. 'Nature,' vol. xv. p. 295. (Feb. 1st, 1877.)
(39°)	Radiant of shooting-stars on this evening apparently near those stars in Ursa Major, but clouds made its determination doubtful.	The meteor halted for 2 seconds near α Canum Venaticorum, and a faint portion then left a train for several degrees further. Several meteors were seen on on the same evening which equalled Jupiter in brightness, for the most part with unusually slow motions.	'Nature,' vol. xv. p. 244. (Jan. 11th, 1877.)

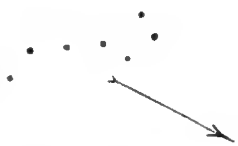
Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1877. Jan. 19	h m About 6 25 p.m. (6 0 p.m. Irish time).	Lisburn, Ireland. (Seen also by Mr. E. J. Bibbs at Wolverhampton.)	....	Variously tinted. (Pale blue at Wolverhampton.)	(Moved very slowly, lasting 7 or 8 seconds, at Wolverhampton.)	Shot westward from a little S.W. of the Pleiades to a point south of Saturn.
Feb. 4	9 6 p.m.	Birmingham ...	= ♃	Yellowish red	3 seconds; slow	$\alpha=$ $\delta=$ From 354° +30° to 2 +16
26	About 6 20 p.m.	Gloucester Railway Station.	Meteor of large size.	....	Moved very slowly.	Some two or three degrees at least below and to right of the moon.
26	About 6 20 p.m.	Ilford (near London, Essex.)	....	....	....	Passed from right to left over and very near the full moon.
Mar. 11	2 0 a.m. (Paris time).	St. Etienne, France.	A fine meteor	Violet-colour..	Very rapid ...	Near the southern horizon.
16	8 0 p.m. (local time).	Uitenhage (and Cape Colony), S. Africa.	Meteor of the largest size.	Blue	Travelled slowly.	Appeared near the eastern horizon, and burst finally in the western sky.
17	9 55 p.m.	Reading	Like the finest and largest rocket; ¼ apparent diameter of the moon.	Giving an intense white light. The train & sparks white near the head but turning redder.	3 or 5 seconds	From 2° above Betelgense (α Orionis) to about 6° below the Pleiades. (From 86° +10° to 54° +15°.)
17	9 56 p.m.	Rossall, near Fleetwood, Lancashire.	....	....	Sailed rather slowly across the sky.	From a point about 3° northwest of ϵ Hydræ to a point in Monoceros at about 112°·5, −20°.
17	A few minutes before 10 p.m.	Brighton	About ⅛ the apparent diameter of the moon.	White at first, then bluish, and at last purple	Moved slowly	Near the western horizon; disappeared between Orion's Belt and the Pleiades.
17	About 9 57 p.m.	West of England and Ireland.	From about ⅛ to ½ apparent size of the moon at different points of observation.	Yellow, green, and red.	Slow apparent speed. About 2 or 3 to 4 or 5 seconds.	From over Taunton (altitude 60 miles) to a point over Pontypool (alt. 29 miles; length of path 58 miles).

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
50°	(Fell almost perpendicularly to the south, at Wolverhampton.)	Magnificent fireball, leaving a brilliant track, and with a final blaze at disappearance. Bright moon and twilight. [For other descriptions of the meteor see Appendix II. (Large Meteors), p. 153.]	Joseph Radley. 'Natural History Journal of Friends Schools' Societies,' vol. i. p. 25. Mar. 1877.
....	K_3 (Quadrans) or MG_2 (Boötes). At 7^h 40^m p.m., Feb. 11, another bright meteor was seen at Birmingham, in the N.W., at no great altitude, travelling slowly towards N.	Nucleus with short tail. Burst at last, projecting some sparks forwards.	W. H. Wood.
....	Moved parallel to the horizon, from right to left.	Left a bright track behind it. A brilliant evening, with no stars yet visible (except (?) Sirius, brightly seen in 20^m), and still almost daylight.	A. J. Mott. 'Nature,' vol. xv. p. 399. (March 8, 1877.)
Length of visible path about twice the moon's diameter.	....	Brilliant, in spite of some daylight and of the moon's extreme brightness.	C. M. Ingleby. 'Nature,' vol. xv. p. 375. (March 1, 1877.)
....	Travelling from west to east ...	No detonation heard	'Nature,' vol. xv. p. 460. (March 22, 1877.)
....	East to west	A detonating fireball, producing an immense illumination.	The 'Times.' [See Appendix on Aërolitic Meteors in this Report, p. 193.]
....	....	It made the stars appear dull and red, and seemed very close to the earth.	H. M. Wallis. 'Nat. Hist. Journal of Friends Schools' Societies,' vol. i. p. 41. April 1877.
....	....	The observer's attention, as he looked towards west, was drawn towards the meteor by its light in the south.	J. H. 'Nature,' vol. xv. p. 471. (March 29, 1877.)
....	Passed obliquely downwards, from right to left, towards [? from left to right, to near] Orion's Belt.	Nucleus pear-shaped, with a bright track. [Similarly described at Gunnersbury, near London, by "W. M."; Ibid., p. 451.]	W. Ainslie Hollis. (Ibid.)
....	Due S. to N., at an inclination downwards of 34° from horizontal. Radiant-point deduced from the observations at 145° −4°, in Sextans, near Cor Hydræ.	The meteor cast a strong light, and was followed in its track by a train resembling fiery ashes. See Appendix I. of this Report, pp. 135, 142.	The 'Observatory,' vol. i. p. 19. Calculation of the meteor's course by Captain Tupman.

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1877. Mar. 28	h m About 9 30 p.m.	Hitchin	Very brilliant meteor.	....	A few seconds	Travelling in a N.E. direction.
Apr. 6	9 0 p.m. (Dublin time.)	Thomastown (Kilkenny).	Twice the apparent size of the moon. Light equal to the full moon on a clear night.	Nucleus with a deep crimson tail 4 or 5 times the length of the head.	4 to 6 seconds	Began at an altitude of about 40°, and shot to the S.W. horizon.
16	About 10 50 p.m.	Leicester [and at Bristol].	2 or 3 × Venus. [Lit up the sky with a strong glare.]	Bluish, with a train of yellowish light.	[A second or two.]	In the northern heavens. Commenced near γ Cephei, and shot towards the eastern horizon. [In the north-east fell rather more perpendicularly than in this sketch.]
16	10 50 p.m.	Douglas (Isle of Man).	....	....	....	In a south-easterly direction. Burst within a point from Buck's Road and Conister. The observer was in Christian Road, whence Buck's Road runs 25° E. from S., and Conister Rock is 70° E. from S.
16	10 50 p.m.	Cambridge (and Newcastle-on-Tyne).	A splendid meteor. (Lighted up the sky.)	White	....	Dropped down from Cassiopeia to the horizon. (Rose upwards in the E.S.E. to altitude about 40°; burst and descended again towards the east.)
May 13	About 10 35 p.m.	Brighton	About 4 × ♃	Ruddy; not unlike Mars.	3 or 4 seconds; slow motion.	Appeared a little S. of Arcturus, and disappeared near β Herculis.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	[S.W. to N.E.?]	Disappeared with a final flame and without audible explosion.	C. O. 'Natural History Journal,' vol. i. p. 41.'
....	From N.E. to S.W.	Appearance of the meteor with its narrow deep-red streak—  [A detonating fireball. See Appendix II.. Large Meteors.]	C. Budds. Communicated by G. J. Symons.
....	Descending at an angle of about 30° from perpendicular. 	Sky cloudless; general appearance like a rocket; but it disappeared suddenly without noise or sparks. A slight zigzag but no curvature was visible in its path.	F. T. Mott. 'Nature,' vol. xv. p. 549. (Apr. 26, 1877.) [Communicated by W. F. Denning.]
....	....	Burst twice with such intense light that the time by St. Thomas's church clock could be read.	Paragraph in 'The Mona's Herald,' April 18th, 1877.
....	(Course ? zigzag, or else near its radiant-point? A very rough description, giving only the general altitude and azimuth, by some landmarks at Newcastle, pretty closely.)	(Disappeared with a flash)	Communicated by A. S. Herschel.
....	Moved eastward	Threw out sparks as it advanced. Followed in about half a minute by another, smaller but quite similar, from almost exactly the same point and direction, visible 3 seconds.	W. H. S. J. Hope. 'Nature,' vol. xvi. p. 43. (May 17, 1877.)

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1877. June 4	h m 0 35 a.m.	East Grinstead (Sussex).	A white ball of light, like the moon.	White	Not more (by recollection) than 3 secs.	Stationary; about 2° nearer the zenith than ε Pegasi (then nearly due east).
14	8 40 p.m. (Clermont time.)	Observatory of Clermont Ferrand, Clermont, Farnce.	Disk of 5′ or 6′ diameter while visible. Observers who saw it reach the horizon compared it to the full moon then.	Dazzling white. Tail with some red and blue in its tints.	About 3 secs. while in sight.	Descended from an altitude of about 40° to a point at alt. 10° 50′, azimuth 75° 15′, W. from S., where it disappeared behind the base of a chimney.
16	About 9 33 p.m.	Bristol	> ♃. Like a large and brilliant comet.	....	....	In the western sky. Disappeared behind a screen of trees.
16	10 50 p.m.	Ibid.	About = ♃	....	....	Proceeded from the stars of Ursa Major, as in the sketch. Approximate position, according to a projection on a globe, α= δ= from 177° +52° to 149 +30
July 2	About 10 20 p.m.	Street, near Glastonbury (Somersetshire).	Four times as bright as a 1st mag. star.	Bluish white..	4 seconds; moved slowly.	From 30° W. of S., alt. 30°, to a point 75° W. of south.
2	10 20 p.m.	Bristol	Larger but not much brighter than Jupiter.	....	Slow motion..	Shot horizontally about 3° or 4° above α Virginis. (From about α= δ= 212° −10° to 183 − 3)
2	About 10 30 p.m. or a little earlier.	Filton, near Bristol.	Very fine meteor...	....	Moved slowly	Passed from south-east to west; about ¼ of the way, in altitude, from the horizon to the zenith.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	[Radiant (or stationary point of foreshortened path) at 323°, +11°.]	It had no visible motion, but flashed out and disappeared just as if the sky had opened and shown the moon through, and then closed again.	J. K. Esdaile.
About 35° ...	Descended to the right, or northwards, at an inclination of 30° to the vertical line of the chimney, where it reached it.	Sky foggy. A train of considerable length and brightness followed the head or nucleus of the meteor.	M. Gruey. 'Comptes Rendus,' vol. lxxxiv. p. 1462. (June 18, 1877.)
....	Descending obliquely in a northerly direction.	In spite of daylight and moonlight, which were both strong in the clear western sky, the meteor was yet distinctly visible.	Newspaper paragraph. Communicated by W. F. Denning.
....	 Path carefully represented by the stars.	(Perhaps from the same radiant-point as the other bright meteors noted on this evening)	C. Holt. (Communicated by W. F. Denning.)
....	Descending slightly (about 15°) from horizontal.	A fine bolide, seen in twilight. Burst, leaving a trail of sparks.	W. S. Clark. 'The Natural History Journal,' vol. i. p. 97. (Sept. 1877.)
....	(Radiant apparently Schmidt's, for June and July, at 266°, −10°.)	The star Spica identified by Mr. Denning with Mr. Carell on a following evening.	A. S. Carell. (Communicated by W. F. Denning.)
....	Moved quite horizontally, thus—  First appeared from behind a house, and disappeared behind a knot of elm trees.	Left very little train or light-track; but the size of the meteor and its blaze of light were quite surprising.	F. W. Gayner. (Communicated by W. F. Denning.)

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1877. July 7	h m 0 5 a.m.	Bristol	Quite = ♃	White	....	Part of the path seen close to β Cephei.
Aug. 10	10 25 p.m.	Birmingham ...	= ♃	Pale green ...	1·5 second ...	From ζ Ursæ Minoris to 227° +29°.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	Directed apparently from α Lyræ, but clouds made the exact line of its path uncertain. Near β Cephei.	Lit up the clouds with a strong glow of light (shining through them).	W. F. Denning.
....	[A Perseïd.]	Left a streak 30° in length. Twenty-six meteors seen between 10^h 15^m and 12^h 30^m, with no clouds after 11^h p.m. A rather poor August-shower display. On the 11th, sixteen meteors in clear sky between 10^h 30^m and 11^h 30^m p.m.	W. H. Wood.

LIST OF DUPLICATE OBSER-

FOR THE

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1875. Nov. 15	h m s 0 54 a.m.	Stonyhurst Observatory, Yorkshire.	=2nd mag.*	White	......	From Pollux to about 10° above δ Orionis.
15	0 53 50 a.m.	Royal Observatory, Greenwich.	> 1st mag.*	......	......	From direction of δ Draconis towards α Cygni.
15	2 46 a.m.	Stonyhurst Observatory, Yorkshire.	=3rd mag.*	White	......	From between α and η Leonis.
15	2 46 13 a.m.	Royal Observatory, Greenwich.	=1st mag.*	......	......	About 5° below μ, and 8° to right of ψ Ursæ Majoris.
1876. July 18	11 42 p.m.	Bristol	=2nd mag.*	......	Rapid	α= δ= From 233° +31° to 340 +20
18	11 43 p.m.	Radcliffe Observatory, Oxford.	=3rd mag.*	......	......	From ½ (β Ophiuchi, ζ Aquilæ) to ζ Aquilæ.
19	10 58 p.m.	Bristol	=♃	......	Rather swift...	α= δ= From 346° +25° to 337 +12
19	10 58 p.m.	Radcliffe Observatory, Oxford.	=1st mag.*	Yellow	0·3 second	From ζ Cygni to β Aquilæ.
20	11 28 p.m.	Ibid.	=1st mag.*	......	......	From θ Pegas- past β Aquarii to below α Ca, pricorni.
20	11 29 p.m.	Bristol	=1st mag.*	......	......	α= δ= From 341° +6° to 335 −8 Just above Saturn.
21	10 25 30 p.m.	Ibid.	=Venus. A very fine meteor.	......	Not very swift	α= δ= From 306° +27° to 317 +49
21	10 26 p.m.	Radcliffe Observatory, Oxford.	=1st mag.*	Reddish	0·6 second	From α Ophiuchi to α Coronæ.
24	11 34 p.m.	Bristol	=♃	......	......	α= δ= From 38° +53° to 55 +39 on the right of α Persei.
24	11 37 p.m.	Radcliffe Observatory, Oxford.	=1st mag.*	White	1·5 second	From f Custodis (Bode) to Capella.

VATIONS OF SHOOTING-STARS

YEAR 1875–76.

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	A Leonid [?]	Left a faint white streak	Communicated by S. J. Perry.
About 6°......	[Radiant-point, 154°, +37°]...	[Identical with the last meteor.] Observed by W. C. Nash.	'Monthly Notices,' R. A. S., vol. xxxvi. p. 272.
....	Shot towards the S.E. horizon	Left no streak.....................	Communicated by S. J. Perry.
Very short course=0°·5.	[Almost stationary at 158°, +40°.]	[Identical with the last meteor.] Observed by W. C. Nash.	'Monthly Notices,' R. A. S., vol. xxxvi. p. 272.
13°	Radiant ι Draconis.............	Left no streak.....................	W. F. Denning.
....	....	....	J. Lucas.
20°	Radiant in Cassiopeia [at ξ, ο, 10°, +32°.]	Left a very fine streak for 1·5 second.	W. F. Denning.
....	....	Left a fine streak	J. Lucas.
....	[Radiant at τ, υ Pegasi, 351°, +25°].	....	Id.
15°	Radiant in Cassiopeia	....	W. F. Denning.
24°	Radiant θ Antinoï	Left a bright streak for 2 seconds	Id.
....	[Radiant 294°, −9°, κ Antinoï]	Left a streak	J. Lucas.
19°	Cassiopeiad	Left no streak.....................	W. F. Denning.
....	[Radiant ι Draconis, 292°, +51°.]	Left a streak	J. Lucas.

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Aug. 5	h m 10 39 p.m.	Radcliffe Observatory, Oxford.	=1st mag *	Red		From α Canum Venaticum [a misdirection, certainly], passed η Boötis 7° or 8°, curving downwards.
5	10 40 p.m.	Bristol	=♃. A splendid meteor.		Rather swift...	α= δ= From 199° +54° to 207 +19 (from ζ Ursæ to η Boötis).
8	10 33 p.m.	Ibid.	=1st mag.*			α= δ= From 44° +46° to 44·5 +37
8	10 34 p.m.	Sunderland	=1st mag.*			On a line from ε Pegasi to 2° above β Aquarii prolonged, began 12° or 15° beyond the latter star.
10	9 56 p.m.	West Hendon, Sunderland (Durham).	=Venus, near the end of its course.			Passed a point at 269°, −15°, and went about 5° further.
10	9 58 p.m.	Edgbaston, Birmingham.	A very brilliant meteor.			Passed from η Draconis nearly across (to a point about 2° beyond) γ Coronæ.
10	About 10 0 p.m.	Writtle, Chelmsford (Essex).	=♃ (?)	Orange (?)	2 seconds	Burst below Arcturus and went on a short distance; no small stars visible there.
10	11 59 p.m.	Bristol	=3rd mag.*; small meteor.			α= δ= From 40° +39° to 40 +33
10	11 59 p.m.	Radcliffe Observatory, Oxford.	=3rd mag.*	Red		From between θ and λ to λ Cassiopeiæ.
11	10 27 p.m.	Bristol	=1st mag.*		Rapid	α= δ= From 315°+9° to 307 +3[?−3]
11	10 27 p.m.	Radcliffe Observatory, Oxford.	=1st mag.*	Yellow	1 second	From ½ (α, ζ) Aquilæ to α Ophiuchi.
11	10 38 p.m.	Bristol	=♃; a very fine meteor.			α= δ= From 151°+69° to 170 +53
11	10 38 p.m.	Ibid.	=2nd mag.*			From 170 +73 to 182 +55

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	[No Radiant-point assignable. The commencement and direction of motion at Oxford were evidently ill seen.]	Burst at disappearance. Left a streak.	J. Lucas.
....	A Perseid or Cassiopeiad	....	W. F. Denning.
0°............	A Pegasid	Accurate. Left a streak across Algol.	Id.
....	[Radiant ι Cassiopeiæ, 40°, +72°].	....	T. W. Backhouse.
....	Directed from 1° to right of θ Serpentis. [Perseïd.]	End of the course seen through trees. Left a pretty bright train.	Id.
....	....	Flared up suddenly at α Coronæ, leaving a light-streak there $1\frac{1}{2}°$ long, for 1^{m}. [Seen also by Mr. Denning at Bristol.]	T. H. Waller.
....	Perseïd	Left a spot of light where it burst. Seen through clouds. [Identical with the last meteor, and with one seen at Bristol, at 9^{h} 54^{m}, . by Mr. Denning (these Reports, vol. for 1876, p. 132). *For* 183°,+7°, in that description, *read* 183°,+79°.]	
5°............	Perseïd	Left a streak	W. F. Denning.
....	[Radiant η Persei, 40°, +57°.]	Left a bright streak	J. Lucas.
15°	Perseus or Cassiopeia	Left a streak. Very accurate ...	W. F. Denning.
....	[λ Andromedæ (a Honorid), 352°, +45°.]	Left a streak	J. Lucas.
19°	Cassiopeiad	Left a streak.. } Appeared almost together; rather doubtful paths.	W. F. Denning.
19°	From the same radiant	....	

Date.	Hour G. M. T. (or local time).	Place of Observation.	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1876. Aug. 11	h m s 10 40 p.m. and 5 seconds later.	Sunderland	=Sirius to ♃ ... =5th mag.*	Orange-yellow	1·4 second	α= δ= From 266° + 3° to 260 −15 5° further to the left.
11	11 8 p.m.	Birmingham ...	=2nd mag.*	Blue	0·5 second ...	α= δ= From 26° +61° to 26 +56
11	11 8 30 p.m.	Sunderland	=3rd mag.*	....	Rapid	Disappeared at ½ (α Equulei, ε Aquarii).
11	11 48 p.m.	Birmingham ...	=2nd mag.*	Blue	0·5 second ...	From ε [? ζ] Cygni to 5° south of α Aquilæ.
11	11 49 p.m.	Radcliffe Observatory, Oxford.	=3rd mag.*	....	....	From δ Draconis to π Herculis.
12	1 49 a.m.	Ibid.	=2nd mag.*	....	....	α= δ= From 123° +62° to 132 +49
12	1 50 a.m.	Bristol	=1st mag.*	....	Rapid	α= δ= From 108° +62° to 128 +55
14	11 3 p.m.	Radcliffe Observatory, Oxford.	=3rd mag.*	White	0·5 second ...	Shot from ζ Ursæ Majoris towards α Canum Venaticorum.
14	11 6 p.m.	Bristol	=2nd mag.*	....	Rapid	α= δ= From 156° +70° to 164 +62
14	11 24 p.m.	Ibid.	=3rd mag.*	....	....	α= δ= From 84° +73° to 121 +74
14	11 24 p.m.	Radcliffe Observatory, Oxford.	=3rd mag.*	Red	Rapid	From α Draconis to η Ursæ Majoris.
14	11 35 p.m.	Bristol	=1st mag.*	....	....	α= δ= From 212° +42° to 204 +36
14	11 36 p.m.	Radcliffe Observatory, Oxford.	=1st mag.*	White	....	At ½ (α, ε) Boötis...

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
16° or 17°.	......	[Radiant about χ Persei, and ϕ, υ Persei. Identical with the last pair.]	T. W. Backhouse.
Long course...	Inclined a good deal more towards the right.		
......	Radiant $N_{12, 13}$	[Cassiopeiad? Accordance of directions not exact.]	W. H. Wood.
......	Directed from 1° below ϵ Pegasi.	Left a streak	T. W. Backhouse.
......	Directed from *k* Persei	A fine moonlight night. Twelve meteors seen from $10^h\ 30^m$ to $12^h\ 15^m$.	W. H. Wood.
......	[*k* (near η)Persei.]	......	J. Lucas.
......	......	[Some error of position in this track, or in that of the next meteor.]	Id.
12°	A Perseïd	Left no streak......	W. F. Denning.
....	[Radiant γ Pegasi (?), at 3°, +15°.]	......	J. Lucas.
8°......	Cassiopeiad	Left a bright streak	W. F. Denning.
11°	......	Accurate position. Left a streak	Id.
......	[Radiant 18°, +5°; rather distant and uncertain.]	......	J. Lucas.
9°......	[Radiant o Draconis.]......	Shone out like a star, almost stationary, at last.	W. F. Denning.
About 1°......		......	J. Lucas.

APPENDIX.

I. Meteors Doubly Observed.

In the list of observations of large meteors presented last year, several descriptions are contained which more or less certainly and correctly describe the same meteor seen at different places. But the observations are not always very perfectly compatible with each other. The following are the principal conclusions which, as far as the data would permit, it has been found possible to obtain from them*. Some of the observations referred to are described in the list of observations of large meteors annexed to this Report, especially of the three last meteors mentioned in the present Table, which were seen after August 1876, and whose real paths have been determined from the accounts of them which are now about to be recorded (see, for the Table, pp. 134, 135.)

Notes on the Results of the Comparisons presented in the Table.

1876, July 25, 10^h 3^m P.M.—The descriptions giving accurate particulars of this meteor's apparent course (at Poplar and Edgeware Road, London, Brighton, Downham, Hersham, Street, and Burnham, Somersetshire) are seven in number; but three of them exhibit anomalies of the meteor's track among the constellations which put them out of useful reference for calculation. The meteor's long path appears to have been traced backwards after its disappearance by a natural tendency of the eye to wander round the sky at a constant altitude in prolonging a great circle to constellations much above those from which it was directed. An account received from Burnham, in Somersetshire, by Mr. Corder, states that the meteor passed from Ophiuchus through Boötes on a line directed from the constellation Pegasus, a line which cannot be a great circle on the globe. The meteor's course, described at Brighton as being remarkable for its apparent length, is still more extraordinary by the unnatural deflection at the middle of its track, by which it proceeded thence on a course about 45° inclined to its original direction. As far as can be gathered from the only thoroughly consistent accounts of its apparent course recorded (a correction of "north" to "south" declination in that at Downham, Norfolk, includes this latter among the most precise of the descriptions), the particular account of the meteor's course through the constellations "Aquila and Hercules to Arcturus" at Edgeware Road, London, while not self-contradictory like the above, appears yet to be affected with the same source of error; and it is the only account so signally in contrast with the remaining well-recorded ones as to make the possibility of two meteors having been visible, either appearing nearly at the same time or together, a question which could be reasonably offered for consideration. The calculated path presented in the Table is derived from the observations at Street (Somersetshire) and Poplar, with the corroborative evidence shown at Hersham (Surrey) and at Downham (Norfolk, assuming the above small but important correction of the point of origin) of its approximate exactness. That the meteor proceeded from a very low southern radiant-point is pretty clearly proved by these accounts; but it is unfortunate that the other circumstantially detailed descriptions of its apparent course point apparently to an origin of the meteor's flight far north of the equator, and accordingly (if they could

[* 'Monthly Notices of the Astronomical Society,' vol. xxxvii. pp. 208–210, with some amplifications in the present columns of the Table.]

be accepted) to a very widely different conclusion. The point of first appearance was too far from the observers to be very certainly determined; but the length and duration of the flight at Street give a velocity (19·5 miles per second) which does not perhaps exceed the theoretical velocity in a parabolic orbit (12·3 miles per second) with the radiant-point observed more than can be accounted for by the unavoidable errors of observation. With regard to the meteor's appearance, an interesting description of the view obtained of it (apparently in London, as no place of observation is named in the letter to 'The English Mechanic,' vol. xxiii. p. 668, September 8, 1876, where this account appears) by Mr. W. J. Lancaster is as follows:—"I saw the meteor of July 25th splendidly at about 2^m after 10 o'clock. Its course terminated far above η Boötis. In fact I fancied that it was higher than ϵ Boötis, but of this I could not be positive because my whole attention was upon the meteor. Of one thing I am, however, positive, and that is, that immediately before it vanished it split into two principal nuclei and a quantity of apparent nuclei. The two fragments were about $\frac{2}{3}$ and $\frac{1}{3}$ the size of the original, the larger fragment being the anterior one; the other fragment vanished first, then the anterior one. The colour before explosion was a magnificent bluish green. In fact it at once impressed me with an idea of its composition. It was as nearly as possible the colour produced by burning magnesium and zinc with a trace of copper. Some of the fragments burned with a red tint. I did not hear any sound of an explosion."

1876, August 11, 11^h 22^m P.M.—This was a splendid Perseïd fireball, of which the streak remained visible for a few minutes, assuming a serpentine form, and which was visible from Sunderland in the north to Clifton and Somerton in the south of England. The length of the light-cloud was about 12 miles, and it must have been fully half a mile in width before it disappeared, at the height of 50 miles above the earth's surface, 20 or 30 miles northward from Swansea and Cardiff, at which it was deposited. The meteor produced a white lightning-like illumination over S. Wales and the whole country in the neighbourhood of the Bristol Channel. No durations of its flight were, unfortunately, recorded by which its velocity might have been exactly ascertained, as the length of its path and the real height and locality of its luminous track were very accurately noted and determined The radiant-point is indicated with some precision, near the usual radiant-point of the August "Perseïds."

1876, August 13, 9^h 27^m P.M.—The observations of this Perseïd at Buntingford, near Ware, in Herts, and at Folkestone, are in perfect accordance for the point of disappearance; but the meteor's oblique descent towards these places makes the distance from them at which it first appeared difficult to decide. The point of first appearance assigned at Oxford (near α Cassiopeiæ) limits the height of the meteor there at 140 miles; but a less early point of appearance by a few degrees at either of the stations diminishes this height to 90 miles over Walton, where the meteor is taken to have first entered the atmosphere. Like the last meteor, although penetrating it to little more than 40 miles above the earth's surface, it gave rise to no audible explosion.

1876, August 15, 9^h 30^m P.M.—This fine Aquariad fireball was observed over an extensive area in England, Wales, and Ireland, and in the Isle of Man. It crossed the Irish Channel from St. Bride's Bay, near Milford Haven, to Arklow in Ireland; and the extent of its further flight is imperfectly known from the distance from all the observers in England who recorded it which it there attained. At Newtown (Montgomeryshire) in Wales, a news-

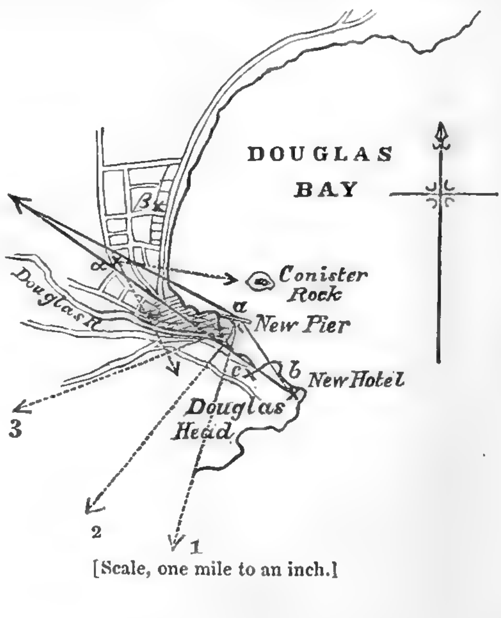
A List of Real Courses of Large Meteors Doubly Observed in England, 1876–77.

Date and Hour (G. M. T.). Size and General Appearance.	Places of Observation employed in the calculations.	Meteor's Real Course. (Distances in B. S. Miles.)				
		Beginning. Height and Locality.	End. Height and Locality.	Length of Path and Velocity.	Observed Radiant-point.	Nearest known Radiant-point.
1876, July 25, about 10h 3m p.m. 15′ × 30′. Green, with train of red sparks; left no streak; no flashes or explosion.	Poplar (London) and Street (Somerset). A good agreement. All the other "exactly" recorded descriptions of the meteor's apparent path are variously contradictory and inconsistent.	62 miles over W. point of Guernsey (commencement at Street). 90 miles over Brittany. (First appearance at Poplar as a small shooting-star.)	27 miles over Crickdale (Wilts), near Cirencester.	107 miles in 5 or 6 secs. (Street); velocity 19·5 miles per sec.; nearly 200 miles in about 6 secs. (Poplar). Velocity about 33 miles per second. (Parabolic velocity 11·5 miles per second.)	α δ Near Antares, at 258° −24° (Street and Poplar.) [A radiant-point very near the ecliptic.]	α δ 258° −20° July (O_2 Neumayer). 262° −33° July 23, ♉ 568 II. ☊ [?]. [(?) Fireball of June 17th, 1873 (Galle), at 246°·5 −19°·3 Vol. for 1874 of these Reports, p. 273.]
1876, Aug. 11, 11h 22m p.m. = full moon. Streak 10° long (Cardiff); lasted fully 1m (Clifton); becoming curved like a sickle (Crediton).	Oxford (Radcliffe Observatory), Crediton, and Sunderland. A good agreement; corroborated at Writtle (Essex), Clifton, and Somerton.	73 (±8) miles over a point 9 miles W. of Ludlow (Salop).	45 (±5) miles over a point midway between Neath and Llandovery (Carmarthenshire, S. Wales).	58 miles in "1 second" (Oxford). No other estimate of the duration was recorded.	60° +51° (±2°) (near λ Perseï). (Oxford, Crediton, and Sunderland.)	44° +56° (near η Perseï, August 9–11). ? An erratic "Perseïd."
1876, Aug. 13, 9h 27m p.m. About = ♀. Left a streak for 5 or 6 secs.	Buntingford (Herts), Folkestone, and Radcliffe Observatory (Oxford). A good agreement; the last for point of first appearance only.	90 miles over Walton near E. Dereham, Norfolk. Limit of extent and height of the upper part of the course very uncertain.	40 (±4) miles over Potter's Bar, between London and Hertford. (Folkestone and Buntingford.)	82 miles in "2 seconds" (Buntingford). The adopted length of path is little more than a general conjecture.	Near ι Cassiopeiæ, at 39°, +66° (±2°) (Buntingford and Folkestone, well-confirmed by Oxford.)	Cassiopeia (July and August). Or an erratic Perseïd?
1876, Aug. 15, 9h 30m p.m. Brilliant over Wales and Ireland. Yellow to blue or green, with long train of sparks and a faint light streak. No flashes or disruption.	Radcliffe Observatory (Oxford), Ashley Park (Bristol), Newton St. Loe (Ib.), and Newtown (Wales). A very fair accordance. With the Douglas observation the termination of the course requires to be considerably extended.	69 (±8) miles over a point 10 miles W. of Gresholm Isle, Saint Bride's Bay (S. Wales).	34 (±5) miles over a point 15 miles W. of Arklow (Ireland). The course continues, by the account at Douglas, to 15 miles over the centre of Ireland, near Mullingar.	75 miles in 4 seconds (Oxford); velocity 19 miles per second (9 seconds at Newtown; 20 or 30 seconds at Bath). The length of path, by the account at Douglas, is about 130 miles (?). (Parabolic velocity 16 miles per second.)	Near μ, ε Aquarii, at 310° −10° (±4°) (Oxford, Bristol, Douglas, and Newtown, Wales.)	306° −8° August 3–31, Schmidt. See also these Reports (vol. for 1876, p. 138), Fireball of August 10, 1874.

1876, Sept. 24, 6h 30m p.m. Globular, with little tail and no sparks or disruption. Two maxima; the last intense, white, leaving a white streak there for 16m. Hull, Hereford, and Paris; vivid over the English Channel.	Orwell Park Observatory (Ipswich), Hull, and Marck or St. Pierre Railway-stations (Dunkirk) for position; with Walmer, Cowes, Dymock (Hereford), &c. for radiant-point.	58 miles over a point between Ostend and Bruges (point of first appearance at Orwell Park Observatory).	16 miles over a point of the German Ocean, 15 miles N. of Ostend (point of extinction at Orwell Park).	45 miles in 3 seconds (Orwell Park Observatory path and duration). Velocity 15 miles per second. (Parabolic velocity 12 miles per second.)	Near δ Lyræ, at 285° +35° (±5) (15° or 20° inclined to vertical, descending from S.S.E. to N.N.W. The mean slope from the above observations.)	No good agreement with any previously known radiant-point.
1876, Nov. 8, about 5h 4m p.m. A great fireball with long train and final separation into sparks; seen in twilight. Middle and West of England.	One precise description only (of the meteor's end-point at Wimbledon, Surrey); with Hay or Manchester for the point of disappearance. All but the radiant-point is very doubtful, and this can only be guessed from the accounts preserved.	50 miles over Sheffield (due north, alt. 20° from London); an altitude implied by the view at New Cross, and here combined with the paths observed at Wimbledon and Manchester.	37 miles over the Irish Channel, 60 or 70 miles W. of Milford Haven (Hay, S. Wales, and Wimbledon). The Manchester account curtails this flight to an explosion about 40 miles over Aberystwith.	The materials for determining the real length, height, and locality of the meteor's course are very defective and not sufficiently reconcilable with each other to fix the length of path (130, or 250 miles) and rate of motion. Duration at Wimborne, Hants, 4 or 5 seconds.	Near η Tauri, at 53° +20° (±5°) (almost on the E.N.E. horizon). No other radiant-point can be made to satisfy approximately the recorded paths, or the general direction everywhere of the meteor's long flight towards the west-south-west.	56° +18° Radiant of the first and principal group of the "Taurids" (Taurids I.) in November.
1877, Jan. 7, 10h 31m 30s p.m. = ♀. Yellow. Slow irregular motion with train of red sparks, and a flash at disappearance. Left no streak.	Birmingham, and two observations in the neighbourhood of London; one of them at Putney Hill.	76 (±5) miles over Staplehurst, Kent. First expansion (Birmingham), at 67 (±5) miles over the channels of the Thames (near the Essex coast; here the two London observations of its course cease and begin respectively).	33 (±5) miles over the North Sea, 25 miles N. and 90 miles E. from Cromer, Norfolk. (Birmingham termination. The last London observation of its course ceases a little earlier on the line of flight than this.)	185 miles in 5 or 6 seconds (Birmingham). Velocity 35·5 miles per second. The longest observed path "near London" gives the length of course 104 miles. The theoretical (parabolic) meteor-speed is 12·3 miles per second.	Near γ Eridani, between 44° −16° and 65° −13° (extreme points of intersection of the three recorded paths; mean central position about 55° −14°; γ Eridani is at 58° −14°).	At γ Eridani, Jan. 1877. A radiant of several bright meteors (W. F. Denning, 'Nature,' vol. xv. p. 346); one of them as bright as Venus, and similar to this one, on Jan. 4, at 8h 51m p.m.
1877, Mar. 17, 9h 57m p.m. ¼ or ⅓ diameter of the moon. Blue, pear-shaped, with fiery sparks on track. Bright illumination in West of England and Ireland.	A good agreement at Cambridge and Frome; confirmed at Tetbury and at Gunnersbury (London); and seen at Brighton, Waterford, and Fleetwood, with particulars of position.	60 miles over Taunton, Somersetshire.	29 miles over Pontypool, Monmouthshire.	58 miles in 3 seconds (measured, Frome), and 2, 3, 3, 4½ seconds estimated durations. Velocity about 19 miles per second. Theoretical parabolic speed 13·3 miles per second.	In Sextaus, near Cor Hydræ; at 145° −5°. A fairly accurate position.	No previously known radiant-point in this position. Calculations by G. L. Tupman, 'Monthly Notices,' R. Astr. Soc. vol. xxxvii. p. 353; and 'The Observatory,' Vol. i. p. 19 (April 1877).

paper might have been read for some time by its light, as it passed along; and it was remarkable for its sustained brilliancy at Bath, Bristol, Cirencester, Swansea, Oxford, Rochdale, at Douglas in the Isle of Man, and at Cookstown, near Loch Neagh, in Ireland. Its course was noted at the Radcliffe Observatory, Oxford; and here, as at other more western places over which its course began, it was followed without extinction to the N.W. horizon. The observation at Douglas enables the radiant-point to be determined, to which the observations in the S.W. of England only point backwards by a nearly common line. As seen to commence, from the new pier, over Douglas Head, and to skirt the high ground of that southern headland of the bay before coming into clearer view westwardly over the town, the altitude of its horizontal motion westwards from the point of origin nearly due south cannot have much exceeded 30°, the apparent altitude assigned by Mr. Binney. If by a reduction which no eye-estimations of altitude near the horizon can dispense with, 25° or even 20° is substituted for the real altitude at which the meteor started horizontally westwards at Douglas from the south meridian, the position for the radiant-point is obtained (by intersection with the other projected courses) which is entered in the Table, and which agrees without discordance with the place which had already been assigned to it generally and independently from their common intersection. The place so found (at 310°, −10°) agrees well with a known radiant-centre for August in Aquarius, close to which the radiant-point of a bright fireball seen on the 10th of August, 1874, was already found to be situated (as described last year in these Reports), at 313°, −14°, near μ, ϵ Aquarii. The velocity (like that of the fireball there described, of 19 miles per second) agrees with the theoretical velocity of bodies moving in a parabolic orbit with this radiant-point.

The President of the Manchester Literary and Philosophical Society, Mr. E. W. Binney, who obliged the Committee with the present details of his observation of the meteor at Douglas, has also kindly communicated two other observations, which it is difficult to reconcile with those of this large meteor, but which may yet indicate that it pursued its course to a considerable distance over Ireland. The annexed map of Douglas town and Bay represents the point (*a*) on the New Pier from which Mr. Binney relates that he obtained the first view of the meteor in the direction *a b*, commencing its course over the New Hotel, whence it took its flight westward, skirting the hills of Douglas Head (whose elevation is about 300 or 400 feet), until it passed clear of them, and pursuing its way over Douglas town, appeared to him to vanish in the north-west near the horizon. Some friends who saw the meteor from near the New Hotel also followed it in view until it disappeared over Fort Anne Hotel (*c* in the sketch), which is nearly in the same



[Scale, one mile to an inch.]

north-west direction. The dotted lines 1, 2, 3 are the directions, respectively, of St. Bride's Bay (Milford Haven), Arklow, and a point near Mullingar in Ireland. It thus appears that a much longer flight than that above supposed must presumably have been performed; but it must yet be remembered that intervals of azimuth, like those of altitude, are commonly far overrated near the horizon; and the real course of the meteor was very probably not more prolonged (even if it was so much, at last) at Mr. Binney's point of observation*, from due south to about west, or a little south of west.

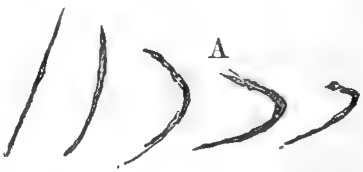
Mr. Binney mentions the occurrence on the night before the 15th of August of another meteor equally brilliant with this large fireball, which made its appearance in the west at Belfast. The hour of its occurrence was the same, and it answered, a correspondent wrote to him, in every particular to the description of the meteor seen at Douglas; and no doubt of the date, he added, was possible, which was the 14th of August. Mr. H. Darbishire, who communicated this intelligence, states that he was on the watch for meteors on the night of August 15, between 9^h and 10^h P.M., and saw nothing at Belfast resembling the large meteor elsewhere recorded at about 9^h 30^m on that night. On the other hand, a notice of such a meteor, seen at Cookstown, 30 miles west of Belfast, appeared in a later Part of the 'Proceedings of the Literary and Philosophical Society of Manchester' (vol. xvi. p. 60, December 12, 1876), showing that either this fireball, or one perfectly resembling it, was very brilliant in that part of Ireland at the hour when other observers noted its appearance.

The following account of the meteor was given by Mr. N. Staples, whose letter to him of December 4th, 1876, on the subject of the meteor, Mr. Binney then communicated to the Society:—"As I noticed in the Paper that you observed a meteor on the night of August 15th, when in the Isle of Man, I beg to inform you that a meteor was observed in Cookstown, about long. W. 6° 45′, on the night of Tuesday, August 15th, about 9^h 45^m, local time, passing over from S.E. to N.W. It was described to me as lighting up the whole street; colour reddish green [!]." Mr. Binney adds that the meteor was also seen at Rochdale in Lancashire, but of its apparent course there he has not been able to obtain particulars. Remarkable as was the brilliancy of the meteor at this far northern point in Ireland, it is not necessary to assume a further continuation of its course than to such a low height as 15 miles over a point near Mullingar (about 80 miles S.S.W. from Cookstown) to satisfy the uncertain information which can alone be gathered without recourse to measurements from such a general description of the meteor's apparition. The earth-point of its course, as derived from the exact observations of its course in England, was 15 miles west from Carrick, 90 miles S.W. by W. from Cookstown, and instead of passing "over" that town towards N.W., if the same meteor (as there seems no reason to doubt) was seen there, it must have moved at no great altitude above the south, on a slightly descending course nearly towards the west point of the horizon. The meteor did not burst or detonate, and left no persistent light-streak on its course; but the strong bluish light of its nucleus cast moving shadows

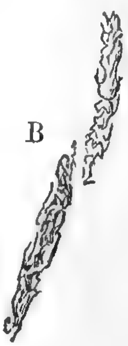
* A point α is added in the map where Christian Road branches off from Buck's Road. The direction of Buck's Road and of Conister from this point (referred to in a description of the meteor of April 16, 1877, in the accompanying fireball-list) are shown by dotted arrow-lines in the map. The point β is the tower of St. Thomas's church, which is also referred to in the same description.

in S. Wales, and it was followed by a long train of red and yellow sparks.

1876, September 24, 6^h 30^m P.M.—Far the most splendid meteor seen in England for some years past burst over the English Channel on the last Sunday evening in September 1876. A view of the phenomenon, complete in every point from first to last, was obtained of the brilliant spectacle at the Orwell Park Observatory, near Ipswich, by Mr. J. J. Plummer, who kindly supplied the Committee with the following details*:—"It was bright twilight throughout the whole time (from 6^h 31^m to 6^h 47^m, local time) that the meteor and its streak were visible. The whole course (whose length I estimate at 25°, traversed in about 3 seconds) may be divided into three portions (roughly equal) in order to describe it accurately. In the first portion its brightness was not remarkable, though it exceeded a first-magnitude star. In the second or middle portion it rapidly increased in brilliancy to many times the brightness of Venus, and then almost suddenly sunk to its former magnitude. In the third portion it again increased in brilliancy, this time much exceeding its former maximum, and with the like suddenness was totally extinguished. This portion of its course was, however, marked out by a narrow luminous train, about 6° long, and with scarcely perceptible width, which enabled me to fix the position of the point of disappearance [by a comparison with the neighbouring planet Saturn, about 3° below it] with considerable precision. There was no explosion; no noise. The diameter of the disk could not exceed 2′ [the inappreciable width of the light-streak plainly betokens this], and might have been less, and was slightly pear-shaped, which appearance may, I think, have been due to the persistence of the impression on the retina. It is very difficult to estimate with any accuracy its maximum brightness, as there is no object in the heavens with which to compare it. I have recently shown that Venus has only $\frac{1}{800}$ of the brilliancy of the full moon, and there is thus a very wide gap between these two standards of reference as regards brilliancy. If the moon had a diameter no greater than that at which I estimate the meteor, with the same amount of light, its intrinsic lustre would of course be 240 times that it has at present, making it a very brilliant body. Still I do not think I exaggerate when I say that the meteor would be equal to such a body. The glare closely resembled that of a very vivid flash of lightning, for which it was mistaken by some persons. After the disappearance the train was seen as a luminous cloud drifting slowly northward, taking successively the following forms (A), and gradually losing its definite outline. During its visibility it drifted about 12° or 15°. The wind was south-south-westerly at the time."


A

A similar description of the streak to this is given by Mr. R. Harding, at Ipswich, as shown in the annexed sketch (B) received from Mr. Corder. "Time, 6^h 20^m. Apparent size equal to the moon, but much brighter. Fell very rapidly from a height of 50° or 60° in the S.S.E. White, followed by a train of brilliant colours, and leaving a broad streak

B


* A similar notice of the meteor, by Mr. Plummer, appeared in 'Nature,' vol. xiv. p. 505. The particulars of the observed positions are recorded in the list of large meteor observations included in the general catalogue annexed to this Report.

which lasted some minutes and broke in halves, one half gaining on the other, appearing thus when it began to break up in clouds."

The sharply defined character of the white streak is mentioned by an observer on the Dunkirk to Calais railway (see the accompanying catalogue), who likens it to a straight vertical chalk-mark on the sky; and at a few places in England where (as in the neighbourhood of Ipswich), after a very wet showery day, the sky had cleared in the evening, the luminous streak which it left was a very notable feature of its unusual appearance.

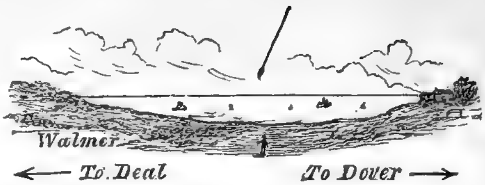
The 'Daily News' gives the following description from the Stoke Hills, near Ipswich, adding, in some introductory lines on the occurrence, that "it must have fallen quite close to Ipswich, for the noise when it burst was plainly distinguishable"; but no other announcements of an audible report having attended it, from places nearer to the meteor's real outbreak and nearest approach to the earth, as far as the Committee has been able to ascertain, were elsewhere recorded.

"It first made its appearance about thirty-two minutes past six, in a S.S.E. direction, about 60° above the horizon, and above and a little to the right of Saturn [altitude 11°]. It descended rapidly, leaving a long tail or train of golden light behind, like a long thin cloud, more or less broken. Just as it was in a line with Saturn, and apparently about a yard [1°] to its left, it opened or burst in the middle like a pod with a crackling noise, showing in the centre a very bright ball of light like the electric light. The light was of greater intensity than that of the moon at the full, quite illuminating a large room from which it was seen. The luminous train or trail was visible for a quarter of an hour after the meteor burst, at first in the tail-like form with a marked division in the middle, but soon afterwards the two divisions became widely separated, assuming the appearance of two horizontal white clouds." Its appearance at Norwich and at Bramford is also noted in the 'Daily News,' at the latter of which places it passed from W.N.W. to the S.S.E., "leaving a stream of light behind it, and casting a lurid crimson belt of light upon the earth immediately beneath its course."

At numberless places in England (and on the mainland of the continent) the intensity of its illumination was a singularity of this meteor, which took observers by surprise, lighting up the interior even of large rooms where they were seated, and revealing all objects out of doors with lightning-like distinctness.

Near Harleston in Norfolk, "a pale light shone through an east window and passed thence about 6 or 7 feet from the floor of the room to a north window, like a flash of lightning." It was mistaken for lightning even at Dymock, near Ross in Hereford; and in the south-eastern counties of England scarcely any persons within or out of doors had not noticed the peculiar brightness of the flash, which, the day having been sultry, was for the most part attributed to unusually vivid lightning. An outhouse was thought, in Kent, to be on fire, and apprehension was not much relieved on looking up to see that the fire was in the sky, "as big as a square room, thrown open," instead of on the earth close by. The illumination of the clouds, where the sky was covered, like that within doors, where the meteor was not seen, caused many erroneous impressions of its real course and aspect, to which few accurate particulars beyond what the accompanying catalogue contains can here unfortunately, from the dark and cloudy nature of the evening generally, now be added.

Mr. H. W. Bele, writing to Mr. Denning, gave a very clear description by a sketch (and an accompanying outline map) of the general direction, from his position, of the meteor's apparent course, near Walmer on the coast of Kent, as it descended directly before him nearly to the sea. From this description, the meteor was visible nearly in the east from Deal or Walmer (descending to a small altitude; and this direction is also given near Folkestone, by Mr. C. J. W. Valpy at Burmarsh, at Broadstairs by "T. W. H." in 'The Standard,' and at Hawkhurst, in Kent). The coast-line of France and Belgium is here added to Mr. Bele's map, with the calculated position over the latter coast of the meteor's real course.



At Walton-on-the-Naze ('The Times') the meteor descended vertically in a south-east by east direction; and this agrees almost exactly with Mr. Plummer's view of it near Ipswich, from which, with combination of these observations and of that at Hull, and from the traveller's note of its bright streak, on the railway between Dunkirk and Calais, marking the sky vertically in the "north-north-west," this approximate place of explosion and disappearance of the meteor over the German ocean is arrived at. The direction of its downward descent, though nearly vertical, is inclined from south to north in all the accounts recorded in the south, while this is less observable in those reported from the neighbourhood of Ipswich. In Paris also the apparent line of motion was "almost perpendicularly" downwards; and a general comparison of these particulars proves the true place of the radiant-point to have been about 15° or 20° from the zenith on its S.S.E. side, at a point then nearly occupied by δ Lyræ, in R.A. 285°, N. Decl. +35°, as is represented in the Table. If it is exact, this position differs sensibly from the point, at 311° +52°, from which, as found by Captain Tupman*, a meteor very similar to this, and almost as strikingly brilliant, fell, off the coast of Sussex, on the 3rd of September, 1875. The latter radiant-point, a little west of the zenith, disagrees with the notes of several observers of the fireball of September 24th, 1876, in the south and west of England, that its falling path in the east, from their points of view, declined northwards very visibly from a vertical direction.

'The Galignani's Messenger' of Paris thus describes the appearance of the meteor in that town:—"It emerged from the dark storm-clouds at 30° above the horizon in the northern sky, and descended slowly towards the earth, emitting showers of sparks and a scintillating train. It fell almost perpendicularly, and grew elongated in falling; it disappeared behind houses, and thereafter illumined the whole northern sky with two successive blazes of fire like lightning, by which the surrounding clouds were tinged as with gold."

* These Reports, vol. for 1876, p. 144; and 'Monthly Notices of the Astronomical Society,' vol. xxxvi. p. 216. The traveller on the Dunkirk railway must be assumed to have misestimated the bearing of the luminous streak left by the meteor by a few points westwards from its above assigned position.

In 'The Times,' a writer from Broadstairs relates that "from the clouds an immense body of blue flame, headed by a brilliant red colour, shot out. Although no report was heard, it appeared distinctly to explode twice, and was visible for from 8 to 12 seconds. It left behind it a streak of reddish-coloured light, indicating the course it had taken." At Walton-on-the-Naze, "the colour was white with a rose edging; and from the old pier, persons standing there say they distinctly saw sparks fly off from the meteor as it rushed down. It left a thin streak of white cloud, which did not wholly disappear for half an hour." The Broadstairs correspondent of the 'Standard' writes that it was "as large as the sun at noonday, with a sort of crown on the top and a long pointed tail. The head was of dazzling brightness and surrounded by a dark rich blue outline, and it left a large white fissure in the clouds [the white streak] where it passed through them, which remained about 3 minutes."

These and similar descriptions (that the meteor-head was "rayed or spiked," that "it split" and "threw out arms," &c., and that it "rose up," lighted the clouds, was perhaps meant, with a second flash), which might be multiplied, when compared with Mr. Plummer's description (which, with a clear view of every feature, mentions none of these singularities), may prove what caution is required not to accept too readily the suddenly received and often hastily formed and doubtfully recalled impressions which are produced upon the minds of unprepared observers by these very startling apparitions.

1876, November 8, $5^{h}\ 3^{m}$ P.M.—Although the twilight was strong, especially in the west, when this meteor traversed the central parts of England from east to west, it was a fine object on most of its course, especially near disappearance, when it separated into a string of several shining globes. The observers remarked (which may be a misconjecture) that it at the same time underwent a sensible downward deflection of its course. Its brightness varied little, surpassing Venus gradually on its long course, and becoming somewhat suddenly brighter at disappearance, and besides a sparkling train it left a persistent light-streak, not visible for many moments. By the account of all observers, it followed with rather slow motion a long horizontal course from between the north and east to between the south and west, the long career of the meteor showing also that its real path must have been nearly horizontal on this course. One exact position only was recorded of its point of disappearance, by Mr. F. C. Penrose at Wimbledon. The altitude of the early part of its flight in the north from that point of view is known approximately from an observer's estimate, 30° (equivalent in measured height to not more than 20°) above the northern horizon, at New Cross. It disappeared at Wimbledon at an altitude of 9°, very nearly, in the west; and even at Hay, near Hereford in Wales, an altitude of 20° or 25° in the west of the last part of its flight was recorded by approximate descriptions. A very different account from this long course is given by Mr. Brothers at Manchester, who estimates its whole path at about 40° in length in the S. and S.W., altitude about 30° as the least admissible, but at 38° as measured from recollection, going almost horizontally between S. and S.W., with a gradually descending course towards the west. This and the imperfect observations at the two or three other points already mentioned only enable its real course to be roughly fixed in space; and especially its length or extent at the starting and disappearing points are quite uncertain. The height in miles cannot have been much more or less than from 50 to 30 miles, along its course; and very slenderly accordant as the observations are for its terminal positions, the apparent radiant-point of the meteor's flight is yet, by the common evidence of these three observations, shown with little uncertainty to have been very near the E.N.E. horizon. The meteor was thus found to have been a 'Taurid' from the earliest of the three Taurid centres (at 58°, +18°, a noted radiant-centre in November); and the characteristic appearance of the meteor was also that which the long bright meteors often seen coursing the sky from east to west in evenings early in the month present by the parallelism of their stream to the horizon, and by the brightness of many of its members, which makes this ordinary meteor system a conspicuous shower of shooting-stars in the early portion of November.

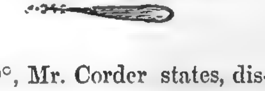
1877, January 7, about $10^h\ 30^m$ P.M.—Besides the fine shooting-star doubly observed at this time in London and at Birmingham, Mr. Denning has described the occurrence of other meteors seen by himself*, which are traceable to the same radiant-point in the first few weeks of January. On the radiant-point near γ Eridani, to which he shows that the meteor of January 7th can be assigned, and on some other meteors seen on the same night as this one, Mr. Denning offers the following observations:—"I can confirm the position of this radiant-point from other meteors seen in January, including one as bright as Venus on the 4th, $8^h\ 51^m$ P.M., which exhibited the same slow halting motion as that noted in regard to the fine one seen on the 7th. I have received other accounts of the latter, but they are mostly vague. At Bermondsey it was seen at $10^h\ 30^m$, and described as large and remarkably brilliant, closely resembling in size and colour the meteor which appeared on September 24, 1876. It was of a bluish colour, left a long tail of light, or streak, in its wake, and its course in the heavens was from S.W. to N.E. At $10^h\ 37^m$, on the same evening, a very large and brilliant meteor was seen at Lower Clapton, and this no doubt refers to the same object.

"Mr. Barrington ('Nature,' vol. xv. p. 275) notes another bright meteor at 6^h P.M. on January 19 (Dublin time, or $6^h\ 25^m$ P.M. Greenwich time, see the account at Bray, below, p. 153); but its apparent path shows it to have been different from one seen by a correspondent at $6^h\ 27^m$, January 19, who writes that he witnessed a meteor of unusual brilliancy. It moved almost perpendicularly in a southerly direction very slowly, the time occupied in its passage being about 7 or 8 seconds."

1877, March 17, $9^h\ 57^m$ P.M.—Several observations of this very luminous fireball were recorded (some of which are included in the accompanying list) and were collected and compared together, with the results given in the present Table, by Captain Tupman. The meteor was exceedingly luminous at places near its line of flight over the Bristol Channel and in Ireland, as its body of brightly-coloured light sailed slowly through the sky. "From Waterford the meteor was seen to be double, one part closely following the other in the same track†, while the light was so brilliant that the coast of Kilmore, 9 miles distant, became distinctly visible. All along the track fiery ashes were observed to fall nearly vertically downwards. At Basingstoke, 90 miles distant, green and red masses of fire seemed to be falling into ad-

* 'Nature,' vol. xv. p. 346 (February 15, 1877). See also the accompanying Large Meteor-list, January 7th, 1877, Putney Hill, London.

† A sketch of the double-headed meteor of September 7, 1875, by Mr. H. Corder, at Writtle, may here be noticed (see these Reports, vol. for 1876, p. 145, footnote), as the division into two heads which it portrays is much rarer than the formation of a second head (perhaps of sparks), like that described in the text, following the principal body of the meteor. The two heads, certainly not in line, after travelling in company for about 20°, Mr. Corder states, disappeared almost together.



jacent fields. From Tetbury, red matter was seen falling after the body of the meteor was extinguished." The point of disappearance, at 29 miles over Pontypool, is very well established by several observations, and a good position of the radiant-point between Sextans and Hydra is deducible from the descriptions. Many estimated durations of the meteor's flight, combined with a very fair determination of its actual length, give in this case a meteor-speed which is a little in excess of what would belong to a parabolic orbit; but it should be remembered that only partial views are generally obtained of a meteor's motion, while more of its real length of path will often be discernible from the streak of light, or sparks, left visible upon its course.

Among the occasional observations of shooting-stars communicated to the Committee during the year 1876 (including long lists, especially from Mr. W. F. Denning, at Bristol, and from the Radcliffe Observatory, Oxford), several duplicate observations of ordinary shooting-stars have been extracted. The second List, above (p. 126), describes these observations, and it may furnish useful conclusions of their apparent radiant-points to examine these accordances more critically, which the Committee hopes at some future period to accomplish. To these it may be added that among the meteor-paths noted in the list of twice-recorded tracks, one described at Writtle (Chelmsford), and at Sunderland at about 10 o'clock P.M., on August 10, 1876, corresponds to that of a meteor observed at Bristol simultaneously (at 9^h 54^m) by Mr. Denning, as described in the list of large meteors presented with last year's Report.

The following double observation (and a real path deduced from it) was also obtained, as Mr. Denning has informed the Committee, from his point of view at Bristol, and from Mr. H. Corder's at Writtle, of a fine meteor well situated for simultaneous observation between them, which appeared on the 30th of May last (1877), at 11^h 26^m P.M., as recorded at each station:—

Place of Observation.	Apparent Size and Colour.	Duration.	Position of Apparent Path.				Length of Path; and Remarks.	Observer.
			From		To			
			α	δ	α	δ		
Bristol	= ♃; yellowish.	2·0 seconds; slow motion.	333°	+27°	324°	+14°	15°. Left a streak. Very accurately observed.	W. F. Denning.
Writtle, near Chelmsford.	± ♃; at first deep yellow, then turning bluish white.	....	335	+47·5	319	+36	A sudden flash near its end; a small spark went on ½° further.	H. Corder.

Mr. Corder adds, "I never mapped one much better, as I was looking exactly at its position when it appeared." Mr. Denning was also watching for meteors, looking eastward towards Chelmsford, so as to have this meteor when it appeared in his full view. The common radiant-point obtained from a projection of these paths is near δ Cassiopeiæ, at 20°, +58°; a position for the end of May and beginning of June which has not yet been recognized in any existing radiant-lists. Mr. J. E. Clark, of York, has calculated the height and real path of the meteor, which he found to be from 101 miles over a point 87 miles E.N.E. from Yarmouth to 75 miles above a point 60 miles E.S.E. from Yarmouth, with a real course of 90 miles performed in 2 seconds, as Mr. Denning estimated its duration. The heights at appearance and disappearance are somewhat greater than usual; and the meteor-speed corresponding to this radiant-point for a parabolic orbit would be 24·5 miles per second instead of 45 miles per second, the actual velocity with which the meteor appears to have been moving, from this comparison of the corresponding observations.

II. Large Meteors.

1873, June 17, 8^h 46^m (Breslau mean time); Hungary, Austria, and Bohemia.—In July and December 1873, Prof. G. von Niessl of Brünn, in Moravia, and Prof. J. G. Galle of Breslau, in Silesia, respectively published investigations * on the real path of this large detonating fireball, which in the main corroborated each other with wonderful exactness, although the accounts which they employed were principally collected from the west and east sides respectively of the tract of country over which the meteor passed near the termination of its course. One very striking difference, however, was exhibited between the independent results which they obtained. While scarcely three or four miles in the locality (Hernhut or Grosschönau in Saxony, on the Lausitzer-Gebirg dividing that province from Bohemia), and scarcely half a mile in the height ($20\frac{1}{4}$ miles above the earth), separates the points of disappearance of the fireball as found by these two computers, while the radiant-point, or direction of the real path along which the meteor approached this place, coincides within about 3° in the results of the two calculations, the meteor was found by Prof. von Niessl to have begun its flight over a point near Chrudim in Bohemia, at a height of $39\frac{1}{2}$ miles, 92 miles from its point of disappearance; while the length of its course, according to Prof. Galle, was 285 miles, and its point of first appearance was far south-eastward from Bohemia, at a height of 101 miles over Raab, in the southern part of Hungary. Some observations in Silesia, especially one at Rybnik, where the meteor appeared at starting to emerge from the planet Saturn, had led Prof. Galle to this result; and the following comparison (taken from Prof. von Niessl's later paper) will show how exaggerated it must have appeared to Prof. Niessl, from all the observations at Brünn, and in Moravia and Bohemia, which he had been able to collect:—

Place of observation.	Distance of the point observed from the end of the Meteor's course. miles.	Height above the Earth. miles.
Rybnik	281	92
Schemnitz	230	78
Vienna, Koritschan, Schönberg	124	51
Brünn, and most other stations. (The first point of the streak)	92	41
Point of the meteor's disappearance (and end-point of the streak)	0	20

* In the 'Verhandlungen des naturforschenden Vereins in Brünn,' vol. xii. 1873–74; and in the 'Jahresbericht der schlesischen Gesellschaft für vaterländische Cultur,' vol. for 1873–74. Abstracts of these papers by the authors also appeared in the 'Astronomische Nachrichten,' Nos. 1955, 1989–90; and they were reviewed at some length in the volume of these Reports for 1874, p. 270 *et seq.* The present notice is taken from a memoir on the meteor to which it relates, by Prof. von Niessl, excerpted from the above mentioned volume of the Brünn 'Verhandlungen,' for the obliging communication of which the Committee is indebted to the author.

A belief that the planet Jupiter had accidentally been mistaken at Rybnik for Saturn (although not participated in by Professor Galle) led Prof. von Niessl to extend his inquiries for descriptions of the meteor to the eastward, and especially to Southern Hungary; but neither in Hungary nor from any eastern towns could he obtain fresh proofs of this early commencement of the meteor's course, nor even any evidence of its having been visible in Steiermark, about half as far off as Raab (in the same direction) from the meteor's point of disappearance, until this was at length furnished to him from Schemnitz, in Hungary, by Baron A. von Pronay, who had noted the meteor's passage there with the greatest care. Although attracted by its light from behind, so as not to see its very first commencement, two thirds of its course, the Baron relates, were traversed with great brightness, but without leaving any very long-enduring streak. It was only in the last third part of its course, near the horizon, that the luminous streak was left which remained visible at his point of view $17^{m}\ 20^{s}$. This point of first commencement of the streak must, it appears, have been attended with a considerable increase of the meteor's light, since it was the point almost universally assigned by all the observers in Bohemia and Moravia as the first point of the meteor's course; and Prof. von Niessl himself, who saw the meteor at Brünn, in Moravia, very favourably, was under no impression whatever that an earlier portion (at least half) of its visible track had escaped his view. A curious illusion also happened in his view of the end point, which he believed to have taken place behind the roof of a house, but which the calculated place shows must have been actually visible close *above* it from his point of view, and that the sudden extinction there must have led him to believe that the end of the meteor's course was prolonged behind the roof, and had been hidden from him by its neighbouring obstruction. It is remarkable that but two or three observations of the meteor's early commencement—at places as distant as Vienna, Schemnitz, and Rybnik from the neighbourhood of its terminal, streak-leaving course and explosion—should have been made among the many scores which were recorded of the latter portion of its flight, while yet the brightness there, some hundred miles from the point which it ultimately reached, was sufficient to make an observer turn round and see it appearing from behind him. A streak was left on its whole course; but only for a few seconds, Baron von Pronay states, during the first two thirds of its path across the sky.

Adopting, therefore, the Rybnik observation as perfectly confirmed, and employing it with all the new materials at his disposal, Prof. von Niessl finds his previous determinations, except in the least significant particular of the total length of course, to require no sensible modifications, and to differ also almost insensibly from those arrived at by Prof. Galle. The apparent radiant-point was at $248°{\cdot}6, -20°{\cdot}2$, and the velocity found from the short streak-bearing portion of the flight, of which several well accordant durations were observed, was 19 miles per second, differing little from those found by Prof. Galle, at $246°{\cdot}7, -19°{\cdot}3$, and between 18·5 and 28·5 miles per second, according to two estimates of the duration from which he separately deduced the meteor's velocity in its entire length of flight. The radiant-point is so near the ecliptic, that when corrected for 'zenithal attraction,' one of the positions thus assigned to it is in north and the other in south latitude, so that the meteor's orbit was almost absolutely zodiacal, or nearly coincided with the plane of the ecliptic. It is perhaps not impossible that the fireball of July 25, 1876, observed in England with a nearly ecliptic radiant-point at $258°, -24°$ may have had some connexion with the hyperbolic meteor stream to which it appears that we must have recourse in order to explain, with Professors Galle and von Niessl, the somewhat sensible excess of speed above that in a parabolic orbit with which this great detonating meteor of June 17, 1873, pursued its long and, it appears, very rapid flight over central Europe.

1874, April 10, 7^{h} 57^{m} P.M. (Prague mean time), Bohemia*.—Several descriptions of the appearance of this detonating meteor were published in Bohemian newspapers, in Heis's 'Wochenschrift für Astronomie,' and in the Proceedings of the Austrian Meteorological Society, while it was well observed at Brünn; and some private communications from other points, especially the Royal Observatory at Prague, and a place near Kuttenberg, in Bohemia, near which the final explosion took place, were received by Prof. von Niessl. It strongly illuminated for two or three seconds the towns of Prague and Brünn, and its flash resembled that of lightning in some of the towns of Silesia. At Leipzig its apparent brightness was about that of the planet Venus; but in the immediate neighbourhood of its fall, where it burst nearly overhead, its glare was like sunlight, and its terrifying flash was followed in about a minute by a hollow peal of thunder, the echoes of which were endlessly reverberated for nearly the space of a minute more. This was at Kuttenberg, where its path among the stars was noted. Combined with the observations at Brünn the point of extinction is found from this account to have been not far southwestwards from Kuttenberg, 18½ miles high over the village Majelovic, in Bohemia. A good position of the radiant-point is afforded by six astronomically described tracks, at 26°, +62°, close to the star ε Cassiopeiæ, which was then 33° above the N.W. by W. horizon. The point of first appearance lay 52 miles along this course from the termination, at a height of 45 miles, unless some imperfect indications of a greater initial height and length of path than this can be trusted for its prolongation to an earlier point. The average duration of this portion of its visible flight gives a velocity of 14 miles per second, while the velocity corresponding to a parabolic orbit with the observed radiant-point is about 14·5 miles per second. Prof. von Niessl is not, however, satisfied with this appearance of agreement, as some of the observations of position render a rather greater length of path than that just assigned for the average observed duration somewhat probable; and he has calculated a hyperbolic orbit of this detonating meteor, at the same time repeating his formerly expressed conviction that aërolites and detonating meteors will be found to differ from ordinary periodic star showers and from the great majority of comets by native velocities of motion in space carrying them with independent speeds from the region of some distant star spheres into the neighbourhood and the attraction of the solar system.

1876, April 9, 8^{h} 20^{m} (Vienna and Brünn mean time), Hungary and Galicia†.—The scene of this meteor's explosion was the neighbourhood of Rosenau, Eperies, and Iglö on the Hungarian flank of the Carpathian Mountains, which witnessed the descent of the great meteorite of Knyahinya (June 9, 1866); and at Eperies the extinction of this fireball is said to have been

* Accounts of the meteor and investigation of its real course. A memoir in the 'Verhandlungen des naturforschenden Vereins in Brünn,' vol. xiii. p. 81, by Prof. G. von Niessl (received from the author).

† "Contributions to the Cosmical Theory of Meteorites," by Prof. G. von Niessl, of Brünn ('Sitzungsberichte der k.-k. Akademie der Wissenschaften in Wien,' vol. lxxv. part 2, April 19, 1877), containing a description of the fireball of April 9, 1877, and an investigation of its real path, together with some general directions for observing luminous meteors (received from the author).

followed by even more violent detonations than accompanied the descent of that ponderous aërolite. It shot from N.N.W. to S.S.E. over that district of Hungary and Galicia, disappearing at a height of 20 miles over a point about 30 miles south of Iglö and Eperies. It presented the appearance of a bluish ball of light as large as the moon, followed by a dense train of sparks and ending with a great outburst of such corruscations as were likened by some to a tree top, and which produced a most intense illumination. Even at Brünn and in Vienna, where it was seen by Prof. Jelinek, its apparent brilliancy was several times greater than that of Venus, and the duration of its luminous course was variously estimated by different observers at between three and eight seconds. For the position of the radiant-point, seven recorded tracks could be compared together, which confirmed the conjecture, already formed by Prof. von Niessl from the observation at Brünn, of its probable situation in Cassiopeia, by indicating 17°, +57° as its true place (within three or four degrees in right ascension and declination), at an altitude of 23° above the N.W. by N. horizon, from which the meteor was directed. The earliest point of observation of the meteor along this line was obtained at Lemberg, when the fireball was still 200 miles from its point of disappearance and its height above the earth's surface was 100 miles. Comparing the lengths of path and durations together which were observed at Lemberg and seven other places, an average velocity of 25·5 miles per second is found, by giving equal weights to all the individual results—a velocity which, Prof. von Niessl again notices, considerably exceeds, as before, the theoretical velocity (of 14·5 miles) in a parabolic orbit, and points to hyperbolic elements being probably assignable also to this aërolitic fireball's real orbit.

With regard to the observed radiant-points of this fireball and of that of April 10, 1874, a rediscussion of the observations of the latter, retaining some previously rejected observations, enables him to present the following impartial comparison of all the observations available for their computation in each case:—

	Long. of ☊.	Position of Radiant point.		Velocity, in miles per sec.
1874, April 10, 8^h 9^m (Vienna mean time)	20°·2	$\alpha=19°$	$\delta=+57°$	14
1876, April 9, 8^h 20^m „	20°·3	17°	+57°	25·5

The almost absolute agreement of these positions can scarcely be altogether accidental; but it still deserves attention, as Prof. Schiaparelli has pointed out, that unless the velocities agree together, this apparent identity of the radiant-points is not sufficient to establish the identity of the two meteor's orbits, since the cosmical motion is the resultant of two parts, one the motion of the earth itself, and the other the meteor's motion relatively to the earth; and the latter must be the same in magnitude as well as in direction, in order that two fireballs occurring on the same date of the year may have identically the same motions in space, or about the sun, and that the identity of their orbits round the sun can be inferred. It cannot be said that the observed velocities of these two fireballs relatively to the earth were observed to be identical, like their radiant-points; but if, as seems to accord fairly with the observations, a velocity of between 14 and 25 miles per second is accepted as a common speed, with which both of these fireballs moved relatively to the earth, the almost absolute coincidence of their orbits round the sun may then fairly be assumed, and a common origin of this fireball-pair in a system of bodies foreign to the solar system, following each other on nearly the same hyperbolic orbit round the sun, becomes at once a very probable and a new and remarkable conclusion from these very exact recent observations *.

* A case of probable coincidence of orbits of two aërolites is noticed by Prof. Kirkwood in 'Nature,' vol. xiv. p. 526 (Oct. 12, 1876)—those of Menö (Mecklenburg, 1861, October 1, 12^h, noon), and one named by Dr. Lawrence Smith after its donor, Mr. Claywater, who described its fall (in Vernon Co., Wisconsin, U.S., 1865, March 25, 9^h A.M.), having been recently shown by Dr. Lawrence Smith (Amer. Journ. of Science, September 1876) to be almost identical in their composition, as if fragments of one and the same very unusually constituted meteorite. Reckoned on the ecliptic the dates of their fall are 183° or 177° apart in longitude, greatly favouring the supposition that in some conic section, the inclination of whose plane to that of the ecliptic is not necessarily restricted, these two bodies may have been pursuing one and the same astronomical orbit round the sun, whose perihelion (if it exists) must evidently lie midway (in longitude 97° or 277°) between the two points of the earth's encounter with the meteorites. Supposing, however, that no very sensible inclination of the orbit plane to that of the ecliptic should exist, the condition either of conjunction or of opposition (or of a six months' interval between the dates) of two meteoric occurrences is not a necessary condition to their belonging to a common circumsolar orbit; and Prof. Kirkwood mentions the great similarity of composition between the meteorites of Somer Co., U.S. (May 22, 1827), and Utrecht, Germany (June 2, 1843), remarked by Baumhauer, which, if these meteorites were pursuing the same orbit, would oblige us to suppose it to have had two intersections with the earth's orbit very near together, and to have therefore had either no sensible or at least only a very small inclination to the ecliptic. As regards the probable inclination of the Menö-Wisconsin pair of strongly resembling meteorites, a very simple consideration of the aspects of the horizon with regard to the sun and to the apex of the earth's way at the times and places of the two aërolitic falls (which were very analogous to each other at the two places) shows that the perihelion of the common orbit (if it was nearly parabolic) must have had southern latitude, lying somewhere on an arc included between long. 97°, S. lat. 5°, and long. 277°, S. lat. 45°. If with this southern perihelion the descending node of the orbit was at Menö (in ecliptic longitude 8°) and the ascending node was at Vernon Co. (in ecliptic longitude 185°), the meteorites' real courses must have been from a low altitude in the north or north-west at Menö, and from a low altitude above the south to east horizon in Wisconsin. If the reverse was the case, and the ascending and descending nodes of the meteoritic orbit were respectively at Menö and Vernon Co., the meteorites must have come from very near the south- and north-western horizons of those two places; but on neither of these two hypotheses have any cometary orbits been recorded which come even roughly within the wide limits of the requirements established by these astronomical conditions. These are summed up in the following table of the orbit elements necessary to satisfy the known circumstances of the aërolitic falls, and the elements of the comets of 1264 (and 1556), which among several such apparent resemblances entirely fail of satisfying them, are added for comparison in the Table.

Menö-Claywater Meteorites and Comets.	Longitude of ☊.	Radius vector of orbit (⊕'s rad. vect. = 1).	Motion.	Long. of perihelion.	Inclination.	Latitude of perihelion.
Stonefall, in Wisconsin, from north-west.	8°	1·00	Retrogr.	97°	between 5° and 90°.	5° to 90° S.
			Direct.	277°	between 90° and 45°.	45° to 90° S.
Stonefall, in Wisconsin, from south-east.	185°	1·00	Direct.	97°	between 45° and 90°.	45° to 90° S.
			Retrogr.	277°	between 90° and 5°.	5° to 90° S.
Comets 1264 (and 1556); (equinox of 1860).	184°	0·98	Direct.	281°	30°	29°·5 N.

The perihelion of the orbit of the comets 1264 (and 1556) is north of the ecliptic, as are also all those of the comets (of A.D. 178, 1580, 1683, and 1763) which otherwise appear

1876, July 8, about 8^h 45^m (Chicago mean time), Indiana and Michigan, U. S.*—The course of this meteor was nearly from the westernmost point of Lake Erie (beginning at a point 88 miles over Ottohee, Fulton County, Ohio, 30 miles west of Toledo on that lake) to the southern extremity of Lake Michigan (ending 34 miles above a point about 35 miles from Chicago, and 25 miles from Michigan City, over the lake), traversing a distance of 145 miles over the line of junction between Michigan State and those of Ohio and Indiana with surprising brilliancy. Of its real speed of motion the observations of the duration of the meteor's flight unfortunately afford no satisfactory determination. The direction of the flight was from 12° S. from E., alt. 21° [or from about the apparent radiant-point 305°, + 7°, near the small star *k* Aquilæ], as deduced, with the other particulars of its real path, from observations made at Bloomington and Paoli in the south, and at several points in the north of Indiana State, as well as at Chicago. At the latter place, "The meteor was a very brilliant one. It lighted up the sky like the glare of the calcium-light, the intensity being several times greater than the light of full moon." It did not seem to burst; but its matter was apparently exhausted in the latter part of its flight, leaving a luminous train along its track, which remained visible at least 40 minutes. No detonation was heard, and if any stones were precipitated at the end of its flight these would necessarily have fallen into the waters of Lake Michigan.

A writer from Stratford, Connecticut, informed Prof. Kirkwood that at nearly the same hour as that of this fireball's appearance, he noted a brilliant meteor shoot from the northernmost visible star in Camelopardus, about 8° from Polaris, and vanish immediately behind a projecting roof after lighting up the eastern portico from which it was observed. Connecticut being far east of Lake Erie, this observation is irreconcilable with the course of the above fireball, and it must without doubt be ascribed to a second large meteor appearing almost simultaneously with the first. A large meteor, very much resembling that one above described, and like it leaving a very persistent light-streak on its course, was seen on the 8th of July, 1856, in Alabama and Mississippi †, and the occurrence of a stonefall in Spain, Prof. Kirkwood remarks, has been recorded on the 8th of July, 1811; but the absence of any statements in the accounts of its appearance that sounds of an explosion were noticed in connexion with the present fireball, makes it doubtful if with all its brilliancy it may properly be regarded as having been an aërolitic meteor, or one projecting any solid residue of its substance from its track.

1876, December 21, 8^h 43^m P.M. (Bloomington mean time), Kansas to Penn-

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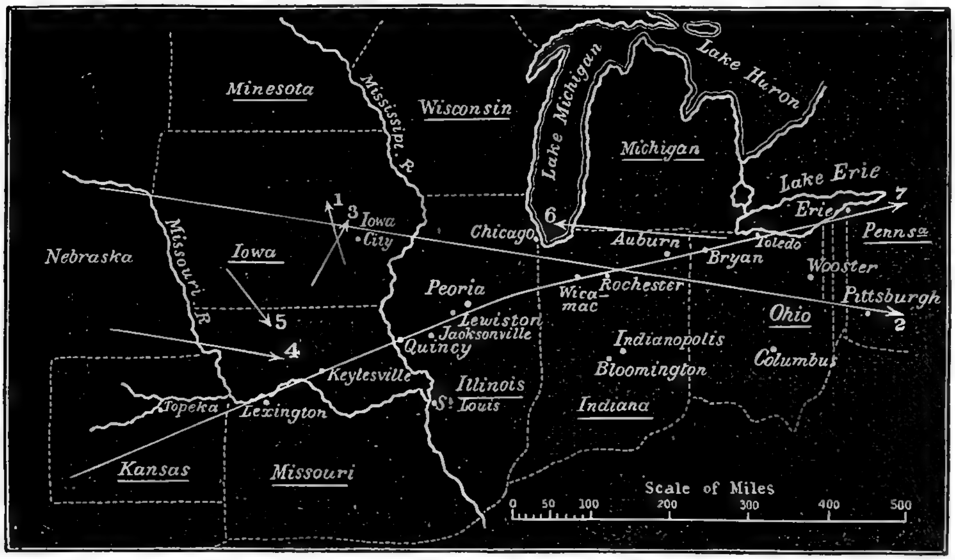
to offer some agreement with the other conditions of the double stonefall. Although it had a high altitude in its descending node, at Menö on October 1, the radiant-point of the comet of A.D. 1264 was in fact 75° below the north horizon of Wisconsin, U.S., when the aërolite fell there, owing to the apse or perihelion of this comet's orbit midway between its two nodal longitudes being at a considerable distance in latitude on the north side of the ecliptic. Even the comet of A.D. 178, which satisfies the conditions generally more nearly than any other, has its perihelion in north latitude 18°, and its radiant-point at the ascending inward-moving node was, for that reason, about 40° below the visible horizon of Wisconsin when the aërolite fell there, as the position of the horizon precludes the impact upon it of meteorites "*ascending*" *and moving inwards* in their orbits from without.

* This account (and other notices below) of bright meteors recently observed in America is contained in a paper "On eight Meteoric Fireballs seen in the United States from July, 1876, to February, 1877," read before the American Philosophical Society by Prof. D. Kirkwood, of Bloomington, Ind., on March 16, 1877, for a copy of which communication the Committee is indebted to the author.

† 'American Journal of Science,' November, 1856, and January and May, 1857.

sylvania and to Western New York, U. S.—A fireball of unprecedented magnificence and length of course (not excluding even the great fireball seen in England on the 18th of August, 1783), was extensively observed in the northern part of the United States of America on the night of the 21st of December last, of which some highly elaborate investigations have been made and an unusual number of exceedingly extraordinary descriptions have been published. The following particulars of its real path and appearance are taken from two very complete discussions of the various accounts and statements concerning it which had appeared, by Prof. H. A. Newton and Prof. D. Kirkwood, in the 'American Journal of Science' of February and March, 1877 (vol. xiii. pp. 166 and 207), and from a further review of its real course by Prof. Kirkwood, contained in a paper (see the note appended to the date and place of appearance of the last meteor) read before the American Philosophical Society on March 16, 1877.



Real tracks of large fireballs observed in the United States of America, 1861–77*.

1. November 15, 1861 (stonefall).
2. September 5, 1872.
3. February 12, 1875 (stonefall).
4. December 27, 1875.
5. January 5, 1876.
6. July 8, 1876.
7. December 21, 1876 (stonefall).

According to Prof. Newton the meteor first made its appearance at a height of about 60 miles over the neighbourhood of Topeka, in Kansas, crossed the Missouri and Mississippi rivers near the towns of Leavensworth and Hannibal respectively, undergoing some explosions over the centre of Missouri State, and breaking into several fragments over Illinois, soon after crossing the Mississippi. The breaking-up continued while the meteor was crossing the States of Illinois, Indiana, and Ohio, and in fact it consisted at this time of a large flock of from 20 to 100 brilliant balls chasing each other across the sky! How far it pursued its course over Pennsylvania into Western New York is uncertain, as a cloudy state of the sky appears to have interfered with its visibility in the latter State, and no accounts of its appearance further east had been received. An appalling sound of an explosion reached the earth in central Illinois, which was less distinct in the southern part of the State, and was not audible at Chicago and St. Louis; but detonations

* Tracks 1–5 communicated by Mr. Irish. For descriptions (except of the Iowa meteorite, No. 3) see pp. 102–4; No. 6, see p. 149.

were heard at Erie, and as far east as Concord, in Pennsylvania. The assigned durations of its flight varied from 15 seconds up to 3 minutes; and the speed with which it pursued its long nearly horizontal course above the earth for a well-determined distance of nearly 1000 miles did not probably much exceed 10 or 15 miles per second. Deducting a certain amount (for the earth's gravitation) from the nearly horizontal altitude, 15° S. from west, from which its course was directed, the radiant-point freed from this zenithal attraction was in the eastern or southern part of the constellation Capricornus, a little south of the ecliptic, where no radiant-point of meteors at the same time of the year appears to have been previously recorded.

With many exact accounts from all points along its course from west to east, Prof. Kirkwood has obtained yet more definite particulars of its real path. Its first appearance, a little S.E. of the zenith of Emporia in Kansas, shows it to have begun its course in the S.W. corner of that State at a height which neighbouring observations make about 70 or 75 miles. When passing the meridian of Bloomington its height, about over Rochester, was 38 miles, and as seen from Wooster its height due north from that town over Lake Erie must have been 29 miles. In its course over Pennsylvania Prof. Kirkwood conjectures from this that its height over that State cannot have much exceeded between 25 and 30 miles; and as after an explosion near the south-western border of New York State it speedily became extinct, it appears to be satisfactorily demonstrated that its real course as a fireball ceased here, and that no particles of its mass can afterwards have escaped out of the atmosphere, although only one small fragment, 12 oz. in weight, is known to have fallen from the meteor. A farmer, 3 miles from Rochester (Indiana), heard this stony fragment fall in the snow (six inches deep), when he left his house to ascertain the cause of the explosion. Returning the next morning to the spot, the meteorite was found close to the spot where it had first fallen and rebounded. In structure it is pisolitic and friable, and from its composition Prof. Sheppard, to whom a portion of it was transmitted, concludes that it resembles the meteorite of Pegu, which fell on December 27, 1857 (in two pieces about ten miles apart, as will be recollected from the accounts and from the discussion of the occurrence of that stonefall which were published by Prof. Maskelyne).

The prodigious violence of the explosion may be gathered from the fact that its sound and jar were heard and felt (and were by some attributed to an earthquake) by hundreds in Monroe Co. round about Bloomington (Ind.), at an interval of 15 minutes, as noted on a clock by one observer near Bloomington, after the passage of the meteor. The corresponding distance, accomplished with the ordinary speed of sound, is 185 miles, representing not the nearest point, over Rochester and Wicamac, of the meteor's course, 135 miles from Bloomington, but a point over Peoria in Central Illinois, where by far the greatest disruption of the meteor in its course must have taken place. Speaking of the meteor's form after this disruption Prof. Kirkwood writes, "When crossing Indiana [according to the exact descriptions at Bloomington] the principal fireball was followed by a train or group of smaller meteors, many of which were superior in apparent magnitude to Venus or Jupiter. The breadth or apparent diameter of this cluster, as seen from Bloomington, was 3 degrees, and its length at least 20 degrees. Its true diameter was therefore five miles, and its length about forty miles. These smaller meteors were chiefly the results of the explosion over Central Illinois. A final disruption occurred over Erie County, Pennsylvania, several minor explosions having taken place during the passage over Indiana and Ohio."

From the list of towns over which its track appears to have been vertical, Prof. Kirkwood concludes that its real course was not a perfectly straight line, and that a convexity towards the north (amounting perhaps to a more or less abrupt deflection at the principal point of explosion) is indicated by the observations near the beginning and near the termination and along the intermediate portions of its track. With this exception, and that the meteor's course approached the earth with a sensible downward inclination, there is no very material difference between the real courses assigned to it independently by Prof. Newton and Prof. Kirkwood. The whole extent of its prodigiously long flight, according to the latter, from the extreme boundary of Kansas in the west to that of Pennsylvania in the east, was not less than between 1000 and 1100 miles!

Accounts in the 'Indianopolis Journal' thus describe the meteor as seen in Southern Indiana:—"A fireball surpassing the moon in apparent magnitude, followed by a great number of smaller meteors, was seen in the northern heavens, from about 10° above the W. by N. to 5° above the N.E. horizon. Many of the meteors following in the train of the principal bolide were larger than Venus or Jupiter. No attempt was made to count them, but their number was certainly nearly one hundred. A remarkable feature of the meteoric group was the slowness of its apparent motion; while it was variously estimated, most of the observers think that its time of flight could not have been less than three minutes." An observer near Columbus, in Southern Ohio, describes it as "a cluster or flock of meteors seemingly huddled together, like a flock of wild geese, and moving with the same velocity and grace of regularity. The colour of their light was a yellowish red, like red rocket-balls. There was no illumination-nimbus or train from them. We saw it first in the west, and some of us only as it was slowly nearing the earth and about crossing the railroad in the north."

From a place on the track, close beneath the point of the meteor's principal outburst and disruption in mid-course, at Jacksonville, Ill., the 'Philadelphia Enquirer' gives a description recording the extreme brilliancy and the startling appearance of the meteor. No notice, however, occurs in this description of the violent explosion, whose sound is said to have been terrific in some counties of Illinois adjoining that from which the writer dates his graphic narrative of the splendid sight. Neither are any descriptive accounts at places near the beginning and end points of its course given in the two memoirs above quoted, which would be of special interest regarding the aspect of the meteor in those parts of its course which were either at or close to the points of its first and last appearance.

Jacksonville, Ill., U. S.—"On Thursday evening [Dec. 21, 1876] a beautiful meteoric display was witnessed here about half-past eight o'clock. The meteor first came in view away to the west, and about 30° above the horizon. It passed but a short distance north of the city, and was finally lost to sight away to the eastward. When first seen it seemed a blazing burning ball, nearly as large as the full moon, and appeared to be moving directly towards this city. As it swept along with its fiery tail, some 20° in length, and some ten to twenty blazing fragments following it [even before the great dismemberment over Peoria, soon afterwards], it presented a sight of surpassing magnificence and beauty. When this great ball of fire reached a point considerably north of east [about over Peoria, Central Ill.], it burst into ten or twelve fragments not unlike in appearance the bursting of a rocket, and these fragments seemed finally to disappear in a bank of clouds which hung near the eastern horizon. The meteor was of such surpassing brilliancy that the whole earth and heavens were lighted up so brightly, that persons could be distinguished at a distance in the streets almost as plainly as in daylight. The light was such that it gave a subdued green colouring to the earth, trees, buildings, and every other object. From the time the meteor was first seen in the west till it was lost sight of in the east, full twenty seconds must have elapsed. A singular feature of the phenomenon was that, instead of passing in its flight earthward, its path from west to east seemed in an exact horizontal direction. Nothing of the kind of such grandeur, brilliancy, and beauty was ever before witnessed here. It was also seen at Burlington, Iowa, St. Louis (Mo.), Laurence (Kansas), and at several places in Indiana."

Regarding the explosions in the early and middle portion of its flight, Prof. Kirkwood states that, "some observers in Missouri report an explosion of the meteor when passing over the central part of the State. At Bloomington, Indiana, Prof. H. B. Boisen, who saw the meteor when due west, and watched it till it disappeared near the eastern horizon, observed it separate into several parts when nearly north-west, or in the direction of Peoria, Illinois." In his estimation of the meteor's real velocity, although very difficult to arrive at accurately, Prof. Kirkwood very nearly corroborates the value given by Prof. Newton, and considers it to have been about 8 or 12 miles per second.

Notices of other large meteors seen in the United States on January 23, and February 8, 1877, contained in Professor Kirkwood's paper, will presently be given, below, in the order of their dates.

1877, January 19, $6^h\ 27^m$ P.M., England and Ireland.—Besides the description at Lisburn, near Belfast (given in the above list), of this large meteor, the following particulars of its appearance at other places were gathered from newspapers and from other sources by Mr. W. H. Wood.

Wolverhampton.—A meteor of unusual magnitude and brilliancy moved almost perpendicularly in a southerly [south-westerly ?] direction, very slowly, the time occupied in its passage being seven or eight seconds. It passed behind a cloud for the space of a second, reappearing with equal brilliancy until it vanished. Colour pale blue; it left no visible streak, although this may have been obscured by clouds.

Walsall, $6^h\ 30^m$ P.M.—A luminous body fell from the heavens, from about the apparent altitude of the moon at the time, in the direction S.W. by W.

Bray, co. Wicklow, Ireland; precisely at 6^h P.M. (Irish time; or $6^h\ 25^m$ P.M., G. M. T.).—A splendid meteor traversed the sky from a point about midway between Orion's Belt and the Pleiades, to a point directly under the moon and about 10° above the horizon. It was pure white and dazzling, and lasted five seconds, emitting no sparks except at the moment of disappearance. It was about half of the moon's apparent size at the time.

The long low flight of the meteor in the south at Bray near Dublin, and at Lisburn near Belfast, 90 miles north of Bray, below the equator, from a little east of the south meridian to an altitude of only 5° or 10° in the south-west (southwards from Saturn, and apparently just below the moon), indicates evidently a very distant line of flight from these towns, which the observations there are not sufficiently exact to make it possible to assign precisely. But their combination with the recorded path at Walsall, near Birmingham (descending in the S.W. by W. from about the moon's altitude), on a course which the Wolverhampton account describes as "nearly perpendicular" towards the horizon, presents a very fair accordance for the point of commencement, and a good determination of the radiant-point and of the remaining portion of the meteor's flight to its termination, if it is assumed that the direction of its fall, so near the moon (which was then due S.W. at Walsall, at an apparent altitude of between 30° and 35°), requires a small westerly correction to about W.S.W., instead of descending in the S.W. by W., as it was described. With this apparent course, or with a direction about half a point *more* westerly at Walsall (which is adopted to diminish the otherwise extravagant length of path and real height of the track found by combination with the Irish observations), the meteor's real path was from 75 miles over the promontory of St. Ann's Head, Milford Haven, to a point 45 miles over the sea at the entrance of St. George's Channel, 130 miles due south of Cape Clear in Ireland, describing thus from the coast of Wales a course to the extreme west longitude of Ireland at about the distance from the Irish coast, along its southern shores, of the Nymph Bank near the middle of the channel. The length of path is about 230 miles, performed with a speed of 35 miles per second (taking $6\frac{1}{2}$ seconds as the mean observed duration at Bray and Wolverhampton), from a radiant-point between 130°, +25° and 140°, +30°, which was then about 10° above the E.N.E. horizon at the places over which the meteor passed. This position, between γ Cancri and κ Leonis, slightly noticed by Mr. Denning (at δ Cancri, see the first list of comet-accordances, p. 167) in the beginning of last January, is new in that month, although catalogues contain positions very closely adjacent to it in the months of February and December. The theoretical speed of a meteor from this radiant-point, having a parabolic orbit, would be 23 miles per second, which would only be satisfied by the observations if the length and real distance of the meteor's course from the observers' stations could be diminished by about one third, or if the observed time of duration of its flight could be increased one half, from $6\frac{1}{2}$ to 10 seconds; either of which assumptions it would not be difficult to reconcile with the scanty data afforded for such determinations by the recorded particulars of this very brilliant and lengthy fireball, seen over a large area of England and Ireland in the twilight sky.

1877, January 23, about 4^h P.M. (local time), Kentucky and Indiana, U. S.—The final explosion of this meteor took place over Harrison County, and an aërolite reached the earth (see the last Appendix of this Report, p. 193) nine miles north of Cynthiana, in Kentucky, U. S. The fireball was observed simultaneously near Bloomington and near Greensburgh, 56 miles east from Bloomington, in Indiana, but only the height at first appearance, which was at least 70 miles, can be roughly assigned from the observed positions. Near Bloomington its visible track was very nearly perpendicular to the earth's surface, descending from an altitude of 35° in the south-east to the horizon of a hill-top, south-east of the observers, behind which it disappeared. In Kenton County, Ky., a rumbling sound was heard as if coming from a point high in the heavens about S.S.E., resembling the discharge of numbers of heavy ordnance blended together, which jarred the earth perceptibly and made windows rattle.

1877, February 8, 2^h 30^m A.M. (local time), Indiana, U. S.—A meteor, about half the apparent magnitude of the full moon, seen near Ellettsville, in Monroe County (chief town, Bloomington), Indiana, U. S., passed a little south of the zenith from south-east to a point 10° above the horizon, 30° or 35° south of west. The body of the meteor emitted numerous sparks in the latter part of its track, and left a luminous streak on its course for several seconds. No sound of an explosion was heard, but its light was so intense that the observer's horse took fright at the sudden vividness of the flash.

1877, April 6, 9^h 26^m P.M. (Greenwich time), Wicklow to Cork Harbour, Ireland.—A detonating fireball passed with great brilliancy south-westwards over the southern part of Ireland, at about 9 o'clock, P.M. (Irish time), bursting about 40 miles S.W. from Cork Harbour over the open sea. A number of published and other particular accounts of its appearance were collected together by Mr. Robert J. Lecky in the 'Observatory' (vol. i. p. 52, May 1877), embracing chiefly a great many points of observation from Cork in the south to Stranorlar in the extreme north of Ireland. Among the most exact accounts were those furnished to him by Mr. R. H. Scott, Director of the Meteorological Office of the Board of Trade, from St. Ann's Head* and Roche's Point, two stations connected with the Meteorological Office, at Milford Haven and in Cork Harbour. The meteor's course was also approximately noted by the stars in Dublin, and at Shillelagh, County Wicklow. It probably commenced its flight 80 or 90 miles over the neighbourhood of the latter place, and proceeded on a south-west course nearly over the mouth of Cork Harbour to a point about 12 miles south of Gally Head, where it burst with a violent explosion (probably at a height of about 20 miles above the sea) heard in three minutes at Roche's Point, and in about five minutes as estimated by observers in the City of Cork. The report was double and so heavy there, and in Queenstown in the harbour, that the houses were shaken, and the powder-mills at Ballincollig, four miles from Cork, were thought to have exploded. It was heard at Waterford and Limerick, 80 or 90 miles from the meteor's point of disappearance. At St. Ann's Head, 150 miles from the same point, and about 100 miles from the nearest point of the meteor's course, its light was equal to that of the full moon, and the body of the meteor, three or four times the apparent size of Sirius, was extended behind to a length equal to the distance between two stars in Orion's belt. It shone with the intensity of the lime-light at Cork, especially at bursting, and objects six miles off were lighted up brilliantly by the glare; at Roche's Point the body of the meteor appeared white, tinged outside with blue, and throwing out jets of coloured light. At Clonmel (under the middle or early part of its course) it was a light blue circular body of some apparent width with, first, a body of crimson flame two or three times its width in length, and then a long train of yellow light following it. At Shillelagh (earlier along the track, where the apparent course was "from the east side of Orion's shoulder to the west of Sirius"), it seemed to "break out again and again, lighting up the country with successive flashes." At Dublin it "fell from the direction of α Orionis, bursting in a shower of vivid sparks." Coloured "stars" or fragments are described as falling from it at other sta-

* It is difficult to reconcile a course beginning "a little west from Polaris" at St. Ann's Head with an observer's view of the meteor between Collon and Drogheda (30 miles north from Dublin), "descending slowly (from an altitude of about 50° in the S.S.W.) *with a very slight inclination towards the east*" (which substantiates perfectly the recorded paths at Dublin and Shillelagh), without assigning an improbable height to the meteor at its commencement. But though the entire course may have had a somewhat more north-west position (laterally shifted about 20 miles) over the southern part of Ireland (as from Portarlington to Cape Clear) than that above assigned to it, yet the slope and the height and direction of the meteor's real path cannot have differed materially from that here described. The length of the path was about 165 miles, and the time of describing it was reckoned at Shillelagh, Thomastown, and Collon, as "three or four," "four to six," and "quite seven or eight seconds." The meteor's velocity with an average of these durations was 31 miles per second, and the theoretical velocity, with a parabolic orbit, of a meteor with the above assigned radiant-point is between 24 and 25 miles per second.

tions; and at Stranorlar, 230 miles from its terminal point, after glancing, red and globe-like and very brilliant, from behind a cloud to the horizon, "suddenly a flame sprang up and all was over" (describing apparently a considerable flash which must have accompanied the terminal disruption).

From the apparent course at Dublin and Shillelagh the commencement cannot have lain southward of the latter place; and if "near the pole star," at first, at St. Ann's Head, it must have then had an elevation of not less than 80 miles. With a south-west flight from this point to a height of 20 miles at disappearance 40 miles S.W. from Cork, a radiant-point of its real course at 275°, +50° is obtained. Although this is suspiciously near the radiant-point of the Lyrids of April 20 (at 270°, + 35°), the course cannot be adjusted to this point without making it very nearly horizontal, a direction of flight which is not at all borne out by the observations; and there is no reason for supposing that this large detonating meteor (even if, like the Lyrids of the brighter class, it had left a long-enduring light-streak) was connected with the cometary or with any tributary system of the Lyrid meteor-stream. Greg's shower 'Draconids I.,' at 267°, +53°, in March and April, also noted by Schiaparelli on April 1 and 14, is the nearest recognized general meteor-system of which this fine detonating fireball may not improbably have been a member.

1877, April 16th, 10^h 50^m P.M., Yorkshire.—A very luminous fireball exhibiting two bright flashes of intense light, descended over the eastern part of Yorkshire, and was visible in many parts of England. Besides the notes of its visible path included in the above fireball-list, the following description of its appearance at Chipstead, Surrey, where its course was well seen, was obligingly communicated to the Committee by Mr. R. H. Scott. The observer, who had seen many meteoric phenomena at sea, had never before witnessed one of such great brilliancy. "The light was so strong, that I could have seen a pin upon the doorstep where I stood"; and it cast this illumination over the surrounding country. It appeared in the north-west as a bluish-white fireball *falling towards the east*, and leaving behind it a long train of sparks. The words italicized corroborate the description at Leicester that it descended in the north (from γ Cephei) on a course inclining eastwards about 30° from vertical towards the right; and from the accordant appearance which its course presented in the north at these two places, the same must also have been about the slope or direction in which it "dropped" (probably at the end of its flight) "from Cassiopeia" above the northern horizon at Cambridge. The direction of its explosion within a point of Conister from the junction of Christian Road and Bucks Road, as seen at Douglas in the Isle of Man, indicates about the neighbourhood of Hull as its locality in the north from Chipstead, Leicester, and Cambridge; but whether it appeared to descend vertically, or with a horizontal or inclined motion at Douglas was not recorded; and no intelligible agreement of its apparent course and position as observed at Newcastle-upon-Tyne with those described at Douglas and at the southern points of view can be extracted from the note of its appearance there, for further determining the height in miles and the position and direction of the meteor's real course. Its radiant-point may be presumed to have been near θ, ι, κ Ursæ Majoris (20° or 30° west of the zenith), and its real path descending from a height of about 60 miles between Leeds and Hull to a height of 30 miles over the sea near the neighbouring coast of Yorkshire, between Flamborough Head and the Humber; but in the absence of good observations of the meteor from that neighbourhood, or from more northern points of view, no exact or positive conclusions of the real direction and position of its visible flight over the counties of the seacoast, near the Humber, can be arrived at.

III. Meteoric Showers.

The moderate intensity of the display of Perseïds on the 9th–11th of August, 1876, was noticed in the last Report. The descriptions of the shower by English observers, which the Committee has received, generally confirm this, although the light of the moon on the 9th, 10th, and 11th concealed many small meteors, and the sky was hazy or partially cloudy at many of the stations. Among the lists of tracks recorded under the most favourable conditions, the following table shows the hourly numbers of conformable and unconformable meteors, respectively, mapped on the principal nights of the shower, together with the percentage numbers of meteors exceeding the first and second magnitudes of the fixed stars, respectively, in brightness which were recorded on the successive nights.

Though the moon's light interfered, yet as it was in its third quarter on the 12th, and as in two hours after midnight on the night of the 11th there were seen at the Radcliffe Observatory, Oxford, 3 fourth mag., 29 third mag., 13 second mag., and only one meteor as bright as a first magnitude star, when the moon was at its brightest, it is evident by comparing this result with the much larger proportion of bright meteors seen on the previous nights, that the most brilliant meteors of the shower were considerably more abundant on the nights of the 9th and 10th than on the 11th. The observations, even where long continued, elsewhere agree with each other very imperfectly in this respect; but

	Date, 1876, August	8.	9.	10.	11.	12.	Totals mapped, Perseïds and unconformable, and meteors of planetary & 1st to 4th magnitudes.
York, J. E. Clark.	Conformable and unconformable meteors per hour	...	(cloudy.)	18, 4	6, 2	9, 3	57, 21.
	1st and 2nd magnitudes, per cent.	...	,,	39, 32	50, 30	32, 32	6, 22, 24, 16, 9.
Sunderland, T. W. Backhouse.	Meteors per hour (for a clear sky)	11	8	14	12	7	42, 11.
	Jupiter or Sirius, and 1st to 4th magnitudes (totals seen)	...	...	...	...	...	8, 17, 9, 15, 9.
Birmingham, W. H. Wood.	Meteors per hour ($\frac{1}{3}$ of the sky)	...	(cloudy.)	5, 3	5, 2	...	14, 8.
	1st and 2nd magnitudes, per cent.	...	,,	50, 40	50, 40	...	1, 11, 9, 0, 0.
Glasgow, R. McClure.	Meteors per hour (cloud and haze)	...	(cloudy.)	10	11	...	(Nearly all Perseïds.)
	1st and 2nd magnitudes, per cent.	...	,,	40, 33	25, 40	...	0, 8, 8, 7, 0.
Radcliffe Observatory, Oxford, J. Lucas.	Conformable and unconformable meteors per hour	...	7, 3	6, 5	8, 6	...	66, 50.
	1st and 2nd magnitudes, per cent.	...	36, 39	18, 36	5, 26	...	3, 16, 41, 55, 3.
Hawkhurst, Kent, A. S. Herschel.	Conformable and unconformable, per hour (clear)	8	11, 2	25, 6	...	...	50, 9.
	1st and 2nd magnitudes, per cent.	...	30, 38	21, 24	...	...	1, 10, 14, 13, 8.

they combine to show that the hourly numbers of the Perseïds, especially as compared with the unconformable meteors visible at the same time, was below the average of what is ordinarily observed. Mr. Backhouse states that, making all allowances for haze and moonlight, the display was by no means equal to that of August 1875; and Mr. Wood, who has watched the appearance of the shower annually for fifteen years, regarded it as decidedly the most meagre and insignificant of all its exhibitions that he has witnessed in that time. In the above analysis of the observations, the shooting-stars counted as "Perseïds" include meteors from several centres, apparently subordinate to the main stream, but associated with it, of which Mr. Clark gives the following positions, η, χ, and α Persei, and ι and γ Cassiopeiæ; the last of these points he regarded as distinctly marked at 10°, +59°·5 on the 10th, and somewhat more diffusely near the same place on the 14th.

An abstract of the radiant-centres, which he obtained from 88 meteor-tracks, recorded between July 16th and 25th at Bristol (chiefly in the two hours preceding midnight), is recorded by Mr. Denning in the 'English Mechanic' of Aug. 4th, 1876, (vol. xxiii. p. 536) in which this radiant in Cassiopeia was shown to be very active towards the end of July*. Fifty-five of the meteor-tracks observed diverged from the following radiant-points. The Cassiopeiads were a marked shower of often very fine meteors, with long courses and trains.

	$\alpha=$	$\delta=$			
July 16–25 1876, Bristol (from 83 meteor-tracks recorded)	18°	+63°,	Cassiopeia	19 meteors, very good.	Schmidt, 6° +59°, July 20–26. Greg, 12° +70°, July 7 to Aug. 4.
	284	+57	o Draconis	14 meteors, good.	
	330	+70	β Cephei	12 meteors, good.	
	298	+ 2	θ Antinoï	10 meteors, good.	
	348	+22	β Pegasi	5 meteors, fairly good.	Schmidt, 342° −9°, July 20–Aug. 31. Neumayer, 337° −10°, August. Tupman 340° −16°, July 27–28.
	337	− 7	Aquarius	4 meteors, fairly good.	

Mr. Greg's average position of this last shower is now at 328°, −12°.

Again, in the following month to August 25th, continuing his observations until (exclusive of Perseïds) 60 more meteor-tracks were reduced to well-centred radiant-points, 9 more of these tracks were assigned by Mr. Denning to the meteor-shower in Cassiopeia, 7 more were assigned to o Draconis, 6 more to β Cephei, and two new meteor-tracks to the radiant-point near θ Antinoï. Only the shower at θ Aquarii was not prolonged; but from β Pegasi, α and β Andromedæ, Honores or Lacerta, α Lyræ, α Cygni, and ζ Ursa Majoris some accurately diverging tracks afforded fairly exact positions of August meteor-showers. Clouds prevented observations between July 26th and Aug. 4th, and meteors were remarkably scarce on July 20th and 25th, and (as regards the Perseïds) also between 10^h and 11^h P.M. on August 11th, when the Cassiopeia shower prevailed, which it did also (with Cepheïds) very abundantly on July 24th. The latter shower was most marked on July 19th, and it was pretty plentiful, accompanied by radiants in Draco and Honores or

* The principal radiant between August 5th and 11th, Mr. Denning found, from 37 Perseïd tracks selected for their accuracy, to be at 43°, +59°, with very little indication of subradiants, unless one of a few meteors from 50°, +59°, (B Camelopardi), and another of less frequent tracks from χ Persei, may have been separately active.

Lacerta, on August 14th; Mr. Clark recorded on that date seven Perseïds and five meteors from other radiant-points in three quarters of an hour; on the 16th, Mr. Clark saw 3 Draconids in half an hour, and Mr. Denning noted two Perseïds between 10^h and 11^h P.M.

Resuming observations during the same periods in the present year, Mr. Denning noted numerous meteors in July and August, 1877 ('Nature' July 27th and Aug. 9th, 1877, vol. xvi. pp. 286, 362), with a similar but more complete list of the radiant-points which were most conspicuous in the middle of July; and among them certain radiants in Cassiopeia and Perseus were very active. These latter correspond approximately in epoch and position to the theoretical radiant-points of the comets of A.D. 770 and 1764, and they appear to be distinct from the true Perseus shower, the first member of which, Mr. Denning states, was not visible until the morning of July 29th, nor any perceptible abundance of them until the 5th of August. During the later period of the first ten days of August, 1877, Mr. Denning recorded 229 meteors unconformable to Perseus, among which a radiant in Cassiopeia was again an active and conspicuous centre of divergence. It thus becomes important to trace in future the exact places and durations of these Cassiopeiad showers, and to fix their dates of maximum abundance, so as to distinguish them completely from the Perseïd shower with which they have probably been confused, and from whose diffuse region of scattered radiation it will perhaps be possible hereafter to separate their meteors.

	α=	δ=		
Principal radiant-points observed at Bristol (W. F. Denning), July 6–20, 1877 (197 meteors seen).	4°	+35°	π Andromedæ;	21 meteors.
	6	+53	α Cassiopeiæ;	11 meteors.
	47	+45	α, β Persei;	5 meteors = ☋ 1764, ☋ (?).
	36	+47	θ Persei;	6 meteors = ☋ 770, ☋ (?).
	(and 15 other showers, in Aquarius, Cygnus, Pegasus, &c.)			
Ditto, Aug. 3–10, 1877 (229 meteors unconformable to Perseus, in a total watch of 15^h 30^m).	333°	+46°.	Lacertids.	
	10	+38	Greg, key map, 1875–76, Nos. 100 and 132.	
	30	+36	,, ,, No. 98.	
	70	+65	A new shower, well marked on the 7th and 10th.	
	315	+51	Cygnids.	
	6	+53	Cassiopeïds, Greg, 1875–76, No. 98.	

Between the 9th and 12th of August, 1876, there were mapped 115 meteor-tracks (by Messrs. Backhouse, Clark, Denning, Herschel, Lucas, and Wood) unconformable to the Perseus radiant region, a preliminary reduction of which was made to assign their radiant-points. No less than seventeen distinct centres of divergence are recognizable in the collection, only the numbers of the meteor-tracks belonging to whose different systems can here be recorded, as they are in general too few to allow positions of any important accuracy to be derived from them; and further corroborations of these meteor-systems contemporaneous with the Perseus shower will be required to define their real centres with precision.

ladiant-centres, ug. 9–12, 1876.	Cassiopeia.	ο Draconis.	α Pegasi.	Honores.	θ Aquarii.	Musca.	β Aurigæ.	Ursa Maj.
Meteor-tracks signed to them.	16	13	10	9	8	8	8	7

Polaris.	η Draconis.	η Herculis.	γ Pegasi.	μ Aquarii.	Delphinus.	Cygnus.
6	5	5	5	5	4	3

One or two meteors with short tracks also indicated radiant-points near 5 Vulpeculæ or θ Serpentis and ι Ophiuchi; five or six Pegasids were derived by Mr. Clark from each two points at 337°, +25°, and 355°, +18°; and on reprojecting all the Draconids of Aug. 6-14, 1870–73 (14 meteors), which he had observed, Mr. Clark obtained from them a good centre point at 276°, +55°, showing them all to have proceeded from a radiant-point near *o* Draconis.

1876, Aug. 13th, 10ʰ P.M. local time, New Plymouth, New Zealand.—"A singular discharge of small meteors was seen here on the 13th inst. [August 1876] from the E.N.E., which lasted an hour, at about 10ʰ P.M. A person to be trusted told me that there was a very brilliant one afterwards, over the sea, very near the horizon. They appeared to descend in all directions."—Letter from Mr. Wm. Crompton, communicated to Mr. Glaisher by Mr. J. Crompton, Bracondale, Norwich.

The time of this shower corresponds to about Aug. 13th, 10ʰ A.M., mean time at Greenwich. The shower cannot have been a branch stream of the August Perseïd-shower, as the radiant-point of that shower near η Perseï was 35 degrees below the N.E. horizon at New Plymouth at the time of the occurrence. The stars ε Pegasi and α, β Aquarii were about 20° or 30° above the N.E. and E.N.E. horizon when the phenomenon was observed, and it may have been from these constellations that a flight of more numerous and frequent meteors than usual was directed.

1876, Aug. 23rd.—Mr. T. W. Backhouse observed several shooting-stars on this night. Out of 15 tracks mapped, 4 and perhaps 7 appeared to be Perseïds; some others were swift meteors, and they probably belonged to the radiant No. 78 in Greg's list, 1874.

1876, Sept. 21st.—A good centre of radiation of several extremely small meteors was noticed by Mr. H. Corder, at Writtle in Essex, on this night, at 352°·5, +16°·5, in Pegasus; and it was the most conspicuous centre of divergence of ordinary meteors which he noticed during August, September, and October. The following list includes all the results of his observations for some months up to the latter date*.

"*Radiants in July.*—Upper part of Aquila and of Cygnus; near α Aquarii (on the 29th); two radiants in Lyra; west part of Pegasus; and Cepheus.

"*Radiants in August.*—On the 9th, 15 [? 5] Vulpeculæ, γ Cephei; on the 10th, Perseus, ε Pegasi; on the 11th, Cygnus.

"*Radiants in September.*—Lacerta (17th, 21st, and 23rd), principally small meteors; δ Cygni (20th and 21st); Pegasus, 352°·5, +16°·5, or +17° (on the 21st; ten of the smallest meteors on this date); near Polaris (near the end of the month).

"*Radiants in October.*—Near Polaris (nearly every night to about the 18th). Near β Tauri, or a little south of β (13th and 16th), rather large orange meteors with trains and long courses. Numbers of small meteors from Aries, Musca, Triangulum, and Lacerta, those from Aries generally getting brighter. Cassiopeia (14th–18th), nearly all 3rd and 4th magnitude, with short courses near the radiant; very white, frequently brightening; a very distinct family. The end of the month quite overcast.

On September 21st, in 2½ hours,	43 meteors;	12 to 30 per hour.
On October 14th, in 2¼ hours,	36	,,	16 per hour.
October 13th–18th (inclusive)	106	,,	about 9 per hour.

* A brief account of these observations was given by Mr. Corder in the 'Astronomical Register' (November 1876). Mr. Denning was noting meteors on the night of September 21st, somewhat earlier than the hour (from 8ʰ 15ᵐ to 11ʰ P.M.) of Mr. Corder's watch, when small meteors were plentiful at Writtle, and he recorded them as rare on that night during the hour when he observed. The marked prevalence of small meteors from Pegasus must therefore either have been local, or have presented itself later on that night than during the period of Mr. Denning's watch.

1876, October 18th–21st.—The only observation which appears to indicate a return of the Orionids of October, on the annual dates of the 18th–21st, was recorded by Professor Kirkwood, in the following paragraph in the 'New York Tribune' of October 27th, 1876:—

"Shooting-stars in unusual abundance, as I am informed by trustworthy witnesses, were observed at this place last evening (October 18th) from 6^h 45^m to 9^h. The meteors appeared to radiate from Auriga, or rather from a point between Taurus and Auriga. No count was kept, but the numbers were such as to attract the attention of several persons in the street. Most of the meteors were small, though two were observed of extreme brilliancy." Professor Kirkwood adds that in consequence of a meteor-shower of this epoch having been recorded * in 1436, 1439, 1743, and 1798, returns of which were observed in 1838 and 1841, a strict watch should be kept on the annual date of the present meteor display for any future apparitions of the shower that may hereafter be observed.

A similar announcement appeared in the 'Newburyport Herald,' Massachusetts, U. S.; 'New York Observer,' November 9th, 1876 (see the list of fireballs in this Report, p. 110, for the description of a large meteor which it records).—"A meteor of remarkable size and brilliancy passed from the zenith to the south-west, at 2 o'clock on the morning of the 19th [of October, 1876], leaving a train which remained visible over a quarter of an hour. While the train was being observed, a large number of smaller meteors passed, as often as one a minute, over the same field [from Taurus towards the south-west], one or two of them leaving a slight train." The time of occurrence of this meteor-shower would be five or six hours later, in local time at Greenwich, its commencement accordingly occurring in England at about midnight on the night of the 18th of October, when no observers of shooting-stars in England were upon the watch.

At Bristol Mr. Denning's nightly registers of meteors were pursued in October, chiefly in the early hours of the evening, with the following results:—

Date, 1876, October	13th.	14th.	15th.	17th.	19th.	21st.	25th.	29th.	Total.
ration of watch...........	3^h 30^m	3^h 30^m	5^h	45^m	2^h 30^m	3^h 15^m	3^h 15^m	1^h 15^m	23^h
. of Meteors { seen	19	23	28	11	17	29	13	15	155
. of Meteors { mapped...	16	18	23	9	12	21	11	12	122

Besides these tracks, 28 meteors were mapped between the 10th and 20th of September, making a total of 150 meteor-tracks for September and October.

Very few of the meteors mapped proceeded from either of the well-marked radiant-points for the month, near ν Orionis and δ Aurigæ; but a radiant, in the constellation Musca, of small trainless meteors with short swift courses (at 46°, +26°, 19 meteors, principally noted on the 15th), was in great activity during October, and 15 other radiant-points comprised the rest of the recorded paths in about equal numbers among their radiations. The very slow-moving

* See these Reports, vol. for 1871, p. 51; and Prof. Kirkwood's work, recently published, on 'Comets and Meteors.' In the 'Astronomical Register' of May 1877 (vol. xiv. p. 124), a letter from Mr. E. F. Sawyer, of Boston, U. S., records the results of 21 months' meteor watchings, giving 2·4 meteors as the average half-hourly number there at 9^h to 9^h 30^m P.M. The number reached six on 1875, May 26, July 30, Oct. 31, and 1876, Oct. 17 and Nov. 13. Of the ten seen on Oct. 17, 19, and 20, 1876, five bright slow ones diverged accurately from the star α Ceti (44°, +4°). This is probably the radiant Tupman 81 (43°, +4°, Oct. 14), a neighbouring shower to the 'Eridanids' of September and October, at 40°, −6° (Greg, 138).

Piscids (at 15°, +11°, near δ, η, 14 meteors) were the next most active shower, and a rather large proportion (13) of the meteors also came from a point in Cassiopeia, at about 14°, +50°; others of the radiant-points detected by Mr. Denning in October are included in the Table given below (pp. 166, 167), and some of their positions will be referred to again in this Appendix.

The 'Leonids,' 'Andromedes,' and 'Taurids,' in November 1876.—No marked returns of the periodical meteor-showers of the 14th, 15th, and 27th of November were detected in 1876. A single determination of the radiant-point in Leo was, however, made by Mr. Denning, from five distinct Leonids (three of them small and short near the radiant-point), leaving white streaks for two or three seconds, on the mornings of November 19th and 20th; constant rainfall interrupted meteor observations almost completely on the ten preceding days, and it is not possible to say if this observation indicated a later recurrence of the Leonids in 1876 than was ever discovered previously among the latterly diminishing evidences of their annual displays. A fine "Leonid-like" meteor, seen by Mr. Backhouse on Nov. 11th (see the fireball list), may not impossibly have belonged to a different meteor-system (in Leo Minor) of which Mr. Denning found, last November, many members leaving streaks, and of great swiftness, abundant in the later days of the month*. Of the 'Andromede' star-shower of November 27th no recognizable meteor representatives were observed.

Mr. Denning and Mr. Corder were again successful during the month of November in securing a great number of observed meteor-paths, and in deducing from them their radiant-points. Up to this time 1300 meteors (including Perseïds) had been registered by Mr. Denning, and his revised list of 52 radiant-points, deduced from 740 ordinary shooting-stars and 560 Perseïds, was communicated to the 'Astronomische Nachrichten' at the end of October, where it formed an extension of a shorter list of 27 radiant-points communicated in April of the same year to the Royal Astronomical Society, and already included in the 'Monthly Notices' of the Society for April, 1876 (vol. xxxvi. p. 284). During November and following months of the past year Mr. Denning's observations were resumed more often and systematically than before, and were continued chiefly in the morning hours of the night, after moonset, when few observations of shooting-stars had hitherto been collected. The Journal of his observations contained at this time 464 meteor-tracks, recorded since January 1876, and by its comparison with that kept at the Radcliffe Observatory, Oxford, and with other lists furnished to them by observers during the same time, the Committee was able to trace among these records fifteen or twenty simultaneous observations of ordinary shooting-stars, particulars of whose appearance have been given in a foregoing list (p. 126). The advantage, in frequency, of the meteors observable in the morning hours over their rate of visibility before midnight was soon found by Mr. Denning to be very sensible. Thus in 23 hours of observation (nearly all P.M.) between October 13th and 29th, 1876, 155 meteors were mapped, while 212 were registered in 25¾ hours (both A.M. and P.M.) in November; of these latter

* The two meteors simultaneously observed at Stonyhurst and at the Royal Observatory, Greenwich, on the morning of Nov. 15th, 1875 (see the list of shooting-stars doubly observed, above, p. 126), one of which appeared stationary, at the latter place, at 158°, +40°, and of which the other had a radiant-point at 154°, +37°, seem both to have been early representatives of the same shower in Leo Minor, whose radiant-point on Nov. 26–29 Mr. Denning found to be at 155°, +36°.—[On the nights of Nov. 5 and 7, 1875, Mr. Backhouse saw 14 meteors in about an hour of cloudless watch, chiefly directed from the radiant-point R_4; and one or two meteors, apparently 'Andromedes,' in 20 minutes' watch on the night of Nov. 28th. (Note omitted from last year's Report.)]

79 were seen in 13¾ hours before midnight, and 133, or nearly double the number, in 12 hours of observation after midnight. Since November last Mr. Denning has continued his early morning observations of shooting-stars at Bristol, whenever the absence of the moon and of overcast and tempestuous weather, which were especially prevalent during many months at the beginning of this year, would permit him to persue them with success.

The best-known meteor-shower in November, to which Mr. Denning's and Mr. Corder's attention was specially directed by the abundance and by the large size and brightness of its meteors, was that of the 'Taurids,' of whose epoch and radiant-point, in the early part of November, many very accordant accounts have already been given in different observers' catalogues of meteor-showers. Two or three different centres of divergence of these meteors, besides the double focus principally assigned to them (at 51°, +13°, and 56°, +21°, in the early part of November) in Captain Tupman's list, appear to exist simultaneosly with this; and the result of Mr. Corder's and Mr. Denning's observations is to trace the continuation of a shower, with nearly this general region of divergence, for several weeks in October and November, presenting various dates of maxima and subordinate radiant-points belonging apparently to its group, followed by another shower of Taurids towards December, the position of whose radiant-point is sensibly different from that of the already known Taurids of the first few weeks in November. The earliest symptoms of the return of these closely allied Taurid showers were noticed on the 13th and 16th of October, by Mr. Corder, producing fine orange-coloured meteors from the direction of β Tauri (79°, +28°; Mr. Denning's position for October 21–29 was at 61°, +18°). Between the 7th and 16th of November the position of the radiant-point appeared to Mr. Corder to lie sometimes on the S.W. and sometimes on the N.E. side of the Pleiades, between the usually assigned position (52°, +22°, from 19 meteors between November 7th and 10th) and a point near ψ Tauri (at 58°, +28°, from 8 meteors on November 16th and 17th). Somewhat more distant points were found at

60°	+26°	Nov.	9–10	3 meteors,
63	+ 9	„	16–17	6 meteors (pretty good position),
67	+26	„	16–17	4 meteors (with short courses),
69	+20	„	16–17	6 meteors (good position),
62	+22	„	21	3 meteors,

showing an apparent tendency of the radiant-point to advance in right ascension towards the middle of the month, without at the same time ever departing very far from the position which it occupies in the early days of November. Radiants of five or six meteors each were also noted near β Persei (44°, +37°), χ Andromedæ (24°, +43°, one at least of which seemed to be a member of the Bielan comet shower), and α Aurigæ (75°, +45°), which are distinct, but not always very easily distinguished meteor-systems, from the Taurus shower.

Besides the position already noticed in October, Mr. Denning found the position of the 'Taurid' radiant-point, from 19 meteors recorded in November, to be at 58°, +16°, and 62°, +22°·5. Seven of these meteors (from the first point) were seen on the morning of the 8th, and nine meteors (from the second point) on the morning of the 20th of November. They formed an exceedingly fine shower on the latter morning, and the position of the radiant-point on that morning was obtained with unusual exactness. Mr. Denning regards the three positions which he observed from October 21st to the end of November as all belonging to a continuous shower (at 60°, +19°), which, in distinction from later showers in the same vicinity, he has designated "Taurids I." The immediately following shower-system, "Taurids II.," with a radiant-point near β, ζ Tauri (78°, +25° Corder, and 80°, +23° Denning, from Nov. 22 to Dec. 14), he regards as distinct from a continuation (at 57°, +26°) of the ε or η and ψ Tauri shower of November, which he observed in sparing activity from November 28th to December 24th, and which he identifies, under the title "Taurids III.," with the long-enduring shower AG_1 in Greg's list, at 60°, +20°, lasting from Dec. 21st(?) to Feb. 6th. The new shower near β, ζ Tauri presented a very decided maximum, nearly half of all the meteors seen in a watch of $3\frac{1}{4}$ hours proceeding from it, with a well-marked radiant-point on the morning of December 6th, while few symptoms of this new Taurid shower remained in activity after the morning of December 8th.

Among other conspicuous new showers detected by Mr. Denning in November and December 1876 (some of the chief of which he noticed and described in letters in 'Nature,' vol xv. pp. 158, 217) a very important one, situated in Leo Minor, at 155°, +36°, was remarkably fine and abundant on the mornings of November 26th to 29th, furnishing (about equally in those successive nights) nineteen meteors with a very exactly defined centre of divergence. It appears not to have been quite unnoticed in the earlier radiant lists of other observers on dates extending from November 7th to December 9th; but the present date and position agree, much better than any previously assigned to it, with the time and direction of the earth's nodal conjunction, with a meteor-stream following the orbit of the comet 1798 II. at its descending node (Dec. 2, 162°, +34°); and it may be added that the brightness of the "Taurid I." shower on the morning of November 20th, at 62°, +22°, is also in much better agreement as to date than any earlier observations had been, with a pretty close appulse to the earth's orbit of the comet of 1702, about the 27th of November, with a radiant-point at 56°, +20°. The Leo-Minorids are swift white meteors, leaving very bright, persistent streaks, and presenting a great resemblance to the Leonids, with which, perhaps, some bolides of its stream, visible before the hour when Leo rises on the east horizon, may have been occasionally confused (see a note, *ante*, p. 162, of some meteors, apparently of this shower, visible on the morning of November 15th, 1875).

Several other cometary radiant-point positions were remarkably identified with recorded star-shower centres during Mr. Denning's observations in November and December, 1876, the principal of which may be here briefly noticed. To make the list of observed meteor-showers presenting analogies with cometary orbits, as indicated by Mr. Denning's recent observations, complete, some examples of such coincidences in September and October and in January and February, as well as the more frequent accordances which were noted in November and December last, are included in the Table (p. 166). The present list of twenty such comparisons would be much increased if those obtained during later months, when (the overcast state of the sky preventing regular observations) Mr. Denning's investigations were chiefly confined to a systematic examination of the long lists of meteor-tracks in printed and MS. catalogues which the Committee has during the past few years received from observers in Austria, Hungary, and Italy*, could be regarded as of the

* The Catalogue of shooting stars observed by the Italian Luminous-Meteor Association (see these Reports for 1872, p. 108) in 1872, containing about 7000 meteor-tracks, including Perseïds, was, a few years since, presented to the Committee, and a still larger catalogue of about 12,000 shooting-star observations, made in later years by the same Association, has quite recently been presented to Mr. Denning by Professor Schiaparelli. Professor Weiss, of the Imperial Observatory of Vienna, transmitted to the Committee, during the past year and in 1874 (see these Reports for 1874, p. 344), two volumes of observations of

same original importance, and were to be comprised in the same Table with his own independently observed determinations. A separate table (p. 168) of eleven such comparisons is annexed; and from the care bestowed upon its reduction and verification, a very important one is besides included in the previous table, presenting a very close analogy with the orbit of Donati's comet, near the date of the earth's nodal conjunction with it on September 8th. It is scarcely possible to say exactly what importance may really be attached to such apparent accordances of meteor-showers with comets, whose recorded paths are in general very far from even nearly intersecting the earth's orbit where they pass nearest to it; but many such cases of exact accordance in time and position of the radiant-points of some meteor-showers with those of comets whose orbits are far removed from proximity to the earth's orbit have now been detected. One of the most memorable and at the same time extreme instances of such defective correspondences is afforded by the coincidence first noticed by Schiaparelli (and here reproduced in the second list of Mr. Denning's accordances), where the perfect parallelism of the 'Coronids' (of about April 11th) with the distant orbit of the great comet of 1847 must, in spite of the excellent agreement between them, be ascribed to accident, unless very bold hypotheses of the mode of derivation of meteor-streams from comets may be adopted to explain it; for the nucleus of the comet in its node and perihelion almost grazed the body of the sun, and only the lengthy tail which it swept or wheeled round with it can be supposed to have reached and even to have extended far beyond the orbit of the earth! What quantity of matter, visible and invisible, may be thrown off from comets by the cloud-jets which appear to be projected from them on all sides during their circumsolar passages, and what forms and varieties of meteor-streams this matter and that projected in the tail may possibly produce, associated with large comets, remains a reasonable subject for conjecture; and no impossibility exists that feeble streams, allied in their radiant-points to such large comets as Donati's and the first comet of 1847, and perhaps to all the ancient comets and to those recent ones which have been more or less plainly visible to the naked eye, may be occasionally detected by observers. It is in fact remarkable that among the plentiful instances of good agreement which might now be enumerated, at least one half (as will be seen by consulting the above two lists) are partial or defective by the remoteness of the comet's orbit, and not nearly so many can be ranked and regarded as unexceptional by the closeness of the conjunction or by the practically direct intersection of the comet's orbit with the orbit of the earth. The new-found accordances, and those which are now established much more closely than before by Mr. Denning's recent observations and reductions, are marked with an asterisk (*) in the lists; and fifteen out of seventy good resemblances (which the total number of approximate cometary coincidences has now reached) have either been brought to light or are raised to a position of considerable certainty, for such determinations, by the close watch and well-directed labour of a few months of meteor-mapping with which Mr. Denning has (prompted by no other

shooting stars made in Austria, under his directions, during the years 1867–70 and 1871–74; the first of these volumes contains 3196 and the second 3039 observations, in which are included some lists and accounts at the Bielan shower of November 1872, and many observations at Herr von Konkoly's observatory at Ogyalla, in Hungary, to whom the Committee is also indebted for a list of meteor-tracks recorded there during the years 1872–73. Besides these lists, Mr. Denning examined and projected the unreduced meteor-tracks contained in Captain Tupman's Catalogue, and the long lists recorded at the Radcliffe Observatory, Oxford, and, during the year 1869, by Padre Denza, at the Observatory of Moncalieri, near Turin.

Comparison of Meteor-showers observed in September to December 1876 and in January to February 1877 by W. F. Denning and H. Corder, with the nodes and radiant-points of Comets.

Comet's Node or Appulse.	Day of Conjunction with Cometary-shower (1875).	Distance of ☋'s orbit from ⊕'s orbit.	Cometary Radiant-point (1875). α δ	Radiant of Meteor-shower (observed or reduced, 1876). α δ	Date or Duration of Meteor-shower (observed or reduced, 1876).	Remarks; and Appearance of the Shower, as observed by W. F. Denning.	General Notes, and References to other Observations of the Shower in 1876 or in former years.
1858 VI. ☋ (Donati's).	September 8 (*).	−0°·29	100° +59°	101° +57°	Aug., Sept., Oct.	....	Reduced by W. F. Denning from 40 meteors in Tupman's, Lucas's, Italian, and other observations.
				99 +57	September 1–15.	....	Reduced by W. F. Denning from 33 meteors in the Italian observations, 1872.
1769 ☋	September 28.	(−0·02)	24 +17	11 + 8 20 +14	September 10–20. October 13–29.	9 meteors } very slow moving. 4 meteors }	'Piscids I." (near δ, η Piscium); well confirmed by Schmidt, Sept. 1–10.
1825 II. ☋	October 7.	−0·11	134 +77	161 +84 [133 +79	Sept. 20 to Oct. 29. Oct. 2–4, 1877.	7 meteors; extremely swift 13 meteors.]	Polarids of October; confirmed by Heis.
1850 II. ☋	October 19.	−0·12	2 +54	15 +52	Oct. 13 to Nov. 8.	20 meteors; small, not swift	Cassiopeiads ... } Confirmed by Schmidt, and by reduction of Hungarian observations, 1872.
				22 +58	October.	....	H. Corder, 1876 }
1842 II. ☋	October 21.	−0·14	81 +57	90 +58	October 14–25.	6 meteors; swift; shower well-marked.	Agrees with Greg, $F_{1,2}$, Sept. 17 to Nov. 24, 88°(±5), +52°(±3).
1848 I. ☋	October 25.	−0·23	78 +60	69 +66	Nov. 8 to Dec. 6.	14 meteors; very active shower before Nov. 20.	[Nov. 22 to Dec. 14, 80°, +50° (Denning and Corder).]
1695 ☋	November 1.	−0·12	318 +53	309 +64	October 13–25.	5 meteors { feeble showers in Cygnus and Lacerta, 1876.	Confirmed at 300°, +55°, Oct. 19, by 10 meteors in the Austrian observations, and by Schmidt, Nov. 1–13.
				299 +50	November 7–25.	5 meteors {	
				310 +60	November 16 & 17.	....	H. Corder; two or three meteors, 1876.
1097 ☋	November 1 (*).	−0·06	205 +48	208 +43	Nov. 21 to Dec. 20.	17 meteors; a bright maximum (7 meteors) on Nov. 26, A.M.	Confirmed at 201°, +44°, Nov. 13 to Dec. 10, by 8 meteors reduced from Italian and Austrian observations, 1872.
837 I. ☋	November 4 (*).	+0·34	104 +27	110 +23	Oct. 25 to Nov. 23.	12 swift meteors; a good position, max. Oct. 30,	The 'Gemellids,' near Castor and Pollux; a marked October to

				106 +23	November 16 & 17.	....	H. Corder, 1876; 4 or 5 meteors with streaks.
1582 ☋	November 9 (*) (?). (orbit uncert.)	0·00(?)	89 +36 (?)	86 +36	Nov. 9–10 & 7.	....	H. Corder, 1876; radiant of large meteors.
				85 +33	November 22–30.	5 meteors, continued in Dec.	Nov. 22 to Dec. 14, 80°, +42°; Aurigid ($F_{1,2}$) branch shower; Corder and Denning, 1876.
1821 ☋	November 11.	+0·03	86 +19	79 +21	November 22–30.	5 meteors, continued in Dec. with a maximum (10 meteors) on Dec. 6, 1876.	[Continues to Dec. 8, 80°, +23°, 20 meteors; and confirmed Dec. 7–13, at 83°, +23°, by 27 meteors, Austrian observations.]
1813 I. ☋	November 24 (*).	−0·30	147 0	148 + 2	Nov. 25 to Dec. 21.	6 meteors in Nov., 5 in Dec.; swift, white, with streaks.	In Sextans; a new shower.
1702 II. ☋	November 29 (*).	(−0·07)	56 +18	62 +22	Oct. 21 to Nov. 24.	20 meteors; slow, long courses; a good mean of three successive positions.	Taurids I.; maxima on Nov. 8, and (9 meteors Denning, 3 meteors Corder) on Nov. 20 and 21, 1876.
1798 II. ☋	December 2 (*).	−0·14	162 +34	155 +36 (accurate.)	Nov. 20 to Dec. 13.	26 meteors; swift, white, with streaks; (max. 21 meteors, Nov. 26–29).	'Leo-Minorids.' (Confirmed by Austrian observations, Nov. 13 to Dec. 13, at 160°, +32°, 10 meteors.) A fine A.M. shower.
1818 I. ☋	December 3 (*).	−0·20	359 +53	342 +62	Nov. to Dec.	14 meteors	In Cepheus. (Five Italian and Austrian tracks, Dec. 7–13, give 333°, +59°.)
1812 ☋ Pons's.	December 6 (*).	−0·20	200 +68	210 +67	Nov. 25 to Dec. 14.	....	H. Corder, 1876; also confirmed by 9 meteors, Austrian observations, Dec. 7–13, at 200°, +67°; and strongly confirmed by Italian observations, 1872.
1858 I. ☋ Méchain's.	December 20 (*).	+0·08	221 +77	209 +67 240 +70	} Dec. to Jan.	19 meteors.	
1846 VII. ☋	December 12–17.	+0·09	200 + 4	207 + 5	Dec. to Jan.	12 meteors	Near Arcturus. Fully confirmed by Austrian observations.
1680 ☋	December 26 (*).	−0·05	132 +21	130 +20	Dec. 21 to Jan. 5.	A feeble shower	At δ Cancri. Confirmed in December by Schmidt.
1759 III. ☋ and Perihel.	Jan. 19 to Feb. 8.	(−0·05)	210 −15 to 231 −21	210 −13	Jan. & Feb.	5 meteors; observed 1877.	Confirmed by 10 meteors in Tupman's Catalogue, at 204°, −10°, Jan. to Feb.
1672 ☋	January 20.	+0·04	256 +20	251 +23	Jan. & Feb.	11 meteors; observed 1877.	Confirmed by other observations.
1857 I. ☋	February 2.	+0·03	261 +23				

(*) Marked thus in the present lists, are new accordances determined by these observations and reductions.

Comparisons of Comet-nodes with Meteor-showers in January to July, observed or reduced from Catalogues of Shooting-stars by Mr. Denning.

Comet's Node or Appulse.	Day of Cometary Shower (1875).	Distance of ☋'s from ⊕'s orbit.	Cometary Radiant-point (1875). α	δ	Radiant-point of Meteor-shower. α	δ	Duration of Meteor-shower.	Remarks. References to the Lists of Meteor-tracks examined and reduced, and to earlier notes of the meteor-shower and of its cometary accordance.
1860 IV. ☊	January 6 (*).	−0·04	187°	−22°	188°	−26°	Jan. to Feb.	Near β Hydræ; 8 meteors in Tupman's Catalogue.
1718 ☊	January 29 (*).	+0·03	208·5	−31	209 to 218	−27 to −37	Jan. to Feb.	Two feeble showers; 8 meteors in Tupman's Catalogue. Confirmed by Tupman, at 198°, −22°, Feb. 3–10.
1746 ☋ and ☊	February 25 to March 8 (*).	−0·03	33	+33	33	+36	Feb. 20 to Mar. 1.	10 meteors; an active shower; Austrian observations.
		(−0·01)	30	+28	28	+35	Feb. to Mar. 12.	Near β Trianguli; 16 meteors in Italian list.
1231 ☋	March 10 (*).	(+0·06)	32	+31				
961 ☋	March 23 (*).	+0·27	308	+12	301·5	+12·5	Mar. 1–19 and April 19–22.	Two almost coincident showers, observed in 1877 (Denning).
1857 V ☋	April 4 (*).	−0·28	302	+11	304	+12	April 1–22.	Delphinids; 15 meteors in Austrian and Italian catalogues.
1847 I. ☋	April 11.	−0·95	231·5	+27	235	+25	April 1–13.	Coronids; 19 meteors in the Italian list. A well-known shower, and a very numerously confirmed accordance (?).
1748 II. ☋	April 22.	−0·11	255	+27	255	+27	April 1–13.	Herculids; 9 meteors in Italian list. Confirmed by Schiaparelli.
1618 III. ☋	June 10 (*).	+0·10	273·5	+ 0·5	273	− 3	June 10–13.	11 meteors in the Italian list. Confirmed by Schmidt and Neumayer in June.
1781 I. ☋	June 14.	−0·19	338	+57	337	+59	May 26 to June 13.	10 meteors in the Italian list. Confirmed by Heis in May and June.
1850 I. ☋	June 24.	+0·06	312	+61	312	+63	May 26 to June 13.	5 meteors in the Italian list. Confirmed by Greg and Herschel (1867 and 1874).
1822 IV. ☋ 1822 III. ☋ 1770 II. ☋	June 25. June 30. July 13.	+0·14 +0·11 −0·09	348 342 349	+28 +14 +12	343	+16	June 1–13.	8 meteors in the Italian list. Confirmed by Schmidt, Greg and Herschel ('Pegasids'), and Tupman in June, and by many observers in July and August.
770 ☋	July 8.	+0·20	39	+45	35	+47	June 1–13.	6 meteors in the Italian list. (An accordance of this comet, and of the comet of 1764, with meteor-showers observed by Mr. Denning in July 1877 is also noticed *antè* p. 159.)

succour and incentive than that of his own unfailing ardour in these investigations) succeeded in surpassing, during the past year, in his own catalogue of meteor-showers the number which any single observer has before been able to chronicle in a protracted time of many successive years of observation. Sufficient illustrations to describe in full the particulars of the meteor-showers which he observed, and the characters of their appearance, in which he was confirmed by Mr. Corder's simultaneous observations, and by the reductions which he contemporaneously made of foreign observers' catalogues, cannot without the aid of tables be presented for discussion in the concise form which the limits of space assigned to this Report require. Comparative Tables of the new meteor-showers and radiant-points, showing the values attached to the observations and the extent to which they agree among themselves and extend or assimilate with earlier determinations, have been arranged and compiled by Mr. Greg, and will be found at the end of this appendix.

Speaking of his observations in October last, when the 1300 meteor-tracks from which his last published list of 52 radiant-points was constructed were all recorded, Mr. Denning wrote, "I found meteors rather frequent between the 13th and 29th of October. Altogether I watched 23 hours (chiefly before midnight) and saw 155 meteors, of which I recorded 122. Subtracting 2 hours of moonlight (when only 4 meteors were mapped), and deducting one sixth from the time of the watch, during which my attention was engaged in mapping, temporary absence, &c., we get an average horary number of 8·6 meteors for October 13th to 29th (P.M.), 1876; but I hardly think meteors during this period were more frequent than during the latter half of July, when Cassiopeiads, Draconids, &c. were very active.

"Confirming a remark which was made some time ago, that the luminous streak of a meteor will occasionally brighten visibly after the actual extinction of the nucleus, I noticed an instance of the kind quite recently. I was looking towards Orion, and had just glimpsed a very faint meteor, almost doubting whether or no it was one at all. While hesitating about it, I kept my eye directed to the same spot, and there, two or three seconds later on, a small train came out very plainly, and enabled me to mark the path of this well-nigh unseen shooting-star most accurately." At 10^h 52^m P.M. on the 12th of August, during the Perseïd shower in 1876, Mr. Clark also noticed a nearly stationary Perseïd, as bright as a star of the second magnitude, at $32°·5, +58°·7$, with a course scarcely longer than $\frac{1}{3}°$, which was visible for $\frac{3}{4}$ of a second, and its streak for two and a half seconds afterwards, very brightly. This shooting-star, Mr. Clark wrote, "looked almost like a double meteor, its streak flared up so brightly." The Orionids (of which the meteor seen by Mr. Denning was probably one) are even more remarkable than the Perseïds or the Leonids for the breadth or volume and for the brightness of the persistent light-streaks which mark their tracks, and the long-enduring or even rekindling lines of light that remain on the tracks of the meteors of these showers indicate their extreme velocity, due to the close proximity of their radiant-points to the apex of the earth's way. A sign so certain of this peculiar situation or proximity to a well-known point in the sky of a meteor's radiant-point is of such essential value in assigning to individual shooting-stars the probable shower-centres from which they emanate, that no ambiguous words should be used, if possible, to describe it; and in recording any luminous appearance, continuous or interrupted, visible in a meteor's wake, observers would do well to reflect and to state in as unambiguous terms as possible if it presented that appearance of rightly-named "phosphorescence" which is so easily recognized and distinguished by the peculiar property of rekindling which it always possesses more or less strongly, as described above in Mr. Clark's and Mr. Denning's observations. While the words "train" or "tail," used to denote "something bright" in a meteor's wake distinct from the head, are perfectly ambiguous (since they would equally be used to denote sparks and flakes or detached embers of every kind which meteors leave or draw after them along their course), the word "streak," implying the mark impressed or imprinted by the meteor *upon the air* when its velocity and heat are great enough to make this visible, is incapable by its ordinary signification of being applied to fragments *of the meteor itself*, such as constitute the great variety of glowing products or residues which are often observable during the process of a good many meteors' deflagrations; but in its proper meaning of a mark made or left by a meteor upon the atmosphere, it probably expresses the real origin of the above-described vapours or cloud-like evolutions of light sometimes produced along a meteor's track. Such streaks (as they should be called) are not always white, nor even, when very permanent, of unchanging colours; for those of the Perseïds are sometimes orange-yellow, and those of the Leonids bright green, changing when long-enduring to white and yellow, and even occasionally to dull red before they fade away; and in their spectra the lines of incandescent magnesium-vapour have been found to be visible up to the extinction of a streak for nearly a quarter of an hour, showing that they are composed of some self-luminous gases in whose light it is believed that the lines of several metallic vapours have been observed. The words "streak" and "no streak," denoting whether a meteor left or did not produce a line of phosphorescence or of kindling and ignited gases along its line of flight, should not be omitted in recording the appearance of even very faint and inconspicuous shooting-stars; while the words "train" and "tail," or "track of sparks," &c., should never be employed to denote it even if its brightness is very marked, but should be used exclusively to describe those luminous appearances in a meteor's flight which evidently proceed from more or less pulverized solid portions of the meteor's substance separated from it in its flight, and which, however luminous at first, in general soon become extinguished.

A very complete review of his observations in November and December, 1876, was given by Mr. Denning in the 'Astronomical Register' of Dec. 1876 (p. 296) and January 1877 (p. 18), to the very carefully compiled results of which sufficient reference will here be made by this allusion. Besides about 30 meteors mapped from September 10th to 20th (which gave nearly the same radiant-points as the October tracks), 122 meteors were mapped from October 13th to 29th, and 183 meteors from November 8th to 30th; the former group presented 16, and the latter 18 meteor-showers. As a class they were small, and mostly white and swift, the magnitudes of 306 which were registered between October 13th and November 28th being thus distributed, beginning with those equal to or exceeding stars of the first magnitude in brightness, and reckoning in their order those equal to the remaining inferior magnitudes of the fixed stars to the 6th inclusive:—

1st mag. or brighter, 19; 49; 61; 107; 65; 5 sixth mag. Total 306*.

During the first half of December 117 meteors were registered, principally

* On the 6th of December, 1876, Mr. Denning counted 14 stars of the Pleiades distinctly with the naked eye; and he varied the monotony of a long and fruitless watch for the Lyrids on the night of April 19th–20th, 1877, by glimpses of Winnecke's telescopic comet, in Lacerta, without instrumental aid. This acuteness of vision will perhaps account for many small meteors being noted in his records which would have passed unnoticed, and even have escaped detection by the eyes of observers less sensitive to exceedingly faint objects.

in the evening hours, belonging chiefly to the showers of the 'Geminids' and of the 'Taurids II.,' from β, ζ Tauri. These meteors were, as a class, slower and brighter than the majority of the shooting-stars which had been recorded in October and November. Mr. Corder's observations were continued simultaneously with Mr. Denning's in November and December, and, as will be seen by the Tables at the end of this Appendix, in general corroborated very nearly the results which he obtained.

The 'Geminids' of December 10th–13th, 1876.—This annual star-shower returned with rather greater brightness than usual on the principal nights (December 11th and 12th) of its periodic display. As was related by Mr. Corder (in the same page of the 'Astronomical Register' as that above referred to), his register included ninety-six meteors from the usual radiant-point in Gemini between the 4th and the 12th (inclusive) of December. Mr. Denning recorded 37 meteors of the same shower; but the night of the 11th being cloudy at Bristol, these were principally noted on the 12th; and the 11th was, by Mr. Backhouse's estimate of the intensity of the shower at Sunderland, rather the better-marked of the two maximum dates of their appearance. He writes:—"On December 11th and 12th the Geminids were numerous, most so on the 11th. On the two nights I saw 28 meteors, which was at the rate of 18 per hour for a cloudless sky. On the 8th and 9th the Geminids were less numerous, but I saw three of them; and I will forward full particulars of the shower if they should be required." On the nights of the 9th, 10th, and 11th the sky was either quite or partly overcast at Writtle; but in a clear interval of 40^m on the night of the 11th Mr. Corder saw 16 Geminids. He saw the first member of the shower on December 4th, and he reckoned the horary number of meteors on the 11th and 12th as "about 13 'Geminids' for one observer, or 16 shooting-stars, when unconformable meteors are included." Although it was very clear on the 13th, but few meteors, Mr. Corder adds, were seen, of which one or two were possibly from the radiant in Gemini.

With regard to their brightness Mr. Denning writes:—"The radiant in Gemini supplied many large meteors, and I noted two as bright as Venus, and several others as bright as Jupiter." Mr. Corder states that "in appearance they were generally quick, short, and white, without trains or streaks, except in the case of the larger ones, [of these] six first magnitude meteors being lemon-yellow in colour, some leaving streaks and others having trains. Several 2nd magnitude ones were bluish in colour."

The radiant-point was very well marked, according to Mr. Corder's description, "between α and θ Geminorum, at R. A. 107°, Decl. $+35°\cdot5$, a few meteors, however, radiating from near Pollux." Mr. Denning also suspected the existence of a second radiant confirming this last position, and while obtaining nearly the same radiant-point, at 106°, $+32°$, for the principal shower, believed that there must be two contemporary showers in Gemini for December, one giving slow meteors with radiant-point between α and θ Geminorum, and the other a few degrees west of β Geminorum [and somewhat eastward from the former point], giving rapid meteors. The first true Geminid was seen on November 21st; and the meteors of this shower must not be confused with the 'Gemellids,' a totally distinct shower in Gemini (first seen by Herrick near ϵ Geminorum, between October 20th and 26th, 1839, and discovered as a very abundant star-shower near ϵ Geminorum from the 21st to the 25th, and especially on the morning of the 23rd of October, 1868, by Zezioli). This shower Mr. Denning found very active, with a radiant-point at δ Geminorum, from the 25th to the 29th of October, and again from the 8th to the 17th of November. From its occurring at an earlier date, in the stars of the southern twin-comrade asterism (Pollux), than the Geminids, which radiate from the northern part of the constellation, the epithet 'Gemellus' (twin brother) is applied to distinguish the shower of Gemellids in October and November from the only other meteor-system (the annual shower of the Geminids on December 11–12th) whose radiant-point at any season of the year has yet been discovered in that constellation. A pretty active December shower in the Lynx was observed by Mr. Corder and Mr. Denning, whose radiant-point agrees very nearly with one noted by Mr. Gruey at Toulouse on the 10th and 11th of December, 1874, at 130°, +46° (see these Reports, vol. for 1875, p. 214).

The Geminids were also well observed in France, according to the bulletins of the French Scientific Association (vol. for 1876–77, p. 208), by the observers under M. Tisserand's direction at the Observatory of Toulouse. Two observers counted 106 meteors in two hours between 11^h P.M. on the 11th and 1^h A.M. on the 12th of December, most of their courses proceeding, according to Mr. Perrotin's determination of its place, from a radiant not more than 2° or 3° from a position at 115°, +33° (which is a little east of, while Mr. Denning's and Mr. Corder's places, coinciding nearly with several previous determinations near τ Geminorum, are a little west of Castor). A translation of this French notice will be found in 'Nature' (vol. xv. p. 207), which also records (p. 208) that the Annuaire du Bureau des Longitudes for the year 1877 contains for the first time, for the guidance of observers, a full table of the situations throughout the year of the various radiant-points of shooting-stars.

The January and April meteor-showers in 1877.—No regular watch was kept, owing to very tempestuous weather, for the meteors of January 1st to 3rd, at the beginning of this year; and although the full moon by its return on the last night of the preceding year partially dispelled the clouds, few stars were visible through the haze, and no meteors of this periodical star-shower were observed.

The watch for the Lyrids on the nights of April 18th to 21st was also very unsuccessful, from the absence, apparently, of the star-shower on its annual date. An account of his attempt to catch some view of the shower on the night of April 19th–20th is given by Mr. Denning in 'The Observatory,' (vol. i. p. 50), when he watched continuously for five hours, from $10^h\ 30^m$ to $15^h\ 30^m$, in a perfectly clear sky, and recorded 29 paths of shooting-stars. Of these four only were Lyrids, and only one was a Coronid, a very remarkable example of the irregular and intermittent intensity of some annual meteor-streams. During two hours on the morning of April 17th three Lyrids and none at all from Corona were registered. In April 1873 and 1874, Mr. Denning states, the Lyrids and Coronids were the most active showers of that month, only the former having a decided maximum of intensity about the 20th of April, while the second, beginning in the first half of April, lasted with little abatement through the whole of May and even into June. The radiant of the few Lyrids mapped was at 269°, +37°. A similar place was obtained (at 265°, +38°) from 31 tracks in the Italian Catalogue between March 31st and April 13th, and again from 15 tracks in the same Catalogue between May 3rd and 13th [the mean position of 6 stationary Lyrids recorded in the Austrian Catalogue, April 20–23, 1867–74, was at 266°·5, +36°·5]. The positions of six other radiant-points faintly marked by the unconformable meteor-tracks of April 19th–20th, 1877, were similarly confirmed by Mr. Denning's reductions of the foreign observers' catalogues, as will be noticed in the comparative Tables at the end of this Appendix containing his deductions from the Italian and Austrian observations. No other observations of the Lyrids of the 18th–21st of April last were received by the Committee in the present year.

The Perseïds of August, 1877.—The Committee is indebted to Mr. Denning and to Mr. Wood for the following abstracts of the rates of frequency and of the time of maximum of this shower on the night of August 10th. The nights of the 9th and 11th were overcast at Bristol, and a cloudy state of the sky was so prevalent during the period of the shower in other parts of England, that equally systematic observations of the intensity of the shower elsewhere have not yet been received.

Times of watch, Bristol, Aug. 10th, 1877.	Length of watch.	Number of Perseïds.	Number of other meteors.	Total number.	State of the sky.
$9^h\ 30^m$ to 11^h	30^m	57	13	70	Very clear; stars bright; no moon.
11^h to 12^h	1^h	70	13	83	
12 to 12 30^m	30^m	25	9	34	
12 30 to 13	30	33	11	44	
13 to 13 30	30	30	9	39	Sky hazy; slight fog.
13 30 to 14	30	31	10	41	
14 to 14 30	30	39	4	43	Partly overcast; fog and clouds.
9 30 to 14 30	5^h	285	69	354	

Seen by one observer looking uninterruptedly towards Cassiopeia.

At $12^h\ 39^m$, 9 meteors seen in one minute.
At 14 15 6 meteors seen in half a minute.
Maximum between 14^h and $14^h\ 30^m$.
} Radiant at 43°, +58°; most accurate and exact.

Observer, W. F. Denning.

Times of watch, Birmingham, 1877.		Length of watch.	Number of meteors seen.	State of the sky.
Aug. 10th	$10^h\ 15^m$ to $10^h\ 30^m$	$2^h\ 15^m$	26	Cloud $\frac{3}{4}$.
	10 30 to 11			Cloud $\frac{1}{4}$.
	11 to 12 30			Clear.
Aug. 11th	10 30 to 11 30	1	16	Clear (cloudy before $10^h\ 30^m$).

Meteors brighter and more numerous on the 10th than on the 11th. General appearance of the shower below the average of its intensity in brightness.—Observer, W. H. Wood.

For the whole interval of Mr. Denning's observations since the publication of his last list of 52 radiant-points (see this Appendix, p. 176) at the end of October, 1876, until June 1877, about 800 shooting-stars were observed, and were reduced to the radiant-points of which the two Tables (Mr. Greg's comparative Tables I., II.) at the end of this Appendix contain the positions compared with the results at the same time obtained by Mr. Corder's observations. These Tables exhibit the places and durations of 83 meteor-showers, of which some twelve are new, and cannot be fairly included in any of the known groups of meteor-showers contained in Mr. Greg's earlier general Catalogues. The two following tables (Tables III. and IV.) contain similar epochs and positions of 105 radiant-points deduced from projections of about 1800 meteors in the Catalogue of shooting-stars observed by the Italian Luminous-Meteor Association in the year 1872, and about 16 or 18 of these showers appear to be distinct from any that have been previously recorded. Among the ten or twelve showers found in Captain Tupman's unreduced observations, and nineteen showers obtained in a preliminary reduction of the meteors recorded in the Austrian Catalogue (added, with a list of stationary meteors extracted from the latter catalogue, to the above Tables), and among the fifty-two radiant-points contained in Mr. Denning's published catalogue of meteor-showers at the end of this Appendix, seven or eight well-marked positions are also new to any previously existing records of known or suspected meteor-showers. Upwards of 35 new radiant-points have accordingly been added, and at the same time about 100 of the already known 200 or 220 general centres of radiation of meteor-showers throughout the year have received from these extensive observations and reductions more or less repeated confirmations.

Some important deductions from his observations during the fourteen months from April 1876 to May 1877 (inclusive) were also presented by Mr. Denning in a paper on the "Visibility of Shooting-stars," in 'The Observatory' of July last (vol. i. p. 106), exhibiting the average horary numbers of meteors visible in the different months, and the total number of shooting-stars observed of the different apparent magnitudes or degrees of brightness. Of these magnitudes 1090 were registered during the interval; and of the various brightnesses recorded, from that of Sirius or of the planets (and brighter), and from the first and successive magnitudes of the fixed stars to the fifth, inclusive, there was noted in all the following series of numbers: Sirius, or brighter, 39; 65; 199; 274; 337; 176 fifth-magnitude meteors. Total number of apparent magnitudes registered, 1090.

In calculating the horary numbers, both the numbers seen and the lengths of the watches having been regularly noted, one sixth is deducted from the latter times to obtain the times actually spent in observation; and clear moonless nights having been generally selected, the numbers found represent very nearly the rates of frequency of the meteors for one observer keeping his gaze constantly directed eastwards to an altitude of about 40° above the horizon.

Horary Numbers visible in

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
P.M.	(in 1876)		...	6·8	11·0	...	8·1	8·0	5·9	7·4	6·9	8·5	7·51
	5·7	4·8	7·5	7·8	6·5	...	...	...	...	... (in 1877).			
A.M.	(in 1876)		...	...	...	...	...	17·2	...	13·4	13·3	11·9	10·74
	8·4	11·0	7·1	8·3	6·9	...	...	...	...	... (in 1877).			

In reference to this summary Mr. Denning writes:—"Consulting the Table it will be seen that shooting-stars were especially numerous in the mornings of October, November, and December, and very rare in the evenings of January and February. The frequency of the Perseïds in August will account for the large hourly proportion A.M. (17·2) in that month; but I have not excluded them from the list, as they have a trivial influence on the total results. I found that as a rule the rate of frequency is at a minimum soon after dark, and at a maximum just preceding dawn, the relative horary numbers being about 6–7 for the former and 12 for the latter period. In fact, as the night advances the numbers go on increasing; and I suppose this would theoretically be the case considering the improving position taken up by the apex of the earth's way during the successive hours of the night."

The position of the apex of the earth's way in the sky is about 90° eastwards along the ecliptic from that point of the ecliptic which is opposite to the sun, or which is on the meridian at midnight. It therefore rises nearly at that time, and passes the meridian at about 6^h A.M. But at the time of the September equinox it is above (and in that of March it is below) the eastern horizon at midnight. As the tendency of the earth's motion is to make five or six times as many meteors (supposing them not to be collected into streams) come from the hemisphere about the apex as reach the earth from that round the antiapex of the earth's way, the altitude which this meteor-apex reaches above the horizon materially affects their horary abundance. Small changes of its altitude when the apex is near the horizon (as it is at midnight) must be much more perceptible in their effect upon the frequency of shooting-stars than the same changes occurring when its altitude above or its distance below the horizon is greater, as it is towards sunrise and sunset. While, therefore, midnight observations are better adapted than those made either at sunrise or at sunset for exhibiting *an annual* variation of the rate of frequency, a somewhat singular and anomalous result is noticeable in the present table, where the annual maximum and minimum of frequency *are not* so strongly marked in the result of the evening watches as they are in the morning observations (although the minimum in the first series towards March and the maximum in the latter series towards September are yet both very plainly indicated). Two sufficient explanations of the difference will, however, probably be found in these considerations, that the collection of meteors into irregularly situated streams must disturb their rate of frequency in the evening hours most sensibly when it is naturally small; and, again, that the A.M. observations may have really been made at an average interval after midnight less than that of the P.M. observations before midnight, and that in consequence the meteor-apex was further from the horizon (below it) during the evening observations than it was above it, on the average, during the morning watches. By consulting the special circumstances of each watch, and applying for the hour when it is kept a 'tabular reduction' for the altitude of the earth's apex above the horizon, so as to determine the absolute meteor frequency for the hour, with the apex of the earth's way in a level position or situation in the horizon, a real knowledge of the actual scarcity and abundance of shooting-stars at different times throughout the year might eventually be obtained. A table of the kind required does not admit of precise calculation; but as it can be approximately constructed and applied, the exact time (the middle of the watch) for which an horary frequency of shooting-stars seen and counted collectively has been determined should be recorded with the date of the watch; and longer watches than two or three hours (at the furthest) should, whenever clear and kept uninterruptedly enough, be divided into two or more intervals, over which separate determinations of the mean horary frequency, for the purpose of determining the true or absolute rate of frequency 'reduced to midnight' in each, should be made to extend.

Professor Schiaparelli and Padre Denza continue to invite the united cooperation of Italian observers of shooting-stars on a series of nearly weekly morning and evening dates of the year 1877–78 favourable by the moon's absence or for contributing special materials to the Italian Catalogue for observing shooting-stars. At the beginning of this year they circulated the eighth annual pamphlet of directions for this purpose, containing besides the concerted and other general occasions for meteor watching, a list of the 14 stations in Piedmont, Italy, and Spain, with the names of their directors, whose connexion with the Association is still zealously maintained. Among the new contributors whose names appear in the present list, Signor Arcimis, of Cadiz in Spain, is this year one of the active Members of the Italian Meteor-registering Association.

A List of Fifty-two Radiant-points of Shooting-stars observed and recorded during the years 1872–76.
By W. F. Denning, F.R.A.S., F.M.S., Ashleydown, Bristol, October 1876.

No. (1876).	Dates of Observations.	Radiant-point. R.A.	Radiant-point. N.Dec.	Position of Radiant-point by the Stars.	Greg's No. 1874.	Notes.
1.	January 2–3, 1873	234°	48°	N. of β Boötis	6	G. and H. give 238°,+45°, with max., Jan. 2–3.
2.	March 12–17, 1876	184	54	δ Ursæ Majoris	21	Also radiation from Cor Caroli.
3.	March 16 to April 22, 1876	142	49	θ Ursæ Majoris	45	Small meteors.
4.	April 1874	223	45	β Boötis	48	G. and H. give 223°,+40°, Mar. 12 to April 30.
5.	April 1873–74	241	69	ζ Draconis	57	Connected with No. 16.
6.	April 1873–74	268	85	North Pole	60	Confirmed at the same place.
7.	April 1874	209	S 3	Virgo	62	Mean of two showers, 208°,−5°.
	April 13–22, 1876	207	S 7			
8.	April 19–20, 1873–74	274	37	α Lyræ	51	Mean of two showers. Well marked.
9.	April 11 to May 1, 1876	241	24	Corona	67	Radiant precisely defined. Meteors small and rapid. Mean of two showers, 241½°,+24½°.
	April 20, 1874	242	25			
10.	April 11–22, 1876	230	38	μ Boötis	48	Small meteors; somewhat slow.
11.	April 13–22, 1876	207	48	η Ursæ Majoris	55	Small meteors; an active radiant.
12.	April 13–22, 1876	171	50	χ Ursæ Majoris	54	Approximate; declination accurate.
13.	April 13–22, 1876	194	30	Comæ Berenices	42	Small meteors.
14.	April 13–22, 1876	195	S 2	Virgo	53	Somewhat bright meteors; rather slow.
15.	April 19 to May 1, 1873	221	20	Boötes	191	Doubtful; not confirmed, 1876.
16.	April 14 to May, 1876	277	57	ο Draconis	10	Small rapid meteors without trains. Mean of the two showers, 280°,+58°.
	April 21, 1873	283	59			
17.	April 21 to May 1, 1873	189	60	δ Ursæ Majoris	46	Continuation of No. 2?
18.	May 1876	221	S 6	Libra	53	Connected with Nos. 7 and 14?
19.	June 25 to July 8, 1876	164	57	β Ursæ Majoris	76	G. and H. give 168°,+55°, June 1–29.
20.	July 1873	267	49	γ Draconis	78	S. and Z. give 270°,+51°, June 28 to Aug. 3.
21.	July 7, 1875	344	27	β Pegasi	96	Small meteors; very slow. A feeble radiant, 1876.
	July 16 to August 25, 1876	349	24			
22.	July 16 to August 25, 1876	330	70	β Cephei	112	Small rapid meteors without trains. An active radiant.
23.	July 16 to August 14, 1876	18	63	Cassiopeia	83	Many fine meteors with trains; like Perseids. An active radiant.
24.	July 16, August, and September, 1876	284	57	ο Draconis	78	Small rapid meteors without trains.
25.	July 16, August, and September, 1876	298	2	θ Antinöi	79	Fine meteors; very slow; with trains.

26.	July 16–25, 1876	337	S 7	θ Aquarii	109	Fine meteors; very slow; with trains.
27.	July 16 to August 16, 1876	340	42	Lacerta (Honores)	95	S. and Z. give 344°, +40°, July 18 to Aug. 4.
28.	July 16 to August 16, 1876	284	40	α Lyræ	72	Approximate; a feeble shower.
29.	July 16 to August 16, 1876	313	40	α Cygni	81	Approximate. Clark gives 315°, +42°, August.
30.	July 26 to August 11, 1873	2	27	α Andromedæ	103	This shower seems continued in October.
	July to August 1876	6	27			See No. 43; and Greg, No. 194.
31.	August 2–11, 1873	10	42	Andromeda	98	G. and H. give 7°, +42°, July 4–11.
32.	August 10, 1874	44	58	η Persei	108	Many fine meteors with trains; rapid.
	August 10, 1876	43	59			Less active in 1876, than in 1874.
						Radiant at 38°, +58°, Aug. 10, 1871.
33.	August 1876	31	59	χ Persei	116	A sub-radiant of Perseids suspected here.
						Forbes gives 33°, +59°, Aug. 10, 1868.
34.	September 20 to October 25, 1876	46	26	Musca	129	An active radiant, well defined; max. Oct. 14–15.
35.	September 18 to October 21, 1876	14	50	Cassiopeia	173	Rather diffuse but active; max. Oct. 13.
36.	October 17–25, 1876	88	17	ν Orionis	157	Well defined; rapid meteors with trains.
	October 18–19, 1874	88	11			
37.	September 17 to October 21, 1876	15	11	δ–η Piscium	195	A mean of two showers; west of Aries.
						Active; meteors *very slow*; max. Oct. 21.
38.	October 13–29, 1876	126	49	Lynx	141	Diffuse; perhaps two showers in this region?
39.	September 17 to October 25, 1876	317	57	Lacerta (α Cephei)	130	A mean of two feeble showers.
					144	
40.	October 14–25, 1876	90	58	δ Aurigæ	136	Possibly these are separate showers.
	October 19 to November 10, 1874	71	43	α Aurigæ		
41.	October 14–17, 1876	38	12	μ Ceti	138	*Very slow* meteors.
	October 17–18, 1874	34	18	Aries	154	These are probably one shower.
42.	October 13–25, 1876	48	71	Tarandus	193	A mean of two feeble showers.
43.	October 13–21, 1876	358	26	α Andromedæ	194	A confirmation of Gruber's new shower, 2°, +25°.
						Max. Oct. 21 (D).
44.	September 17–20, 1876	313	43	α Cygni	151	A feeble continuation of No. 29.
45.	September 20 to October 29, 1876	161	84	Polaris	128	A diffuse radiant, giving rapid white meteors.
					143	
46.	September 20 to October 19, 1876	31	37	Triangulum	129	Mean at 35°, +38°; and = G. 129, at 36°, +35°.
		40	40			
47.	September 16 to October 25, 1876	346	44	Lacerta (Honores)	160	Continuation of No. 27.
48.	October 21–29, 1876	61	18	α Tauri	156	A marked shower; near Aldebaran.
	November 6–10, 1872	64	20			
49.	October 25–29, 1876	109	23	Gemini	142	Very rapid meteors; max. Oct. 30, A.M.
50.	November 27, 1872	29	46	γ Andromedæ	172	A great shower.
51.	December 31, 1872	140	45	θ Ursæ Majoris	2	G. and H. give 135°, +40°.
52.	December 31, 1872	106	36	α Geminorum	178	Slow meteors.

A List of Radiant-points of Meteor-showers found from a partial reduction of Dr. Weiss's Austrian Observations of Shooting-stars in the years 1867–74. By W. F. Denning (April 1877).

Dates.	Radiant; and number of meteors alligned to it.			Value.
	°	°		
December 7–13	83	+23	27 meteors	c 1
February 20 to March 3...	83	+20	8 meteors	c 2
February 20 to March 1...	33	+36		c 2
November 13	204	+43		d
December 7–13..............	200	+67	9 meteors	c 3 or d
December 7–13..............	160	+32	11 meteors	c 3
November 13	240	+62	new.	d
November to December ...	180	+53		c 3
October 20–29	286	+39		c 3
November 13–29	173	+12	10 meteors; new.	c 2
December 7–13..............	170	+48 ??		d
February to March	72	+55		d
February to March	100	+31		d
December 7–11	109	+20		c 3
December 7–13	130	+20	new.	d
October 19–29	300	+55	10 meteors	c 3
April 22	304	+12	6 meteors new. (bracketed with the two following)	c 3
April 20–23	284	+ 8		d
December 7–13..............	203	+ 5		d

All these showers were regarded as clearly indicated from the paths examined. (In some cases the number of Meteors was uncertain, ranging from about 6 to 12.)

A Lis of Twenty-eight Stationary Meteors, selected from Dr. Weiss's Austrian Observations, 1867–74. By W. F. Denning.

Date.		Position of Meteor. α	δ	Radiant-point, or Meteor-shower.
1869.	August 13	48°·7	+61°·5	Perseid.
,,	December 11	120·7	+49·2	Lyncid.
,,	,, ,,	82·9	+22·9	Taurid II.
1870.	January 26	10·8	+49·4	Cassiopeiad.
,,	February 23	33·8	+36·5	β Trianguli.
,,	April 5	237·0	+ 4·3	
,,	,, 19	270·1	+31·4	Lyrid.
,,	,, ,,	258·9	+41·4	Lyrid ?
,,	,, ,,	289·4	+26·4	
,,	,, ,,	266·7	+27·7	
,,	,, 21	225·0	+69·0	
,,	,, ,,	175·8	+19·3	
,,	,, ,,	272·8	+40·1	Lyrid.
,,	,, 23	199·8	+69·8	
,,	,, ,,	262·4	+32·3	Lyrid.
,,	,, ,,	273·4	+37·3	Lyrid.
,,	July 26	350·0	+47·1	Lacertid.
,,	,, 29	351·0	+18·0	Pegasid.
,,	August 22	308·2	−20·3	
1872.	,, 10	48·8	+62·0	Perseid.
,,	,, ,,	43·1	+ 1·8	
,,	,, 12	211·2	+34·5	
,,	October 22	334·0	+61·1	Cepheid.
,,	July 27	339·5	+52·2	
1874.	April 20	223·4	− 5·8	
,,	,, 21	258·9	+38·1	Lyrid.
,,	,, 22	260·4	+59·3	
,,	,, ,,	248·8	+ 6·1	

Mean radiant-point of six Stationary Lyrids, April 19–23, =266°·5, +36°·5.

Table I.—A Comparative List of Meteor-showers observed between September and December 1876, and April and June 1877, by Mr. Corder and Mr. Denning. By R. P. Greg.

Greg's Cat. No. 1875–76.	Date of Meteor-shower.	Constellation of Radiant-point.	H. Corder's Radiant-positions. R.A.	H. Corder's Radiant-positions. N.D.	W. F. Denning's Radiant-positions. R.A.	W. F. Denning's Radiant-positions. N.D.	Value of Meteor-shower.	Observations.
5.	November 20 to December 15	Crater	*		165°	−6°	*c* 3	
169.	November 2 to December 10 ? 24	Canes Venatici	*		188	+37	*c* 2	Confirmed by GH*. At 179°, +47°, Jan. 4–22, Denning.
165.	November 20 to December 5	Leo Minor	*		155	+36	*c* 1	A bright shower, Nov. 26–29.
209.	November 20–28	α Boötis	*		213	+23	*c* 2	
187.	November 20 to December 21	β Canis Minoris	130	+16?	110	+8	*c* 3	
181*a*.	November 25 to December 4	Sextans	*		148	+2	*c* 3	Confirmed by GH*.
176 or 179.	November 25 to December 14	β Ursæ Majoris	210	+67	208	+71	*c* 2	? Continued to Jan. 22, Denning, at 209°, +67°.
210.	December 5–14	(ζ, β) Tauri	78	+25	81	+22	*c* 3	Confirmed by GH*. = *Taurids* II.
182.	December 5–14	*f* Cameleopardi	103	+54	*		*d*	At 84°, +74°, Denning, Jan. 4–22.
2 or 175.	December 5–14	θ Ursæ Majoris	139	+45	*		*c* 3	? Continued to Jan. 22, Denning, at 130°, +44°.
(14) 156.	November 28 to December 24	ε, η Tauri	?		{ 57 60 }	+26 +19 }	*b* 1	(GH. = 60°, +19½°) { 14? = AG_1, Jan. 156? = *Taurids* I. ? = new shower.
136.	November 22 to December 14	Auriga	{ 80 81	+42 +52 }	78	+43	*b* 1	"*Aurigids*," (83°, +48°, GH.).
173 or 172*a*.	December 5–14	γ Cassiopeiæ	10	+62	*		*c* 3	Confirms Heis and GH*.
?	December 5–14	Lacerta	329	+34	*		*d*	(New ?). Very slightly supported.
169*a*.	November 20–28	η Ursæ Majoris	*		208	+43	*c* 2	
142.	October 25 to November 17	δ Geminorum	106	+23	110	+22	*b* 1	(GH. = 105°, +27°). "*Gemellids.*"
178.	September 28 to November 8	Cassiopeia	*		15	+52	*c* 2	
170.	October 13 to November 25	Lynx	130	+44	125	+47	*c* 2	Also by Denning on Jan. 14.
129.	September 20 to November 17	Musca	44	+37	46	+26	*c* 1	(GH. = 44°, +34°, Aug.–Oct. 20.)
106.	October 17 to November 8	Pisces	*		15	+11	*c* 2	

156.	October 21 to November 20	ε, η Tauri	60	+18 (Average of five.)	60	+19	b 1	"*Taurids*" I. (60°,+19½°, GH.).
(?) 74.	April (1877); May 15–17	Cygnus	308	+38	315	+38	c 2	Greg, No. 74. 310°,+24°, May 2 to June 30.
			*		299	+36		
189.	April to May	Custos	14	+68	*		?	
*	April 16–19	ρ Aquilæ	*		303	+13	......	New Shower. Confirmed by the Italian Observations 1872, at 304°,+2°.
*	April 16–19	δ Aquilæ	*		286	+ 5	......	Ditto.
50.	April 16–19	B Cerberi	*		267	+21	......	
28.	April to May	β, ν Virginis	175	+ 8	*		......	
*	April 16–19	Vulpecula	*		298	+25	......	New Shower. Confirmed by Italian List, 1872, at 287°,+27°.
58.	April 16–19	ζ Serpentis	260	− 4	260	+ 2	......	(Tupman, 256°,−2°. April 27.)
			May 30 to June 9					
*	April 16 to May 31	κ Virginis	208	− 6	206	− 8	......	New and active shower. Confirmed by Italian Observations 1872, at 204°,−8°.
53.	April 16 to May 31	β Libræ	227	− 8	228	− 2	......	
51.	April	κ Lyræ	275	+35	269	+37 (April 16–19)	......	"*Lyrids.*"
47.	April to May	θ Draconis	242	+55	255	+50	......	"*Draconids* I." (Greg, 263°, +50°).
53*a*.	April 4 to May 7	ξ Boötis	218	+22	*		......	(Greg, 226°,+10°.)
65.	May	κ Cephei	290	+80	*		......	"*Polarids.*"
73.	April to June	Canes Venatici	*		196	+42	......	
52.	April 16 to May 17	κ Antinoï	*		289	−12	......	
69–72.	May to June 17	β Lyræ	283	+32	282	+28	......	(Greg, 280°,+34°.)
			273	+42				
67.	May 30 to June 9	β Herculis	248	+22	*		......	
74.	April to May 15	s Vulpeculæ	312	+18	312	+21	......	Greg, 310°,+24°. May 2 to June 30.
(?) 74.	June 6–9	υ Cygni	324	+36	*		......	
*	June 3–9	A Draconis	*		240	+70	......	New shower (Ital. at 233°,+60°) 250°,+62°.
*	May 15–17	Honores	*		354	+41	......	Ditto. (Italian, at 353°,+39°).
79*a*, 107 (?)	May 15	ρ Delphini	*		304	+ 7	......	(N.B. Greg, for June and July.)
64.	May 17	ο Draconis	273	+55	283	+55	......	(Greg, 281°,+57°.)
80–85.	April to May	ν Serpentis	*		258	−12	......	(N.B. Greg, for June to Aug.)
77.	June 2–17	μ Cephei	320	+56	302	+64	......	(Greg, 317°,+62°.)

Table II.—A Comparative List of Meteor-showers observed in January, February, and March, 1877, by Mr. Corder and Mr. Denning. By R. P. Greg.

Epoch, 1877.	Constellation of Radiant-point.	105 meteors. Radiant-position. Corder. R.A.	Dec.	237 meteors. Radiant-position. Denning. R.A.	Dec.	Tupman, Heis, S., SZ., GH. R.A.	Dec.	Greg, New Catalogue, 1876. R.A.	Dec.	New B.A. Cat. No. Greg.	Value of Shower.	Observations.
Dec. and Jan. ...	Quadrans..........	° *	°	220°	+52°	° *	°	230°	+55°	17.	*c* 1	Denning; 26 meteors; small and slow.
January 4–20 ...	γ Ursæ Minoris ...	*		240	+70	*		240	+70	179*a*.	*c* 3	Denning and Italian Observations; 12 meteors; small and slow.
Jan. and Feb. ...	α Serpentis	*		236	+11	*		248	+12	41.	*c* 3	
January 1–21 ...	ψ Cygni	*		295	+53	*		*		*	*c* 1	"*Cygnids.*" New shower; good; 20 meteors.
January 4–20 ...	Ursa Minor........	*		248	+73	245 Feb., Heis.	+76	258	+68	33, 34.	*d*	
January	γ Eridani	*		57	−12	*		*		*	*c* 2	New; very slow meteors.
January	Tellescopium	95	+45	*		*		*		*	*d*	New, if correct; feeble.
January 4–20 ...	δ Herculis	*		251	+23	*		*		*	*d*	New.
Jan. 20–Feb. 4...	ζ Persei	56	+33	61	+28	*		67	+22	14?	*d*	Corroborated by Mr. Denning.
Jan. 20–Feb. 4...	λ Ursæ Majoris ...	135	+50	129	+44	*		135	+48	2.	*c* 3	
Jan. and Feb. ...	δ Boötis	*		221 234	+39 +30	*		230	+30	18.	*c* 3	
January	θ Herculis ... β Draconis ...	264	+36	260	+47	*		*		*	*c* 3	Denning and Italian Observations; 9 meteors.
February	Comæ Berenices...	*		189	+25	*		190	+24	54.	*d*	
Feb. 11–20	η Boötis	207	+19	209	+15	209 Mar. 2–3.	+18 T.	205	+17 GH.	29, 39.	*c* 3	
February	σ Leonis	*		167	+ 4	*		167	+ 4	5.	*d*	
Feb. 20–29	λ Leonis	155	+27	*		*		158 Feb.–Mar.	+29	26.	*c* 2	
Mar. (? Jan.) ...	δ Leonis	165	+20	160 Jan.	+20	*		*		*	*d*	

Feb. 25–Mar. 17	λ Draconis	173 +68 (170 +58, aver^e)	*	*	180 +56	46, 21?	c 3	(M. 6, 7 of GH. at 180°, +60°.) Denning, 184°, +54°, Mar. 12–17, 1876.
Feb. 25–Mar. 17	ψ Ursæ Majoris ...	167 +48	*	*	180 +56	46, 21?	d	
February	d Ursæ Majoris ...	*	133 +69	*	136 +69	13.	c 2	
Feb. 25–Mar. 17	Cancer and Lynx...	130 +37	*	*	133 +26	31 ?	d	(Average of 130°, +31°, by Mr. Greg, and 130°, +43°, by Mr. Corder.)
February 20 ...	α Canum Venat. ...	*	181 +34	*	180 +35	11.	c 2	
February 20 ...	α Lyræ	*	263 +36	*	*	*	d	New. Average 270°, +30°. N.B. Too early for the April "*Lyrids.*"
March 14	β Lyræ	*	277 +25	*	*	*	d	
March 1–15......	κ Cephei	*	300 +80	*	15 +80	34, 1 ?	c 3	Denning and Italian Observations (9 meteors).
March	γ Boötis	208 +40	206 +44	209 +52 T. Feb. 14, 15.	209 +52	35 ?	d	Feeble.
March	β Coronæ	224 +28	*	*	*	*	d ?	Doubtful.
March	Cygnus	323 +33	320 +44	*	307 +40 Mar. 15–Apr. 21.	49 ?	c 3	Denning, 315°, +38°, April 1877, = c 3.
April 21, 1872...	Cygnus	*	310 +44	*	307 +40	49.	*	
March	β, γ Ophiuchi	260 − 1	252 +12 March 17.	*	*	27 ?	d	Probably same shower.
Jan. and Feb. ...	Ophiuchus	*	261 + 4	260 0 T. Feb. 13.	260 0	27.	d	
March	ο Draconis	280 +69	263 +48 250 +54	267 +53 GH.	263 +48	47.	c 3	N.B. (280°, +69° of Corder doubtful.)
March	σ Herculis	247 +48	244 +50 250 +54	240 +39 T. Mar. 2–3.	249 +45	20, 30.	c 2	(244°, +50° of Denning, Mar. 14); (255°, +50°, Denning, April 19, 1877).
March 16.........	γ Aquilæ	*	300 +12	*	*	*	c 3	New. Confirmed at 303°, +13°, April; Denning.
March 14.........	γ Boötis	*	218 +36	*	223 +42	48.	d	
March 18.........	Scutum Sobiesii....	*	280 −14	*	280 −17	22.	d	
Mar. and Apr....	δ Serpentis	229 +12 March.	220 +20 April.	230 + 5 T. April 27–28.	226 +10	53a.	c 2	

TABLE III.—A Comparative List of Meteor-showers obtained by Mr. Denning from Reductions of the Italian Observations Shooting-stars between February 1st and April 13th, 1872. By R. P. GREG.

Mr. Greg's B.A. Catalogue.			Mr. W. F. Denning's Reduction of the Italian Observations in 1872.									Observations.
1874 and 1876. No.	Corresponding Position. R.A.	Dec.	February. R.A.	Dec.	No. of Meteors.	March 1–12. R.A.	Dec.	No. of Meteors.	Mar. 31 to Apr. 13. R.A	Dec.	No. of Meteors.	
28.	175°	+14°	180°	+13°	6	172°	+13°	19	179°	+ 9°	15	(175°, +10°. Denning, March 1877.)
59 ?	154	+17	150	+ 3	12	145	+ 4	12	147	+ 1	7	
2.	135	+48	123	+46	5	*		*	*		*	
*	*		51	+32	5	*		*	*		*	? New shower.
105.	120	+52	110	+60	11	112	+65	11	105	+54	7	
31.	133	+26	139	+16	10	124	+25	9	139	+16	8	
*	*		85	+22	7	82	+27	9	*		*	New shower.
193.	65	+61	51	+65	8	55	+65	5	*		*	
1? cont.	116	+87	300	+81	7	300	+80	5	215	+83	*	Continued to June. Heis, 222°, +87°. (4 positions.)
*	*		210	+70	14	*		*	*		*	New shower.
26.	158	+29	160	+28	13	156	+29	8	160	+39	25	In Leo Minor; a strong shower. Continued to May 15.
13.	136	+69	133	+67	12	*		*	*		*	
188.	105	− 5	106	± 0	4	*		*	*		*	
*	*		105	+30	12	*		*	*		*	New shower.
42.	192	+ 4	187	± 0	7	*		*	*		*	
21, 46.	180	+56	*		*	182	+56	20	*		*	Well-marked shower.
37.	80	+ 6	*		*	85	+ 6	8	*		*	
54.	190	+24	*		*	180	+36	12	190 184	+20 +35	12 15	At 189°, +25°, March 8, 1877. Denning. Continued into June.
24.	75	+44	*		*	77	+49	7	*		*	
47.	263	+50	*		*	260	+66	6	258	+60	20	Continued into June. 255, +50, April. *Draconids* I. Denning.
55.	204	+56	*		*	205	+51	7	210	+66	25	α "*Draconids*." Continued into May and June.
67.	235	+38	*		*	227	+31	4	223 235	+23 +25	14 19	ε Boötis (225°, +23°, Schmidt). Continued into June, Denning.
*	*		25	+35	9	30	+35	7	*		*	New shower.
14.	67	+22	*		*	67	+27	5	*		*	
43.	105	+39	103	+44	6	100	+44	6	*		*	
*	*		*		*	10	+60	8	*		*	New shower.

	*		*	*	288	+12	6	277	+10	7	286°,+5°, April 19, 1877. Mean of 3 = 284°,+9°.
45.	147	+47	*	*	145	+55	5	157	+45	12	
13.	136	+69	*	*	*		*	133	+66	15	Continued to May 15, Denning.
60.	210	+81	*	*	*		*	215	+83	10	Continued to May 15, Denning.
73.	206 April to May.	+39	*	*	*		*	206	+44	33	Strong shower. Continued into May and June.
53*a*.	226	+10	*	*	*		*	231	+ 7	17	Denning, 218°,+25°, Apr. 1877. „ 219°,+17°, May 7, „
62.	199	+ 9	*	*	*		*	205 205	+12 − 8	40 7	Denning. Mean of 3 positions. Continued into May.
51.	272	+35	*	*	*		*	265 278	+38 +46	31 8	"*Lyrids.*" (267°, +35. Herschel, April 20, 1871.)
57.	237	+63	*	*	(233 May.)	+47	*	232	+54	17	(240°,+55°, Schmidt.) (220°,+52°, Denning, 1876.) (223°,+42°, GH.)
*	*		*	*	*		*	338	+61	18	New.
58.	256	− 2	*	*	*		*	262	± 0	10	Denning, 260°,+2°, April 1877.
50.	265	+23	*	*	*		*	255	+27	9	261°,+34°, May and June. 267°,+21°, Apr., 1877, Denning.
53.	225	− 8	*	*	*		*	228	− 5	9	228°, −2°, April 19, and 229°, −4°, May 15, 1877, Denning.
*	*		*	*	*		*	304	+12	9	New. Well-confirmed by Denning, Mar.–Apr. 1877; also by Corder.
*	*		*	*	*		*	23	+62	6	New shower.
36.	142	−25	*	*	*		*	137	−19	3	
26.	210	+81	*	*	*		*	170	+78	7	
59.	154	+17	*	*	*		*	151	+23	7	
42.	192	+ 1	*	*	*		*	195	− 6	6	203°, −8°. Denning, April. 191°, +1°. Tupman (mean of three positions, Mar. 2–19).
*	*		*	*	*		*	*		*	
48.	234	+28	*	*	*		*	229	+35	6	New. Denning, 225°,+23°. Corder 218°, +24°.
*	*		*	*	*		*	287	+27	5	New? Feeble shower.
?	295	+54	*	*	*		*	305	+56	4	Doubtful.
205.	279	−28	*	*	*		*	277	−25	4	
190.	174	−30	*	*	*		*	180	−20	4	
42.	192	+ 1	*	*	*		*	204	− 8	7	203°, −8°. Denning, April.
49.	307	+40	*	*	*		*	(April.)		9	209°, −8°. May 3–15.
								?		*	315°,+38°. Denning, Apr. 1877.
Total Numbers of Meteors...............				148	....		179	....		487	814 meteors projected and reduced.

TABLE IV.—A Comparative List of Meteor-showers obtained by Mr. Denning from a Reduction of the Italian Observations of Shooting-stars between May 3rd and July 11th, 1872. By R. P. GREG.

Mr. Greg's B.A. Catalogue.			Mr. W. F. Denning's Reduction of the Italian Observations in 1872.									
1874 and 1876. No.	Corresponding Position. R.A.	Dec.	May 3–15. R.A.	Dec.	No. of Meteors.	May 26 to June 13. R.A.	Dec.	No. of Meteors.	June 26 to July 11. R.A.	Dec.	No. of Meteors.	Observations.
54.	190°	+24°	186°	+36°	8	192°	+35°	7	188°	+29°	9	Probably = Winnecke's Comet, at 180°, +36°, in Mar. and Apr.
*	*		162	+34	10	*		*	*		*	New shower.
53.	225	− 8	229	− 4	18	*		...	*		*	Commences in April.
47.	263	+50	252	+47	8	250	+45	5	250	+48	10	"*Draconids*" No. I. Commences in March, at 259°, +63°.
*	*		*		*	*		*	*		*	
67.	235	+23	242	+26	7	246	+21	9	248	+22	16	Denning, 241°, +24°, Apr., May.
58.	256	− 2(T.)	251	+ 8	10	260	+ 8	9	261	+11	14	Heis, at 262°, +12°, July. Commences April 1. Perhaps two showers.
13 (?)	136 Feb. to Mar.	+69	135	+68	10	*		*	*		*	Commences April 1. Denning, 133°, +66°.
55. } 84. }	204 Apr. and May. 214 July.	+56 +55	218	+62	7	215	+70	7	210	+62	7	April to July. *Two* showers?
55 ?	204	+56	210	+48	18	215	+55	17	216	+47	10	? Commences in April!
*	*		170	−10	9	*		*	*		*	Probably a new shower.
65.	289	+81	300	+79	7	279	+77	10	290	+82	8	
62.	199	+ 9	202	+12	31	201	+11	9	*		*	Commences on April 1st.
51.	272	+35	265	+38	15	*		*	*		*	Commences in April, "*Lyrids*" (see Table III.).
110. } 90. }	257	+30	*		*	257	+30	14	255	+37	12	
45.	147	+47	150	+45	7	*		*	*		*	Commences March 1st.
57.	237	+63	247	+57	8	233	+60	15	*		18	At 240°, +70°, June 3–9, Denning, and 242°, +55°, April to May, Corder.
62.	199	+ 9	209	− 8	9	*		*	*		*	Commences April 1st. Confirmed by Corder and Denning.
65 (?)	289	+80	180	+79	6	*		*	*		*	Doubtful.
71.	235	+45	233	+47	24	*		*	*		*	Ditto.
68 (?)	329	+49	315	+55	6	312	+63	5	310	+51	13	At 325°, +55°, May. Heis. = Comet I. [1850?
73.	206	+39	203	+39	9	*		*	*		*	
41*a* (?)	247 [illegible]	− 2	*		*	248	− 3	14	253	− 5	7	Probably a new shower.

	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	279	+59	26	"*Draconids*" II.
109.	337	− 6	*		*	332	− 1	8	325	+ 3	9	Continued to August?
74. / 101.	310 / 315	+24 / +30	*		*	315	+32	22	315	+33	15	Continued to August? At 312°,+21°.
97.	338	+17	*		*	343	+16	8	344	+12	9	Continued to August. = Comet III. [1822?
87.	270	+ 7	*		*	273	− 3	11	273	− 2	20	= Comet III. 1618?
80. / 85.	264	−11	*		*	258	−14	19	269	−13	12	Continued to August.
66. / 79*a*.	291 / 301	+ 9 / + 9	*		*	293	+14	22	290	+15	18	Well-marked shower.
65.	289	+81	*		*	10	+80	6	*		*	
87.	270	+ 7	*		*	285	+ 1	8	*		*	
74.	310	+24	*		*	312	+22	16	313	+20	7	? = No. 101 (July to August?).
69. / 72.	280	+34	*		*	286	+36	15	278	+35	29	
53*a*.	226 (April.)	+10	219 May, Denning	+17	*	214	+16	12	215	+16	7	Possibly commences April 1? But probably distinct from No. 53*a*.
*	*		*		*	353	+39	7	*		*	Confirmed by Denning, at 354°,+41°.
*	*		*		*	35	+47	7	*		*	
79.	299	− 7	*		*	305	−10	8	*		*	New shower? [New shower.
112.	335 (August.)	+52	*		*	337	+59	10	325 / 327	+66 / +50	8 / 7	= Comet I. 1781?
91.	284	−40	*		*	278	−35	5	*		*	Confirms Neumayer.
111? / 86.	359 August.	+13	*		*	5	+17	5	*		*	Confirms Schmidt at 359°,+17° for July.
83.	12	+64	*		*	*		*	24	+61	10	
102.	248	+62	*		*	*		*	250	+62	18	Corder, at 240°,+70°, June 3–9, 1877.
95.	340	+41	*		*	*		*	344	+46	13	
103.	7	+33	*		*	*		*	15	+35	11	Continues to September?
79*a*.	301	+ 8	*		*	*		*	303	+ 7	7	"*Aquilids*" I.
78?	282	+60	*		*	*		*	290	+70	11	See *ante* (? also in May). Rather [doubtful.
82.	237	+ 1(T.)	*		*	*		*	235	+ 7	14	
*	*		*		*	*		*	53	+62	7	New shower?
114.	67 (August.)	+47	*		*	*		*	64	+46	10	? Continues to August.
96.	338	+26	*		*	*		*	335	+26	10	"*Pegasids*," No. I.
76.	168	+55	*		*	*		*	163	+59	9	
98.	7	+50	*		*	*		*	8	+54	6	
*	*		*		*	*		*	291	+45	8	Denning, 290°,+42°, July 6–16, 1877.
*	*		*		*	*		*	320	−12	6	New shower? [New shower.
81.	309 July to Aug.	+48	315	+55	6	312	+63	5	310	+51	13	"*Cygnids*" I. (May and June; doubtful.)
Total Numbers of Meteors............					233	....		330	....		444	1007 meteors projected and reduced.

Table of Meteor-radiants deduced by Mr. Denning from 130 unreduced Meteor-tracks, Jan. 21–Feb. 23, 1869, and February, 1870, in Captain Tupman's Catalogue of shooting-stars observed in the Mediterranean.

No.	Position of Radiant-point.	$\alpha=$ °	$\delta=$ °	No. of Meteors.	Previously known radiant-points confirmed.
1.	β Ophiuchi	260	+ 4	8	Tupman, 16, 21; Greg, 27.
2.	α Virginis	195	− 7	6	T. 6; G. 8, 20.
3.	α Serpentis	236	+11	20	(Jan. 21–Feb. 23), T. 10, 19, 17 (G. 18, too far north ?)
4.	α Scorpii	245	−22	9	(Feb. 16–23); a new shower.
5.	π Hydræ	209	−27	10	T. 11, 17; G. 44 (March 11–19); new for February.
6.	Serpens	228	− 4	8	T. 15 (Feb. 13).
7.	Leo	168	+ 4	5	T. 2; G. 5.
8.	Capricornus	188	−26	8	T. 11, 13.
9.	η Centauri	218	−37	8	T. 17, at 217°, −41° (suspected).
10.	α Leonis	174	+13	5	T. 5; G. 28.

Suspected Showers.

	{ ϵ Boötis	221	+26	—	} G. 18; probably one shower.
	{ Corona	234	+31	—	
	Monoceros	120	− 5	—	A new shower.
	Libra	212	−13	—	G. 8.
	Comæ	180	+27	—	G. 12.

The Serpentids, no. 3, are a very fine shower of swift, white meteors, often leaving streaks, with *a very exactly* centred radiant; confirmed by Mr. Denning, February 1877, at 236°, +11° (10 meteors). Nos. 1, 2, 7, and 10 were also confirmed by Mr. Denning in February 1877. No. 4 seems new; and also no. 9, though the latter was suspected by Tupman from a stationary meteor at 217°, −41°, seen at 3^h 41^m A.M. on February 23rd, 1869.

Appendix IV.—On Aërolites and Detonating Meteors. By Walter Flight.

The Meteoric Irons of the Mexican Desert*.

Dr. Lawrence Smith takes stock afresh of our knowledge of the masses of meteoric iron of that region of Mexico called the *Bolson de Mapini*, or the Mexican Desert situated in Cohahuila and Chihuahua, two of the northern provinces of the Mexican Republic. In 1854 he described three masses, two of which (one weighing 630 kilogrammes and the other 125 kilog.) were subsequently conveyed to the United States; in 1868 eight other masses, the largest of which weighed 325 kilog., were conveyed to the United States; and later still, in 1871, Dr. Smith published a description of a still larger block, estimated to weigh 3500 kilog., now lying in the western boundary of the Desert near El Para. There is, moreover, some account of a mass yet vaster to be seen in the very centre of the desolate region. In this district alone not less than 15,000 kilogrammes in weight of meteoritic masses have been discovered.

While examining sections of two of the above-mentioned masses, Dr. Smith noticed a number of nodular concretions imbedded in the metal, having at

* J. L. Smith, 'Amer. Journ. Sc.' 1876, xii. 107.

first sight the appearance of "very finely crystallized troilite;" closer inspection, however, reveals the fact that most of these nodules have more or less of a black mineral associated with them. This substance was ascertained to be—not graphite, as might at first sight have been supposed,—but *chromium monosulphide*, a mineral new both to terrestrial and celestial mineralogy.

Daubréelite, as Dr. Smith has named it, is a black lustrous mineral, highly crystalline, usually occurring on the surface of the nodules of troilite, but sometimes traversing them; in one nodule a vein of the mineral, 2 millims. wide and 12 millims. in length, crosses the very centre of a nodule. It exhibits a distinct cleavage, is very fragile, and is feebly magnetic: the powdered mineral is perfectly black and is but slightly acted upon by strong acids, with the exception of nitric acid, in which it completely dissolves; this reaction serves to distinguish and separate it from chromite. The mineral has not yet been completely analyzed; one hundred milligrammes were examined and found to contain 36·48 per cent. of sulphur, the remainder being chromium with nearly ten per cent. of iron and a little carbonaceous matter. (Chromiun monosulphide contains chromium = 62·38, and sulphur = 37·62; iron-monosulphide troilite contains iron = 63·64, and sulphur = 36·36.) The discovery of this new body is of great interest in extending the knowledge already arrived at by aid of the spectroscope of the distribution of chromium in cosmical bodies.

Found about 1850.—Pittsburg, Alleghany Co., Pennsylvania*.

This large mass of meteoric iron, weighing 132 kilog., was turned up by a plough at Pittsburg. It was briefly described at the time by Silliman, and has now been analyzed by Dr. Genth. The specific gravity appears to be 7·741; and the chemical composition of a somewhat oxidized specimen was found to be

Iron	92·809
Nickel	4·665
Cobalt	0·395
Copper	0·034
Manganese	0·141
Sulphur	0·037
Phosphorus	0·251
	98·332

The phosphorus corresponds with about 1·8 per cent. of Schreibersite. The iron, when etched, exhibits Widmannstättian figures, and the presence of minute crystals of a phosphide could be recognized on the surface of the section.

Found 1870.—Ovifak, Disko, Greenland†.

M. Daubrée gives the name *Lawrencite* to the iron protochloride, the presence of which he has detected in the curious meteoric irons of Ovifak. It was earlier recognized in the Tennessee meteoric iron by Dr. Lawrence Smith.

Found August 1873.—Duel Hill, Madison Co., N. Carolina‡.

A mass of meteoric iron was found in August 1873, on the land of Mr.

* F. A. Genth, 'Amer. Journ. Sc.' 1876, vol. xii. p. 72. Report of Geological Survey of Pennsylvania, 1875.

† G. A. Daubrée, 'Compt. Rend.' 1877, January 8th, vol. lxxxiv. p. 66.

‡ B. S. Burton, 'Amer. Journ. Sc.' 1876, vol. xii. p. 439.

Robert Farnesworth, lying on a hillside, where it had been used probably by the first settlers to support a corner of a rail fence since rotted away. (A similar block, weighing about 40 lb., was discovered about a mile further west, " before the war, perhaps about 1857," but has since been covered over and lost.) The mass above referred to originally weighed some 25 lb.; but specimens have been hammered off it, and it now weighs 21 lb. and measures $9 \times 6\frac{1}{2} \times 3\frac{1}{2}$ inches. It has the usual coating of magnetite, and from various points of the surface bead-like drops of iron chloride exude. When polished and etched "the usual markings appeared, though rather indistinct," and when the action of acid was prolonged distinct particles of Schreibersite were seen to protrude from the face of the metal. The meteorite has a specific gravity =7·46 and the following composition:—

Iron	94·24
Nickel	5·17
Cobalt	0·37
Copper	*Trace*
Phosphorus	0·14
Residue	0·15
	100·07

Found 1874.—Waconda, Mitchel Co., Kansas*.

This meteorite was found in 1874, lying above ground upon the slope of a ravine about two miles from the village of Waconda. Fragments amounting to about one half of the stone were removed at the time; the remainder, weighing about 58 lb., is partially covered with a black crust. The freshness of the original fracture, at the time when the stone was submitted to examination, points to the fall being one of recent date.

It closely resembles the stone of Searsmont (21st May, 1871) in colour, but is less chondritic, and only exhibits this characteristic of certain meteorites in a very imperfect manner. Crystals of what appear to be augite are observed imbedded in an amorphous whitish ground-mass; nickel-iron is present thickly scattered throughout the stone in minute rounded lustrous grains; while troilite is now and then met with in grains of considerable size or aggregations of imperfect crystals. A fragment partially covered with crust was found to have a specific gravity =3·81; that of another fragment without crust was =3·58.

Mechanical separation of the ingredients was attempted and 5·66 per cent. of nickel-iron and 1·34 per cent. of troilite were isolated. Of the remaining siliceous portion rather more than one half gelatinized with acid and was, presumably, olivine; the remainder, according to Prof. Shepard, consists of " augite, some felspathic species, and chladnite," by which last mineral enstatite presumably is meant. There exists a rumour that a second meteorite has been met with twelve miles distant from the above.

1874, April 10th, 7^h 57^m P.M. (Prague mean time).—Bohemia†. (See Appendix II. Large Meteors, p. 146.)

A detonating meteor; conforms in radiant-point with that of 1876, April 9th.

* C. U. Shepard, 'Amer. Journ. Sc.' 1876, vol. xi. p. 473.

† Prof. G. von Niessl, 'Sitzungsber. Akad. Wiss. Wien,' vol. lxxv., April 19th, 1877.

Found 1875 (?).—Red River, northward of Young Co., Texas*.

There is preserved in the State collections at Austin a mass of meteoric iron weighing 315 lb., which is said to have been found on the head waters of the Red River, northward of Young County.

1875, August 16th (about noon).—Feid-Chair, Cercle de la Calle, Constantine †.

This meteorite fell about midday at a spot named Feid-Chair, about 30 kilometres from La Calle, the descent being attended with the accustomed luminous appearance. It weighs about 380 grammes; all search to discover other stones has proved of no avail. The stone has a black crust and a grey interior, in which particles of nickel-iron and troilite are imbedded. Spherules are recognized, but the matrix likewise exhibits a brecciated structure; grains of a dull black hue are also distributed through the mass. The siliceous portion acts on polarized light. The enclosed crystals are too small to allow of their form being recognized. This portion of the stone is acted upon by acid, and appears to consist of a mixture of olivine and enstatite. The Feid-Chair meteorite closely resembles the stones which fell at La Baffe Dép. des Vosges (1822, September 13th), Heredia, Costa Rica (1857, April 1st), Canellas, near Barcelona (1861, May 14th), and Khetree, Rajpootana, India (1867, January 19th). This is the third occasion within the space of twelve years that meteorites have been seen to fall in Algiers and have been preserved.

1875, September 14th, 4 P.M.—Supino, circ. Frosinone, Rome.

The asserted fall of an aërolite on this date, recorded in the last volume of these reports (vol. for 1876, p. 164), and again as an authentic stonefall in the 'Monthly Notices of the Royal Astronomical Society' (vol. xxxvii. pp. 205–6), is entirely refuted by a letter from Padre Secchi, in the latter volume of the 'Monthly Notices' (p. 365), in which the real circumstances of the supposed meteor and stonefall are related and described. A flash of lightning which occurred in the public square of Supino struck a neighbouring house with sufficient violence to dislodge a stone from the roof, without doing any more material damage to the house. The supposed "meteorite," which fell in the courtyard of the house, is identified by Padre Secchi with the ordinary volcanic stones of the district, which is in the neighbourhood of an extinct volcano, and it probably lay (as it is customary to protect them against the force of the wind) upon the tiles of the roof until it was projected from its place by the lightning-stroke.

1876, April 9th, 8.20 P.M. (Vienna mean time).—Hungary ‡.

A detonating meteor; see above, 1874, April 10th.

1876, June 25th, 9–10 A.M.—Kansas City, Missouri §.

A small meteorite fell between nine and ten in the morning of the above day, on the tin roof of the house, No. 556 Main Street, Kansas City. It

* S. B. Buckley, 'Second Annual Report of the Geological and Agricultural Survey of Texas.' Houston, Texas, 1876.

† G. A. Daubrée, 'Compt. Rend.' 1877, vol. lxxxiv. p. 70.

‡ Prof. von Niessl, 'Sitzungsber. Akad. Wiss. Wien,' vol. lxxv., April 19th, 1877.

§ J. D. Parker, 'Amer. Journ. Sc.' 1876, vol. xii. p. 316.

struck the roof with sufficient force to cut a hole in the metal; but it did not pass through, bounding back a few feet and coming to rest on the roof. Two observers who were at a window close by heard the sharp concussion when it struck the roof, and one of them immediately picked up the meteorite as it lay near her on the roof, but let it fall again, finding it too hot to retain in the hand. It is described as of a plano-convex form, one inch and three quarters along its greatest length and about one third of an inch thick. "The convex surface possesses the usual crusted appearance, while the inside or plane surface differs from ordinary meteorites in possessing the appearance of sulphuret of iron, subjected to some degree of heat, instead of nickeliferous iron. One might easily infer that the meteorite was shaled off from a large bolide that passed over the city at that time." It is much to be desired that this meteorite will pass into the hands of a scientific expert for examination and description.

Prof. Kirkwood describes eight large fireballs, between July 1876 and February 1877 (American Journal of Science, 1877, vol. xiv. p. 75); the time and the real path and appearance of one was :—

1876, July 8th, 8.45 P.M.—From an altitude of 88 miles, passed N. 78° W. across the N.E. of Indiana and exploded over Lake Michigan at an altitude of 34 miles. The path was inclined 21° to the horizon; no detonation reported; train visible 40 minutes. The account of the meteor given in Appendix II. of this Report contains all the observed particulars of its appearance.

1876, December 21st, 8.40 P.M.—Rochester, Fulton Co., Indiana.
[Lat. 41° 8′, long. 86° 12′ *.]

This remarkable meteor passed over the States of Kansas, Missouri, Illinois, Indiana, and Ohio, a distance from E. to W. of about 800 miles. It burst into numerous fragments during its passage, producing "a flock of brilliant balls chasing each other across the sky, the number being variously estimated from twenty to one hundred." Over all the regions of Central Illinois a series of terrific explosions was heard. Over the northern part of Indiana the passage of the body was followed by loud explosions. A piece of the meteorite, a few ounces in weight, fell near Rochester, Ia. A portion in the possession of Prof. Shepard was discovered on the following day lying in the snow. Two places were noticed where it had previously struck, whence it had bounded to its resting place. It is stated by Prof. Shepard to closely resemble the meteorite of Pegu, India (27th December, 1857), and to consist of dark ash-grey spherules (Boltonite), imbedded in a nearly white pulverulent matrix, "chladnite," olivine in distinct grains, nickel-iron, and a little troilite. The specific gravity of a fragment partially covered with crust was 3·65.

1877, January 3rd (sunrise).—Warren County, Missouri †.
[Lat. 38° 50′, long. 91° 10′.]

A brief note by Dr. Lawrence Smith records the occurrence. At sunrise the usual phenomena accompanying the fall of meteorites attracted the

* H. A. Newton, 'Amer. Journ. Sc.' 1877, vol. xiii. p. 166; J. L. Smith, 'Amer. Journ. Sc.' 1877, vol. xiii. p. 243, and xiv. p. 219; C. U. Shepard, 'Amer. Journ. Sc.' 1877, vol. xiii. p. 207.

† J. L. Smith, 'Amer. Journ. Sc.' 1877, vol. xiii. p. 243, and vol. xiv. p. 222.

attention of several observers, who saw the stone strike the branch of a tree, which it broke; then fall to the ground, penetrating it slightly and melting the snow which lay on the frozen surface. The meteorite was picked up immediately afterwards, and a portion of it has been sent to him for examination.

1877, January 23rd (afternoon).—Cynthiana, Kentucky*.
[Lat. 38° 25′, long. 84° 15′.]

A meteorite was seen to fall to the ground, at a spot a few miles north of Cynthiana, on the afternoon of the above day. It penetrated the soil to the depth of thirteen inches, and the fall was accompanied by "great atmospheric disturbance." An observer close at hand immediately dug it up. It weighs 15 lbs.

1877, March 16th, 8 P.M.—Uitenhage, Cape of Good Hope, S. Africa †.

A magnificent fireball, such as few would ever see in a lifetime, made its appearance in the East, "coming out of the eastern horizon" at Uitenhage, "and travelling slowly across the firmament in an oblique direction to the westward, when it burst, sending forth streams of fire, as if from a hundred rockets, and then was heard a low rumbling noise as of thunder in the distance. The meteor appeared to be nearly if not quite as large as the full moon, but not round, more of an oblong shape, and while travelling through the air it very much resembled a large turpentine ball. It gave forth a bright bluish light, which lit up the whole sky, and you could distinguish every thing around you for miles as plainly as in the daytime." Native Hottentots and Kaffirs, the account adds, were so terrified that they sought refuge in the nearest houses, and the apparition of the fireball was regarded by them as a warning of approaching famine, drought, or some other calamity. None of them had ever seen a meteor of any thing like the size or half so brilliant as the present one. The oxen in the waggons stopped on the road and could not for some time be got to start again, others turned round, snapped off the disselbooms of the waggons, and bolted for some distance into the bush. The consternation was general in the country round Uitenhage. The illumination lasted nearly a minute, and the light was such that it dazzled the eyes of all who saw it. The events recorded took place on a beautiful starlight evening.

1877, June 12th, 9.15 P.M.—A large meteor passed over Indiana, in the United States ‡. It did not detonate.

* J. L. Smith, 'Amer. Journ. Sc.' 1877, vol. xiii. p. 243, and vol. xiv. p. 225.
† 'The Times,' London, May 21, 1877.
‡ D. Kirkwood, 'Amer. Journ. Sc.' 1877, vol. xiv. p. 163.

Tenth Report of the Committee, consisting of Prof. EVERETT, Sir W. THOMSON, F.R.S., Prof. J. CLERK MAXWELL, F.R.S., G. J. SYMONS, F.M.S., Prof. RAMSAY, F.R.S., Prof. A. GEIKIE, F.R.S., JAMES GLAISHER, F.R.S., W. PENGELLY, F.R.S., Prof. HULL, F.R.S., Prof. ANSTED, F.R.S., Prof. PRESTWICH, F.R.S., Dr. C. LE NEVE FOSTER, F.G.S., Prof. A. S. HERSCHEL, F.R.A.S., G. A. LEBOUR, F.G.S., A. B. WYNNE, F.G.S., W. GALLOWAY, *and* JOSEPH DICKINSON, F.G.S., *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Prof. EVERETT, *Secretary.*

OBSERVATIONS on a very elaborate scale have been received from the important mining district of Schemnitz, in Hungary. A request for observations was sent by the Secretary in 1873 to the Imperial School of Forests and Mines at Schemnitz; and, on the receipt of two thermometers, a Committee was formed to plan and carry out observations. The leading part in the observations has been taken by Dr. Otto Schwartz, Professor of Physics and Mathematics, who has furnished an elaborate Report of the results obtained. This is accompanied by a geological Report drawn up by Professor Gustav von Liszkay, and by a geological map with plans and sections of the mines.

The two thermometers sent being deemed insufficient for the numerous observations which were comtemplated, 25 large thermometers were ordered from a local maker (T. T. Greiner), and the 10 best of these, after being minutely compared with one of the two thermometers sent (which was non-registering, and had a Kew certificate), were devoted to the observations. Three of them were divided to tenths, and the others to fifths of a degree Centigrade, and all had bulbs of thick glass to ensure slowness of action. They were found not to change their indications during the time requisite for an observation.

The observations were, for the most part, taken by boring a hole in the rock to a depth, in the earlier observations, of ·422, and in the later ones of ·79 of a metre, then filling the hole with water, and, after leaving it, in some cases for a few hours, in others for several days, to plunge a thermometer to the bottom of the hole, and after 30 or 45 minutes take it out and read it. The tenths of a degree were read first, and there was time for this to be done before the reading changed. As a rule, three observations were taken in each gallery, two of them in bore-holes to give the temperature of the rock, and the third in the air of the gallery at an intermediate position. Pyrites and also decaying timber were avoided, as being known to generate heat; and, as far as possible, currents of air and the neighbourhood of shafts were avoided also.

A table which forms part of Dr. Schwartz's Report contains observations made in no fewer than thirty-eight galleries. Besides the temperatures, it gives the depth of the place of observation beneath the shaft-mouth, and the height of the latter above sea-level. Dr. Schwartz takes exception to a few of the observations in the table, as being vitiated by the presence of pyrites or by currents of air.

All the galleries mentioned in the table are classified according to the shafts with which they are connected, and there are, for the most part, six of these galleries to each shaft. In the final reductions, Dr. Schwartz compares the temperature in the deepest gallery of each shaft with the assumed mean annual temperature of the ground at the shaft-mouth. For determining this latter element the following data are employed.

The mean temperature of the air at the School of Mines, from twenty years' observation, is 7°·2 C., at the height of 612·6 metres above sea-level. The shaft-mouths are at heights of from 498 to 763 metres above sea-level; and it is assumed that the temperature of the air falls 1° C. for 100 metres of elevation. It is further assumed that the mean temperature one metre deep in the soil is, in these particular localities, 1° C. higher than the mean temperature of the air. The reasons given for this last assumption may be thus summarized:—

(1) Observations in various localities show that in sandy soils the excess in question amounts, on the average, to about half a degree Centigrade.

(2) In this locality, the surface is a compact rock, which is highly heated by the sun in summer, and is protected from radiation by a covering of snow in winter; and the conformation of the hills in the neighbourhood is such as to give protection against the prevailing winds. Hence the excess is probably greater here than in most places, and may fairly be assumed to be double of the above average.

Omitting one shaft (Franz shaft), in which, owing to the presence of pyrites, the temperatures are abnormal, the following are the principal results:—

Name of shaft.	Depth in metres.	Increase of temp. Cent.	Quotient or metres per deg. Cent.	Feet per degree Fahr.
Elizabeth	417	°8·5	°49·1	°89·5
Maximilian	253	6·4	39·5	72·0
Amelia	285	8·1	35·2	64·2
Stefan..............	218	7·2	30·3	55·2
Siglisberg	414	8·1	51·1	93·2
Sums, &c	1587	38·3	41·4	75·5

The best mode of combining the results from these five shafts is indicated in the last line of the above Table, where the sum of the depths is compared with the sum of the increments of temperature. We have thus a total increase of 38°·3 C. in 1587 m., which is at the rate of 1° C. in 41·4 metres, or 1° F. in 75·5 feet.

As these results depend on an assumption regarding the surface temperature, it seems desirable to check them by a comparison of actual observations, namely, by comparing the deepest with the shallowest observation in each mine. We thus obtain the following results:—

Name of shaft.	Difference of depth. Metres.	Difference of temp. Cent.	Quotient. Metres per degree Cent.	Feet per deg. Fahr.
Elizabeth	145·2	°4·6	°31·6	57·6
Maximilian	191·6	3·9	49·1	89·5
Amelia	228·2	5·1	44·8	81·7
Stefan	82·0	4·7	17·4	31·7
Siglisberg	400·3	8·0	50·0	91·2
Sums, &c......	1047·3	26·3	39·8	72·5

Combining these results in the same manner as the others, we have a total difference of 26°·3 C. in 1047·3 m., which is at the rate of 1° C. in 39·8 m., or 1° F. in 72·5 feet.

The near agreement of this result with that obtained from comparison with the assumed surface-temperature is very satisfactory. The mean of the two would be 1° F. in 74 feet. The rocks consist, for the most part, of trachyte and greenstone.

Dr. Schwartz concludes his Report with the suggestion that the heat developed by the decomposition of pyrites and galena, in seams which are not altogether air-tight and water-tight, may possibly be utilized as a guide to the whereabouts of metallic lodes; and that "we shall thus obtain, by means of the thermometer, scientific information which the ancients sought by means of the divining rod."

Thanks are due to Herr Antoine Péch, Ministerial Councillor and Director of the Mines, and to Herr Edouard Pöschl, Director of the School, for energetic cooperation in this extensive and valuable series of observations.

Mr. Lebour, having been requested to supplement the above *résumé* of the Schemnitz observations by an account of the connexion (if any) between the geological and thermal conditions of the several mines, as indicated by a comparison of the Reports of Dr. Schwartz and Professor von Liszkay, remarks:—

"The rock at all the mines except Franzschacht is green hornblende-andesite (in German *Grünstein-Trachyt*), a compact, fine-grained, crystalline, more or less vitreous rock, containing crystals of oligoclase and hornblende, but *no quartz or sanidine*. This rock is a good heat-conductor, with a conductivity probably nearly approaching that of 'Calton trap-rock.'

"The Franzschacht is sunk in rhyolite (a highly siliceous vitreous trachyte), a rock the conductivity of which would presumably be nearly the same as that of hornblende-andesite, probably a little greater. Elements of temperature-disturbance are, however, present in the form of thermal springs and, possibly, in the proximity of a basaltic cone. This last element of disturbance is, I should imagine, a very doubtful one indeed, although Councillor A. Péch appears to think it of importance. The rate of increase, as deduced from observations in the rhyolite here, was 1° C. for 40·55 metres, or about 1° F. for 74 feet.

"The Report brings out strongly the important variations of rock-temperature, which may be, and are occasionally, generated by the decomposition of metallic sulphides, a point which, I think, is here prominently mentioned for the first time."

At the request of Mr. Lebour, observations have been taken by Mr.

Matthew Heckels, Manager of Boldon Colliery, between Newcastle and Sunderland, in holes bored upwards to a distance of 10 feet from some of the deepest seams. The mine is described as "perfectly dry," and those parts of it in which these observations were made are quite free from currents of air. The surface of the ground is tolerably level, and is 97 feet above Trinity high-water mark.

Hole No. 1 is bored up from the roof of the Bensham seam. The thermometer (one of the new slow-action instruments, not self-registering) was placed at the end of the hole, so as to be 10 feet within the rock, and protected by air-tight plugging. The surrounding strata consist of arenaceous strata known as "grey metal." The distance of the thermometer from the surface of the ground overhead was 1365 feet.

The hole had been standing idle for some time when the thermometer was inserted, April 5, 1876. The first reading was taken April 26, and was 75°, the surrounding air being at 75½° and almost stagnant. The readings were repeated during four consecutive weeks, without change of the indications.

Hole No. 2 is in the same vertical with No. 1, and is bored up (also to the height of 10 feet) from a deeper seam—the Hutton seam. The same thermometer was employed and in the same manner. The surrounding strata consist of a close compact sandstone known as "hard post." The distance of the thermometer from the surface of the ground overhead was 1514 feet.

Immediately after the drilling of the hole, June 6, 1876, the thermometer was inserted, and on July 4 the first reading was taken, namely 81°. On July 24 it had fallen to 79½°, and on August 1 to 79°. Readings taken August 15 and 29 and September 1 also showed 79°, the surrounding air having never altered from the fixed temperature 78½°. It would therefore appear that the first observation in this hole was 2° too high, owing to the remains of the heat generated in boring, notwithstanding the lapse of 4 weeks which had intervened. Four readings have since been taken at regular intervals, ending with July 1877, and the same temperature, 79°, continues to be shown.

Assuming 48° as the mean annual temperature of the surface, we have the following data for calculating the rate of increase downwards:—

Surface	48° F.
1365 feet	75
1514 feet	79

For the interval of 149 feet between the two holes we have an increase of 4° F., which is at the rate of 1° F. in 37 feet.

For the whole depth of 1514 feet, from the surface to the lower hole, we have an increase of 31°, which is at the rate of 1° F. in 49 feet.

In explanation of the length of time required for the heat of boring to disappear in the second hole, Mr. Heckels remarks that "it required two men sixteen hours with a hand boring-machine to drill this hole, so hard is the stratum." He further says, "the tool by which this hole was bored, on being drawn out, was too hot to allow of it being touched with the hand, so that the temperature of the hole, on being finished, must have been considerable; and no doubt it would be, when we consider the immense pressure required to bore holes in such strata as this." With respect to the permanent temperature (78½°) of the surrounding air, Mr. Heckels remarks—"The air of this district is almost stagnant, and what circulation there is will have travelled a distance of three miles underground, and hence it may be expected to be itself pretty near the temperature of the rocks through which it is circulating."

The dryness of the mine, the absence of currents of air, and the great depth render these observations extremely valuable for the purpose which the Committee have in view; and their best thanks are due to Mr. Heckels and the proprietors of the colliery for the trouble and expense which have been incurred in procuring them. Observations will shortly be taken in another bore in the same colliery.

During the past year the first observations have been received from India. They were taken by Mr. H. B. Medlicott, M.A., of the Geological Survey, in holes made in search of coal, and have been published by him in the 'Records of the Geological Survey of India,' vol. x. pt. i. The instrument employed was a protected Negretti thermometer, sent by the Secretary of this Committee to Dr. Oldham, the Director of the Survey. A Casella-Miller thermometer was used to check the observations, but was found much less sensitive and steady, and its readings, though placed on record, are therefore left out of account by Mr. Medlicott in his reductions.

The observations were taken in three bores, at places named Khappa, Manegaon, and Moran; but the observations at Moran were made only four hours after the boring tool had been at work; and the Khappa bore exhibited a strong bubbling, besides other marks of convection. The results obtained at these two bores must therefore be discarded: but in the Manegaon bore every thing was favourable for satisfactory observation. "It was closed on the 24th of April, 1875, so that it had been at rest for 20 months. There is only one guide-pipe, ten feet long, at the top of the bore, there never having been any pressure of water in the hole. The position is low, and the water had always stood at or near the mouth of the tube. There was no difficulty in removing the plug. The very equable series of temperatures is the natural result of these conditions. The observations were taken in the evening of the 5th and morning of the 6th of December. At 5 P.M. the air temperature was 72°; at 8 P.M., 59°; at 8 A.M., 65°; at 11 A.M., 84°. The slight decrease of temperature in the top readings is a good proof of the perfectly tranquil conditions of observation. It is no doubt due to the excess of summer heat not yet abstracted; and it is apparent that that influence reaches to a considerable depth, quite to 60 feet." The following are the observations:—

Depth in feet.	Temperature Fahr.
10	81·15°
20	81·1
40	81·0
60	81·0
80	81·3
100	81·8
150	82·7
200	83·3
250	84·0
300	84·65
310	84·70

The observation at 310 feet was in mud, the hole, which had originally a depth of 420 feet, having silted up to such an extent that 310 feet was the lowest depth attainable. The increase from 60 feet downwards is remarkably uniform, and the whole increase from this depth to the lowest reached is 3°·7, which is at the rate of 1° F. for 68 feet.

The elevation of Manegaon is estimated at 1400 feet. It lies "in an open valley of the Satpuras, traversed by the Dudhi river, south of the wide plains of the Narbada valley, about halfway between Jabalpur and Hoshungabad, which are 150 miles apart." Jabalpur is 1351 feet above sea-level, and has a mean annual temperature of 75°·2. Hoshungabad is 1020 feet above sea-level, and has a mean annual temperature of 78°·3.

"The geological conditions of the position are favourable for these observations. The rocks consist of steady alternations, in about equal proportions, of fine softish sandstones and hard silty clays of the Upper Gondwana strata, having a steady dip of about 10°. . . . Strong trap-dykes are frequent in many parts of the stratigraphical basin; but there are none within a considerable distance of these borings. There are no faults near, nor any rock features having a known disturbing effect upon the heat-distribution."

Mention was made in last Report (p. 209) of two methods, which had been suggested by members of the Committee, for plugging bores to prevent the convection of heat. Mr. Lebour, at the request of the Committee, has conducted experiments during the past year on both forms of plug. He reports that—"In accordance with Sir W. Thomson's suggestion, disks of india-rubber fixed to the lowering wire above and below the thermometer have been tried. The chief difficulty met with was the unwieldiness of the armed portion of the wire, which could not be wound and unwound from the drum, owing to the fixed disk-holders. This difficulty prevented the placing of the disks anywhere but at the extremity of the wire, whereas it would be very desirable to have a large number of them at intervals along the greater part of its entire length. Disks for a 2½-inch bore were found to work well with a diameter of 2¼ inches. The lowering and especially the raising of the wire armed with the disk-plugging were very slow operations, owing to the resistance opposed by the water to the passage of the disks."

Experiments with the form of plug devised by Mr. Lebour himself were continued with a set of better made plugs. "The great disadvantage of this system of plugging is the necessity of using two wires, one to lower the thermometer and plug as usual, and the other to let down weights upon the upper ends of the plugs when they are to be expanded, and to remove them when they are to be collapsed. This necessitates not only the ordinary drum for the first wire, but also an independent reel for the second. With care, however, and after some practice, the apparatus was found to work well; but it certainly is extremely inconvenient for rapid work, as it requires a good deal of setting up."

Experiments were made with both forms of plug at the depth of 360 feet, in a bore of the total depth of 420 feet. In the one case eight india-rubber disks were employed, four above and four below the thermometer; in the other, two collapsible plugs, one above and one below.

The experiments had chiefly in view the mechanical difficulties of the subject, and are not decisive as to the sufficiency of the plugs to prevent convection.

Report of the Committee, consisting of James R. Napier, *F.R.S.*, Sir W. Thomson, *F.R.S.*, W. Froude, *F.R.S.*, J. T. Bottomley, *and* Osborne Reynolds, *F.R.S.* (Secretary), *appointed to investigate the Effect of Propellers on the Steering of Vessels.*

Since the meeting of the British Association held in Glasgow last year, the Committee has been able to carry out some further experiments on steering as affected by the reversing of the screw.

The largest vessel experimented upon last year was the barge No. 12, of about 500 tons, and it appeared, on comparing the behaviour of this vessel with the behaviour of those of smaller size, that the larger the ship the more important would the effect of reversing the screw become. This view has been completely borne out by the experiments of this year, made with one vessel of 850 tons and another of 3594 tons.

In May last the 'Melrose,' a new vessel belonging to Messrs. Donald Currie & Co., was tried at the instance and under the superintendence of Mr. James R. Napier. The 'Melrose' is 228 feet in length by 29 feet in breadth, and 16 feet 3 inches in depth. She is 850 tons gross register; her propeller makes 90 revolutions per minute with the vessel going at a speed of $10\frac{3}{4}$ knots.

The following is Mr. Napier's report of the trials:—"These experiments were made on 3rd of May 1877, between Wemyss Bay and Rothsay. There was little or no wind; the sea was glassy smooth. The draft of water was 9 feet 1 inch forward, and 12 feet 5 inches aft; the diameter of the propeller was 11 feet 6 inches, the pitch 14 feet 3 inches, it had 4 blades and was right-handed. The maximum speed at the nautical mile was $10\frac{3}{4}$ knots; but the speed was about 10 knots when the trials were made.

"A trial was made with the rudder said to be amidships, and the ship's head turned to starboard; but it was found afterwards that the pointer on the bridge had been misplaced, and, as it was difficult at the time to ascertain the rudder's position, the result was uncertain.

"*First mock collision trial.*—The vessel was steaming about 10 knots when the telegraph bell warned the engineer to stand by his engines, and shortly after the bell was rung for him to reverse at full speed (no intermediate order to slow or stop being given); in 15 seconds after this order was given the engines began to reverse, and in 2 minutes 15 seconds after the giving of the order to reverse, the forward motion of the ship had entirely stopped.

"At the instant that the engineer below telegraphed to the captain on deck that his engines were reversing, the captain gave the order "*Hard aport,*" which was quickly obeyed by the two men at the weel. *The vessel's head almost immediately commenced turning to port,* and when the ship's way was stopped, or about 2 minutes after the order to port was given, the vessel's head had turned 26 or 28 degrees to port.

"*Second mock collision trial.*—Every thing was done in the same manner as in the first trial, except in this case the order was to *starboard hard.* The vessel's way was lost in about the same time. *The vessel's head commenced to turn to starboard almost immediately after the engines began to reverse*, and when the forward way was lost, her head had gone round 40° to starboard.

"These results were so contrary to the expectation of some of the nautical party on board, that they made a *third mock collision trial* (a second one with the helm *hard aport*); but on this occasion the orders to reverse the engines and to port the helm were given simultaneously. The result was similar to the first trial, the head turning a long way to port; but I was not on the bridge to note the angle through which her head moved before head-way was lost.

"Mr. Currie, one of the owners of the ship, most of the nautical men and visitors on board learned, I think, something regarding the steering of screw-steamers, and a cause of some, if not of many, collisions which they did not know before. The Captain of the ship, however, when asked before the trials what would be the result of the sudden reversal of the engines, with the helm aport or starboard, stated the direction in which the ship's head would turn as it actually happened."

The Committee wish to thank Mr. Currie for allowing them the use of his ship for the experiments.

It will be seen, from Mr. Napier's report, that the 'Melrose' behaved in precisely the same way as did the vessels last year, except that the effect of the reversed screw on the action of the rudder was even more apparent than in the previous trials. This was obviously owing to the greater size of the ship, and the consequently greater time taken by the reversed screw in bringing her to rest, and the result led the Committee to conclude that with still larger ships the result would be yet more pronounced.

This conclusion has been verified in a somewhat unexpected although in a most satisfactory manner; for, after arriving at Plymouth, the Secretary received the following account of trials made in the s.s. 'Hankow,' of London, 3594 tons, by Captain Symmington, the commander, in response to the circular issued by the Committee last year, but otherwise at his own instance.

Capt. Symmington's Report.

"S.s. 'Hankow,' of London,
"8th March, 1877.

"Gross tonnage 3594^{12}, net 2331^{75} tons.

"Length 389 feet, breadth 42·1, depth 28·8.

"Some experiments were conducted this forenoon from 9.20 A.M. to 11.20 A.M., in lat. 8° 50′ S., long. 153° 58′ E., in order to determine how the ship's head turned on reversing the engines suddenly when going full speed ahead with the helm amidships, port, and starboard; also the time and diameter of the circles made when going slow and full speed ahead on the port helm.

"Sea smooth or between No. 1 and 2 of the Beaufort scale; ship drawing, on leaving Sydney on the 28th ult., 26 feet forward and 24 feet 3 inches aft; today the probable draft will be 24 feet 8 inches forward and 23 feet 8 inches aft, mean 24·2.

"*First Experiment.*

"Ship going ahead full speed, engines were suddenly reversed, helm put hard aport; immediately the engines started, time noted and bearing of ship's head by standard (Admiralty compass) noted, and the bearing of the ship's head also noted at every 15 seconds until the ship came to a dead stop.

Time. A.M.			Interval.	Ship's Head by Compass.			Head turned to Port.	Head turned to Starboard.
h.	m.	s.	m. s.		°		°	°
9	20	7	...	N.	62	W.		
		22	15	„	62½	„	0½	
		37	15	„	66	„	3½	
		52	15	„	69	„	3	
	21	7	15	„	78½	„	4½	
		22	15	„	77	„	3½	
		37	15	„	80	„	3½	
		52	15	„	84½	„	4	
	22	7	15	„	88	„	3½	
		22	15	„	88	„	Stationary.	
		37	15	„	87	„		1
		52	15	„	85½	„		1½
	23	7	15	„	84	„		1½
		22	15	„	82½	„		1½
		37	15	„	79½	„		3
	3	30	3 30				26	8½

"Ship came to a dead stop in 3 min. 30 sec., and turned *to port* 26° in 2 min., then turned to starboard 8½° in 1 min. 30 sec.

"*Second Experiment.*

"Ship going ahead full speed, say 10 knots. The engines were suddenly reversed full speed astern, helm put hard astarboard; bearing of ship's head taken and time. At every 15 seconds the bearing of ship's head was also noted until the ship came to a dead stop.

Time. A.M.			Interval.	Ship's Head by Compass.			Head turned to Port.	Head turned to Starboard.
h.	m.	s.	m. s.		°		°	°
9	45	30	...	N.	39	W.		
	45	45	15	„	41	„	2	
	46	0	15	„	41	„		
	46	15	15	„	39½	„	...	1½
	46	30	15	„	37½	„	...	2
	46	45	15	„	32½	„	...	5
	47	0	15	„	28	„	...	4½
	47	15	15	„	44½	„	...	3½
	47	30	15	„	21½	„	...	3
	47	45	15	„	18	„	...	3½
	48	0	15	„	13	„	...	5
	48	15	15	„	9	„	...	4
	48	30	15	„	5	„	...	4
	48	45	15	„	2½	„	...	2½
	48	53	8	„	2	„	...	0½
	3	23	3 23				2	39

"Ship came to a dead stop in 3 min. 23 sec. Her head payed off to port 2° during the first 15 sec., and afterwards turned to starboard 39° before coming to rest.

"*Third Experiment.*

"Ship going full speed ahead, say 10 knots, the engines were suddenly reversed, full speed astern, the helm put amidships, and the bearing of the ship's head noted by the standard azimuth compass (Admiralty) at every 15 seconds until the ship came to absolute rest. Wind and weather as before. Going full speed ahead 10 knots, reversed full speed astern, helm amidships.

Time. A.M.	Interval.	Ship's Head by Compass.	Head turned to Port.	Head turned to Starboard.
h. m. s.	m. s.		°	°
10 34 16	...	N. 29½° E.		
34 31	15	,, 29 ,,	0½	
34 46	15	,, 29½ ,,	...	0½
35 1	15	,, 30½ ,,	...	1
35 16	15	,, 32 ,,	...	1½
35 31	15	,, 36 ,,	...	4
35 46	15	,, 39 ,,	...	3
36 1	15	,, 44 ,,	...	5
36 16	15	,, 46½ ,,	...	2½
36 31	15	,, 48 ,,	...	1½
36 46	15	,, 50½ ,,	...	2½
37 1	15	,, 51½ ,,	...	1
37 16	15	,, 52 ,,	...	0½
37 31	15	,, 53½ ,,	...	1½
37 46	15	,, 54 ,,	...	0½
38 1	15	,, 54½ ,,	...	0½
38 16	15	,, 55 ,,	...	0½
38 31	15	,, 56 ,,	...	1
4 15	4 15		0½	27

"Ship came to absolute rest in 4 min. 15 sec., her head turned to port $\frac{1}{2}$° and then 27° to starboard before coming to rest.

"*Fourth Experiment.*

"In this case the ship was going full speed astern, say about 9 knots, when the engines were suddenly reversed to full speed ahead, helm put *hard to port*, time and direction of ship's head noted until the ship came to a dead stop. Sea, wind, and weather as before, viz. most favourable conditions for these trials.

Time. A.M.	Interval.	Ship's Head by Compass.	Head turned to Port.	Head turned to Starboard.
h. m. s.	m. s.		°	°
11 3 11	...	S. 65½° E.		
3 26	15	,, 66 ,,	0½	
3 41	15	,, 67 ,,	1	
3 56	15	,, 67½ ,,	0½	
4 11	15	,, 67½ ,,		
4 26	15	,, 66½ ,,	...	1
4 41	15	,, 65½ ,,	...	1
4 56	15	,, 63½ ,,	...	2
5 11	15	,, 60½ ,,	...	3
5 26	15	,, 57½ ,,	...	3
5 41	15	,, 53½ ,,	...	4
5 56	15	,, 48 ,,	...	5½
2 45	2 45		2	19½

"Ship came to a dead stop in 2 min. 45 sec., and her head turned 2° to port in the first 45 seconds and 19½ to starboard in the next 2 minutes.

Fifth Experiment.

"Making the circle: *hard to port: full speed ahead.* Lat. 8° 50′ S., long. 153° 58′ E.

"Ship started full speed from a position of absolute rest, with the helm hard aport, and at the instant of starting an empty flour barrel was dropped from the stern to mark the point started from. Sea smooth or nearly so, between No. 1 and 2 of the Beaufort Scale. Wind very light, about No. 1 to 2.

Time. A.M.	Interval.	Ship's Head by Compass.	Arc turned.
h. m. s.	m. s.	°	°
9 27 54	...	N. 56½ W.	
28 24	1 30	„ 54 „	2½
28 54	30	„ 49 „	5
29 24	30	„ 38 „	11
29 54	30	„ 28 „	10
30 24	30	„ 18 „	10
30 54	30	„ 5 „	13
31 24	30	N. 6 E.	11
31 54	30	„ 19 „	13
32 24	30	„ 30 „	11
32 54	30	„ 43½ „	13½
33 24	30	„ 58 „	14½
33 54	30	„ 74 „	16
34 24	30	„ 89 „	15
34 54	30	S. 75 E.	16
35 24	30	„ 61 „	14
35 54	30	„ 46½ „	14½
36 24	30	„ 33 „	13½
36 54	30	„ 20 „	13
37 24	30	„ 7½ „	12½
37 54	30	„ 4½ „	12
38 24	30	„ 16½ „	12
38 54	30	„ 30 „	13½
39 24	30	„ 45½ „	15½
39 54	30	„ 61 „	15½
40 24	30	„ 78½ „	17½
40 54	30	„ 84 „	17½
41 24	30	„ 67 „	17
41 40	16	„ 57 „	10

"Ship completed the circle in 13 min. 46 sec., and came outside the barrel (point of starting), about 150 feet, when the barrel was abreast of the taffrail. That is, we had the barrel on our starboard side when circle was completed.

(Signed) "W. SYMMINGTON,
"Commander s.s. 'Hankow.'"

These experiments need no comment; they are conclusive as to the truth and importance of the results previously obtained; and the Committee thank Capt. Symmington for his report.

In answer to the request of the Committee, made last year, the Admiralty have caused experiments to be made as to the effect of reversing the screw on the steering of H.M.S. 'Speedy,' 273 tons, with a maximum speed of

5 knots an hour. The perusal of the extract of the report on these trials received by the Committee and appended to this report, shows at once that the conditions under which the experiments were made were such as to preclude the possibility of their throwing much light on the subject. The greatest speed of the vessel was 5 knots, and the effect of the rudder with the screw reversed was so small, that the vessel, in most instances, turned her forward end into the wind.

On the receipt of the report of these trials, a letter was written to the Admiralty, urging them to have experiments made with larger and more powerful ships, but as yet no further communication has been received.

In accordance with the resolution by which they were appointed, the Committee have communicated with the Admiralty, the Board of Trade, the Elder Brethren of the Trinity House, and other Corporations, and copies of the last year's report were forwarded as soon as they could be obtained; no intimation has yet been received of any action being taken by these bodies.

It appears, from an article in the 'Nautical Magazine' of December, that the last report of the Committee was discussed at the conference of the Association for the Reform and Codification of the Law of Nations, held last year at the Ancient House, City of Bremen, when the following resolution was agreed to:—

"It is the opinion of the Conference that the existing international rules for preventing collisions at sea are not of a satisfactory character, and that it is desirable that the Governments of the maritime states should take counsel together with a view to amend these rules and to adapt them more carefully to the novel exigencies of steam navigation."

The article in the 'Nautical Magazine' was written by Sir Travers Twiss, and in this and in a subsequent article he discusses the facts established by the Committee, and their bearing on the question of the alteration of the rule of the road at sea, pointing out the absolute necessity of modifying Article 15 of the Amended Board of Trade Steering and Sailing Rules, which are likely to become law.

These and other notices which have appeared in English and foreign publications show that the subject has already attracted considerable attention; and it is important to notice that in no way have the conclusions of the Committee been in the smallest degree controverted.

Numerous collisions have occurred during the year, which, to judge from the law reports, might in many instances have been avoided had the effect of reversing the screw been known and acted upon; but it does not appear as if a consideration of this has influenced any of the judgments given.

The collisions have for the most part been with small ships, and so have not attracted much attention; but the loss of the 'Dakota' was a disaster of the first magnitude, and if it was not due to the porting of the helm with the screw reversed it might have been, for as soon as the officers became aware of their extreme danger (the shore being on their port bow) the helm was put hard aport and the screw reversed full speed, after which, according to the evidence of Mr. Jones, a pilot on board, the vessel turned to port until she struck. The evidence offered by the Secretary of the Committee was, however, rejected by the Commissioner of Wrecks (Mr. Rothery), on the ground that the ship was virtually lost before the screw was reversed. It is to be noted, however, that the orders to reverse the engines and to port the helm were avowedly given in the hope of saving the ship, and that had there been a chance of escape, such action, as shown by all the experiments of the Committee, must most certainly have reduced it.

APPENDIX.

Extract from Report of Captain of Steam Reserve at Portsmouth, dated 24th January, 1877.

Experiments on the Turning of Screw Ships.

I have the honour to report that, as already reported in my letter, dated 30th September, 1876, to the Admiral Superintendent (through whom I received the original copy of experiments required), there have been no opportunities of making experiments on this subject, on account of ships going out on trial having their time fully occupied, and there have been no ships in the First Reserve which could be taken out for the purpose.

Observing, however, from the report in the 'Nautical Magazine' referred to, that the largest vessel of which particulars of trial are given is only 80 tons, I took the 'Speedy,' of 273 tons, out and tried the experiments required with her: her speed is only about 5 knots; draught of water 7 feet 10 inches; rig one small mast forward; screw right-handed, Griffith's, two-bladed, diameter 6 feet 1 inch, pitch 6 feet. The results are given in attached sheet.

An opportunity also occurred of getting one trial of No. 6 in the 'Euphrates,' while waiting for tide. While going ahead the screw was stopped and reversed, the helm being kept amidships; the ship's head came steadily round to starboard (windward) 12° till head to wind, then fell off to port, and continued to do so till stern to wind. An experienced pilot (Mr. Harding) who was with me told me beforehand that this would be the case.

The experiments with the 'Speedy' were conducted by myself, with the assistance of Staff-Commander Parker, and Mr. Riley, chief gunner of 'Asia' for Reserve.

I think it may be taken as nearly certain that in all cases of putting the helm over and reversing the screw at the same time the ship will obey the helm for a limited time, the amount depending on the way the ship has, her rig, and the direction of the wind and sea with reference to her course, and that as she loses her way she will fall off from the wind until she brings it astern or nearly so. Also, that on reversing the engines with the helm kept amidships, she will come up head towards the wind, and then fall off before the wind as she loses her way.

It is going beyond the part of the article marked for my remarks, but I would venture to express an opinion that it would be highly undesirable to remove the obligation now imposed on ships "approaching each other, so as to involve risk of collision," to reverse their engines. If the action of ships with engines reversed is as I have said above, the reversing not only reduces the risk of serious damage, by lessening the way of both ships, but brings them parallel to each other, thereby placing them in a good position to avoid collision.

I would also submit that it is desirable that attention should be called to the power of the steering-gear. I think it probable that in large steamers of great speed, with small crews, and not fitted with steam steering-gear, the number of men usually kept at the wheel would be found quite inadequate to get the helm hard over till the speed of the ship was reduced.

It is worth consideration whether it should not be made obligatory, on steam-ships over a certain size and speed carrying emigrants or passengers, to be fitted with steam steering-gear, which I believe is not the case at present.

I believe a doubt exists with many people whether it is safe and proper to reverse engines when going at full speed ahead at once to full speed astern: this doubt (if it exists) should be removed, and it should be clearly understood that engines are to stand being suddenly reversed from extreme speed one way to the opposite extreme.

H.M.S. 'Speedy,' gunboat, 273 tons, 60 horse-power, Griffith's screw, right-handed, 2-bladed, diameter 6 feet 1 inch, pitch 6 feet. January 24th, 1877.

Trial.	Engines.	Helm.	Wind.	Result.
1.	Going full speed ahead, suddenly reversed to full speed astern.	Hard aport.	Ahead.	Before headway was lost head went to starboard 15°, lost headway in 1′ 15″; ship's head still went to starboard with sternway 180° in 8′ 15″.
2.	Going full speed ahead, suddenly reversed to full speed astern.	Hard astarboard.	Ahead.	Before headway was lost, head went to port 20°, lost headway in 50″; with sternway ship's head went to starboard 88° in 3′ 20″.
3.	Going full speed astern, suddenly reversed to full speed ahead.	Hard aport.	4 points on starboard quarter.	Before sternway was lost, head went to port 9°, lost sternway in 25″; then ship's head went to starboard.
4.	Going full speed astern, suddenly reversed to full speed ahead.	Hard astarboard.	4 points on starboard quarter.	Before sternway was lost, head went to port, lost sternway in 1′ 22″; ship's head went off to port immediately helm was put to starboard 101° in 4′.
5.	Full speed ahead and reversed to full speed astern.	Amidships.	Starboard beam.	Ship's head went to starboard; lost headway in 1′ 10″; still going to starboard, 90° in 4′ 20″.
6.	Full speed ahead.	Amidships.	Starboard beam.	Ship's head went to starboard $22\frac{1}{2}$° in 5′, and $67\frac{1}{2}$° in 9′ 32″.
	Full speed ahead. (No cause could be seen for the ship's head going opposite ways in these two trials.)	Amidships.	2 points on starboard quarter.	Ship's head went to port 31° in 3′ 37″, and continued to go to port till wind was astern 51° in 9′ 4″.
	Full speed astern.	Put from hard aport to amidships.	......	Ship's head went fast to port.
	Full speed astern.	Put from hard astarboard to amidships.	......	Ship's head went to starboard 66° in 3′ 55″.

(Signed) CHARLES J. WADDILOVE, Captain, W. A. PARKER, Staff-Commander, W. J. RILEY, Chief Gunner, } H.M.S. 'Asia.'

Report of the Committee, consisting of the Rev. H. F. BARNES, C. SPENCE BATE, *Esq.*, H. E. DRESSER, *Esq.* (*Secretary*), Dr. A. GÜNTHER, J. E. HARTING, *Esq.*, J. GWYN JEFFREYS, *Esq.*, Professor NEWTON, *and the* Rev. Canon TRISTRAM, *appointed for the purpose of enquiring into the possibility of establishing a Close Time for the protection of Indigenous Animals.*

YOUR Committee begs leave to report that the object for which it was appointed continues to receive a considerable share of public attention, and that during the past year the three Acts of Parliament establishing a Close Time for certain kinds of Birds have attracted so much notice that there is no fear of their falling into neglect.

There is no symptom of the diminution of the interest which the Sea-birds Preservation Act (1869) has always excited; and within the past twelve months application for the extension of the Close Time has been made, according to the provisions of that Act, by the Justices in Quarter-Sessions of Northumberland, Lancashire, and the North Riding of Yorkshire—facts which sufficiently speak for the general appreciation of the measure.

The Wild-Birds Protection Act (1872) is possibly viewed by the public with greater favour than either of the others; but your Committee sees little reason to modify the opinion of it expressed in former Reports. Nevertheless a conviction under it, presenting some rather important features, in May last, indicates that it is not so entirely useless as had been thought.

The Wild-Fowl Preservation Act (1876) came into operation this year, and at first undoubtedly caused some discontent in many quarters, a warm discussion of its principle and provisions being raised by a portion of the public press. Your Committee, however, has noticed with much satisfaction that virtually no objection was taken to its principle, while the necessity of some enactment of the kind was conceded on almost every side. Furthermore, very nearly the sole cause of complaint lay in regard to the limits of the Close Time therein imposed, on which point no blame attaches to your Committee. The limits of the Close Time proposed in the Bill, as draughted by your Committee and introduced into Parliament, were, as stated in last year's Report, altered in its passage through the House of Commons; the change being such as your Committee then declared did not meet with its approval. Your Committee is therefore in no way responsible for the unseasonableness of the Close Time which was enacted, and believes that the soundness of its views on the subject is now generally admitted. In confirmation of this belief, it may be stated that the Justices in Quarter-Sessions of the counties of Dorset, Norfolk, Kent, Somerset, Southampton, Wigtown, and Essex have severally made application to the Home Office for such an alteration of the Close Time as will bring it more or less nearly in accordance with that originally proposed by your Committee.

Another charge was brought against this Act. It was alleged to be imperfect in that it did not expressly prohibit the possession or sale during the Close Time of birds of the kinds professedly protected, which had been imported into this country from abroad. This charge was supported by the dismissal (on the latter ground) by two magistrates of informations laid against certain poultrymen or game-dealers in London, and if it could have been sustained would undoubtedly have proved the Act to be defective. But the Royal Society for the Prevention of Cruelty to Animals appealed against one of these decisions; and on the 15th of June judgment was given in the Common Pleas Division of Her Majesty's Court of Appeal against the defendants in the case, thus proving that the legal interpretation of the Act agreed with the intention of its promoters.

Your Committee has satisfaction in finding that the Fisheries (Oysters, Crabs and Lobsters) Bill passed the House of Commons on the 2nd of August, and it has now doubtless become law. It appears curious that no Close Time had hitherto been provided by the legislature for these important and favourite articles of food.

Having regard to the applications made from time to time to different members of your Committee, by various persons interested in seeing the Close Time principle more widely applied, your Committee respectfully solicits its reappointment.

Report of the Committee, consisting of Mr. W. N. Hartley, *F.R.S.E.*, Mr. W. C. Roberts, *F.R.S., and* Mr. John M. Thomson, *appointed for the purpose of investigating some Double Compounds of Nickel and Cobalt. By* Mr. John M. Thomson.

Part I.

On attempting to form the conjugated sulphate of Nickel, Cobalt, and Potassium, the existence of which is mentioned by Vohl (Ann. Chem. Pharm., vol. lxv.), who assigns as its composition the formula $NiCoK_4(SO_4)_4,12H_2O$, it was found that the several fractions of crystals deposited consecutively from a solution containing molecular quantities of the simple potassic sulphates of the two metals were of different colours, and showed also to a remarkable degree the property of dichroism. The operation being repeated several times with a like result, it was determined to prepare a series of fractions from a solution containing the two potassic sulphates

$$NiK_2(SO_4)_2,6H_2O \quad \text{and} \quad CoK_2(SO_4)_2,6H_2O$$

in molecular proportions, to submit each fraction to analysis, and to examine whether or not any regular replacement between the nickel and cobalt took place.

For this purpose 250 grammes of each potassic sulphate in the anhydrous condition were accurately weighed, dissolved in a sufficient quantity of water, and evaporated gently over a water-bath, the temperature of the solution never being allowed to rise above 80° C. The solution was thus fractionally crystallized, the several fractions consecutively deposited constituting the series of salts marked A i., ii., iii., iv., v.

A second quantity, consisting of 250 grammes of each potassic sulphate in the pure crystallized condition, having been crushed, pressed between blotting-paper and finally air-dried, was dissolved in water and fractionally crystallized at the same temperature as in the first instance. These fractions constitute the series of salts marked B i., ii., iii., iv., v., vi. In both these cases care was taken to purify the salts before commencing the experiments.

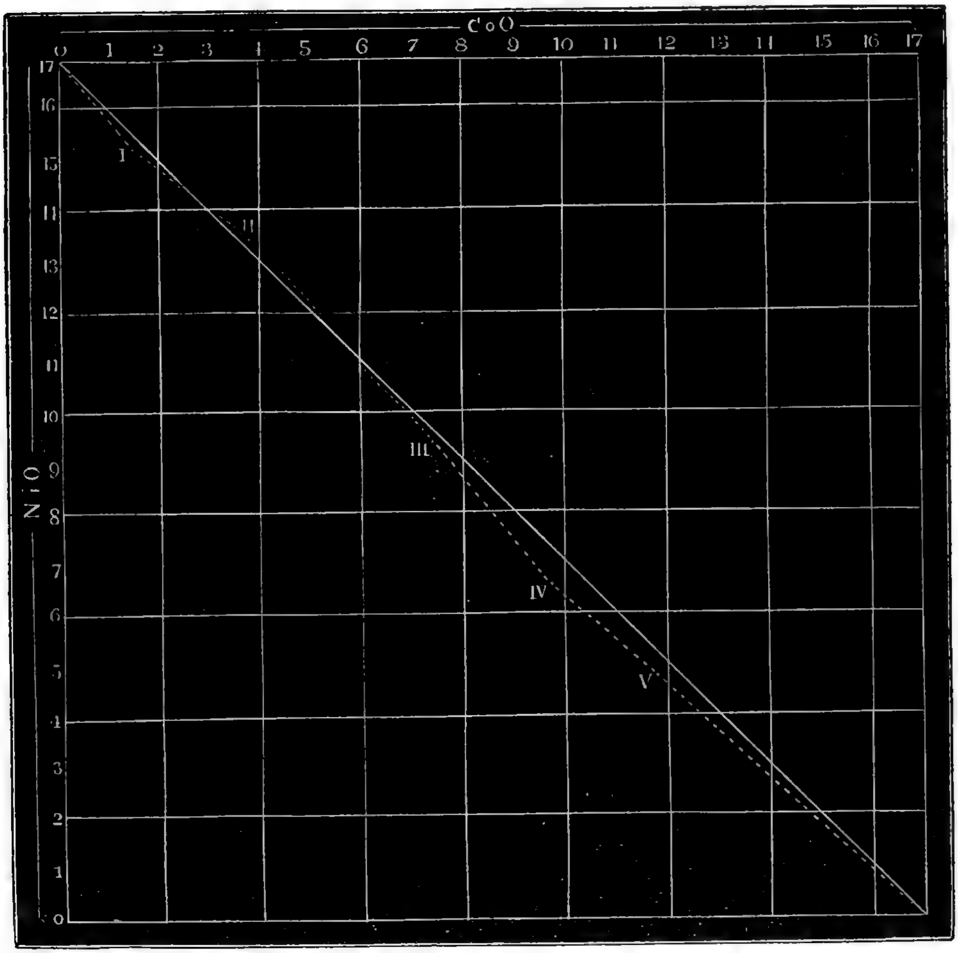
The crystals of the conjugated double sulphates are oblique rhombic prisms, having a tendency to modification when allowed to grow to any great size. The first fractions possess a greenish-grey colour when seen in the mass, showing the preponderance in them of the nickel over the cobalt; the latter fractions, however, become more crimson in colour as the reverse action takes place. The salts do not lose their water entirely till between 150° to 180° C., and can be fused without decomposition. On heating the first fractions in a crushed condition in the air-bath, the colour changes from a light grey to purple, finally becoming pink when the water is entirely driven off; if the salts be heated in a porcelain or platinum capsule they fuse, the liquid mass becoming of an intensely deep-blue colour, which fades on cooling, the mass solidifying to the pink anhydrous salt. This deep-blue colour can be again produced, however, by fusing the dried salt, and is evidently due to some change not explained by loss of water.

The following Tables give the details and results of the analyses of the two series of salts marked A and B. The replacement of the nickel and cobalt is also graphically represented by the curves in the diagrams of each series of salts given below.

The method generally employed in the determination of the nickel and cobalt was that of Liebig, viz. by treatment with HCy and KHO to obtain the cyanides in solution, precipitating the nickel as NiO with mercuric oxide and separating the cobalt from the filtrate by mercurous nitrate, the mercurous cobalticyanide being ignited and weighed as Co_3O_4. It may be mentioned that in many cases the determinations by this method were checked by others conducted by separating the cobalt as double nitrite of cobalt and potassium, incinerating this body, washing out the alkali, and finally determining the cobalt as $CoSO_4$ by evaporation with sulphuric acid. In these latter cases the nickel was determined in the filtrate from the double nitrite of potassium and cobalt by precipitation with potash.

The water and sulphuric acid were determined in the usual manner. The potash was determined by difference in most cases, but was occasionally checked by determining it as potassium sulphate.

Fig. 1.—Series A.



The Roman numbers indicate the different fractions of the conjugated salts. The co-ordinate numbers show the percentage of NiO, and the abscissæ numbers the percentage of CoO in the several fractions.

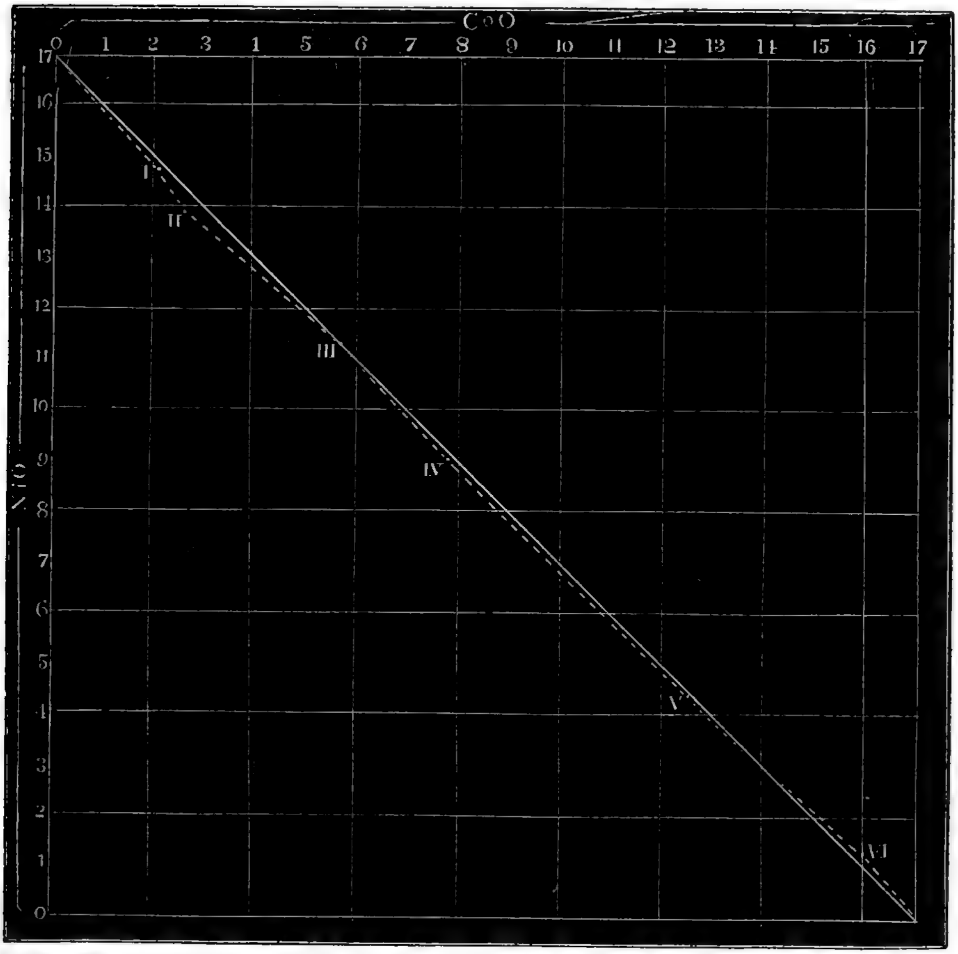
SERIES A.

	Details of Analyses.							Percentages found.						
Salt.	Subs.	At 100°, loss.	NiO.	Co_3O_4.	CoO.	$BaSO_4$.	SO_3.	H_2O.	NiO.	CoO.	SO_3.	K_2O.	Mean.	
A I. 1.	1·084	·271				1·1623	·3994	25·00			36·84		24·91	H_2O.
	·742		·1148	·0127	·0112				15·47	1·509			16·23	NiO.
2.	·600		·0914	·0087	·0080				15·23	1·33			1·434	CoO.
3.	1·000		·1500	·0157	·0146				15·00	1·46			36·51	SO_3.
												21·91	21·810	K_2O.
A II. 1.	·338	·084						24·85					24·91	H_2O.
	·831		·1697	·0523	·0487				13·45	3·86			13·41	NiO.
2.	·753		·1008	·0315	·0293				13·38	3·89			3·87	CoO.
													36·51	SO_3.
												21·30	21·81	K_2O.
A III. 1.	1·004	·250				1·062		24·90			36·33		24·91	H_2O.
	1·000		·0984	·0783	·0730				9·84	7·305			9·58	NiO.
2.	1·000		·0932	·0798	·0744				9·32	7·440			7·37	CoO.
													36·51	SO_3.
												21·63	21·81	K_2O.
A IV. 1.	1·004	·251				1·067	·3667	25·00			36·52		24·91	H_2O.
	·462		·0292	·0495	·04619				6·32	10·00			6·57	NiO.
2.	·701		·0477	·0703	·0661				6·82	9·42			9·71	CoO.
	·290	·072						24·82					36·51	SO_3.
												22·30	21·81	K_2O.
A V. 1.	1·000	·249				1·058	·3636	24·90			36·36		24·91	H_2O.
	1·200		·0543	·1573	·1468				4·52	12·23			4·605	NiO.
	·635		·0298	·0807	·0752				4·69	11·84			12·030	CoO.
	·418	·1035						24·76					36·51	SO_3.
												21·94	21·810	K_2O.

SERIES B.

	Details of Analyses.							Percentages found						
Salt.	Subs.	At 100°, loss.	NiO.	Co_3O_4.	CoO.	$BaSO_4$.	SO_3.	H_2O.	NiO.	CoO.	SO_3.	K_2O.	Mean.	
B I. 1. 2.	{ ·997 ·881 } ·873 1·281	·247 ·213	·1277 ·1906	·0183 ·0316	·01707 ·0294	·929	·3191	24·77 24·17	14·62 14·87	1·955 2·29	36·22	22·02	24·51 14·74 2·12 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.
B II. 1. 2.	·711 1·004 ·966	·170	·1389 ·1353	·0286 ·0279	·0266 ·02603	·7662	·2631	23·91	13·83 14·00	26·49 2·69	36·94	22·31	24·51 13·91 2·66 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.
B III. 1. 2.	·849 1·000 1·000	·212	·1163 ·1127	·0584 ·0638	·0541 ·0595						36·54	21·75	24·51 11·45 5·68 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.
B IV. 1. 2.	1·005 1·000 1·000	·245	·0892 ·0935	·0814 ·0848	·0759 ·0791	1·068	·3669	24·37	8·92 9·35	7·59 7·91	36·507	21·00	24·51 9·13 7·75 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.
B V. 1. 2.	1·146 1·000 1·000	·285	·0470 ·0424	·1297 ·1390	·12101 ·1296	·1235	·4243	24·86	4·70 4·24	12·101 12·96	37·01	21·88	24·51 4·47 12·53 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.
B VI. 1. 2.	·890 1·000 1·000	·2164	·0131 ·0111	·1697 ·1753	·1583 ·1635	·9375	·3248	24·33	1·31 1·11	15·83 16·35	36·49	21·58	24·51 1·21 16·09 36·61 21·75	H_2O. NiO. CoO. SO_3. K_2O.

Fig. 2.—Series B.



The Roman numbers indicate the different fractions of the conjugated salts. The coordinate numbers show the percentage of NiO, and the abscissæ numbers the percentage of CoO in the several fractions.

It will be seen from these numbers that a regular replacement between the nickel and cobalt oxides takes place, while the percentage amounts of water, sulphuric anhydide, and potassium oxide remain the same. In the several successive fractions we have a regular decrease of the quantity of nickel with an increase in the quantity of cobalt, the amounts of both together, however, giving a practically constant number for each fraction.

Taking the quantities of nickel and cobalt together, the formula given by Vohl might express the relation thus $(M''M'')K_4(SO_4)_4,12H_2O$; but to express the replacement we have found between the metals, a much higher molecular formula is necessary—the one which admits of all the replacements shown by the numbers we have obtained being $24[M''M''K_4(SO_4)_4, 12H_2O]$, and it is possible fractions containing a higher replacement of the metals might be obtained requiring a still higher molecular formula; in fact the limits of replacement are only defined by the powers of analysis.

There are certain further conclusions which may be drawn from the replacement in these fractions; but these must be reserved for the second part of the report.

The examination of the optical properties of the several fractions presents some details of considerable interest. When the crystals are examined through the two opposite axes, a change of colour in the several fractions may be observed to take place in the following order down the series:—

Salt.	Colour shown through Nickel axis.	Colour shown through Cobalt axis.
I.	Light green.	Indigo-blue.
II.	Deep green.	Bluish purple.
III.	Yellow green.	Purple.
IV.	Yellow.	Pink.
V.	Orange-yellow.	Crimson.
VI.	Orange (deep).	Deep crimson.

It may be seen from this Table that the colours shown through the different axes pass in a direct order down the spectrum in each column.

In the first fractions the more highly refractive rays of the cobalt spectrum mingle with the green of the nickel, whilst in the last the two rays are those adjacent to each other in the cobalt spectrum only.

It is worthy of remark also, that as the cobalt spectrum consists of all the colours except the green, the nickel spectrum consists of none but the green rays.

Differences in the ratio of nickel and cobalt, which would be detected only by very carefully conducted analyses, can be remarked by the distinct and differing dichroism when the crystals are examined by the dichroiscope.

That these fractions are not mere isomorphous mixtures, as is generally understood by the word, we think is shown from the fact that large crystals taken for analysis exhibited the same dichroism throughout. It thus becomes interesting to determine, if possible, how far the phenomenon of dichroism is dependent on, or consequent upon, molecular constitution; in this direction some preliminary experiments have been made to see whether crystals could be stained in such a manner as to show dichroism by the influence of their impurities. It is not easy to secure the necessary conditions without the possibility of forming molecular compounds; but results have been obtained which when thoroughly examined will be reported.

We may mention that from the ease with which the fractions may be prepared, and from the great variety in their dichroism, they form an excellent series for the study of that phenomenon.

Fifth Report of the Committee, consisting of Sir JOHN LUBBOCK, *Bart.*, Prof. PRESTWICH, Prof. BUSK, Prof. T. M'K. HUGHES, Prof. W. BOYD DAWKINS, Prof. MIALL, Rev. H. W. CROSSKEY, *and* Mr. R. H. TIDDEMAN, *appointed for the purpose of assisting in the Exploration of the Settle Caves* (*Victoria Cave*). *Drawn up by* R. H. TIDDEMAN (*Reporter*).

THE Local Committee have this year sustained a great loss in the death of their Chairman, Sir James P. Kay-Shuttleworth, Bart. Sir James took a great interest in the work from the commencement. He recommended us to employ in working the admirable methods of excavation so inseparably connected with the names of Mr. Pengelly and Kent's Cavern, and which, with slight modifications, were adopted. Besides his liberal contributions to the fund, his business-like method of conducting the Committee's meetings was of the greatest service to the undertaking.

The work has been carried on almost continuously since we last reported at Glasgow up to the 14th of July last. As the state of our funds was then very low, it was determined to give up work for a time; and it has not yet been resumed.

In our last Report we called attention to a very stiff, dark, laminated clay which occurred in chambers A and D at a lower level than the principal bone-bed or hyæna-bed. It was separated from the underlying yellow sandy clay by a thin bed of stalagmite of varying thickness. A large part of our time in the past year has been taken up in removing portions of these beds in these two chambers, working them down to a lower level inwards, in order to be able to work at the back of the cave. In doing this it was found that these beds rose as we proceeded inwards towards the junction of the ends of chambers A and D. Large blocks of fallen limestone occurred along the right wall of chamber D and much impeded us and others at the junction of A and D. No bones occurred in this portion of the work, except at 2 feet Parallel 34, where we obtained bones of a large bear, of a goat, of a large ox, also a gnawed antler of Red Deer. These were at a depth of 13 feet.

On the 16th of November we had made a sufficiently good clearance of the route to the further junction of these two chambers to enable us to carry on our investigation in this direction; and as the beds were rising inwards, we entertained a hope that by working on these we might come to earlier beds than we had yet discovered. The result confirmed our expectations, and, although not in any way sensational, was very interesting. We had previously worked for some time in an easterly direction from this point, but without much practical result. The beds were so wet and slippery that the section could not be properly observed. There was no drainage for the water which was accumulating; and in short, to use a miner's phrase, we were "drowned out." We now resolved to try in another direction; and finding that at the end of chamber A the deposits ran further north beneath the limestone, and that there was no true wall to the cave at that spot, we proceeded to make a cut to the north in the direction of an old shaft at the end of chamber B. There were two reasons for selecting this direction. First, it would show us the extent of the cave to the north, and whether B was separated from A or continuous with it at the further end, as A and D had been proved to be. Secondly, in that old shaft hyæna had been first discovered, many years ago, by Mr. Jackson in his earlier researches, and identified by Dr. Buckland;

there was therefore a chance of our again hitting the hyæna-bed at this spot.

We began by cutting a level 6 feet wide and 9 feet high (*i. e.* up to the rocky roof); but we very soon had to widen this at the top, for the materials were of so slippery a nature that they would not stand in a vertical face for long together. The section, however, was carefully measured and drawn to scale as the work proceeded; so that no errors could arise from slips. The black laminated clay which lies beneath the hyæna-bed, and to which we referred in our last Report, was seen to rise towards the roof; and beneath it was a bed of stalagmite about 1 foot thick. This also rose for a distance of 16 feet, then fell, and rose again when nearing chamber B, except at the end, where it again had a slight dip north. In a kind of basin lying on this stalagmite in the middle part of the cut lay three beds, each about half a foot thick, consisting in ascending order of yellow sandy clay, stalagmite, and a darker clay. All these beds were destitute of animal remains. The same may be said of a lower great mass of dark clay lying below the thick stalagmite, from 4 to 6 feet in thickness, which was similar to that above the same stalagmite at the south end of the cut. It ran along the whole section, and, indeed, in a mass of broken and confused stalagmite and clay at the end of chamber B.

The entire absence of remains from these beds, at so short a distance from others which present a throng of animal life, would almost lead us to speculate upon the absence of any fauna from the district when they were being formed. Or perhaps we might be led to suppose that the wet slippery mud of which they are chiefly composed was not of a nature to tempt beasts of prey into these recesses to devour their quarry. But in this we must be cautious. Chamber D, when first explored, was (though not ankle-deep certainly, for we could not stand up in it) at least fist-deep in soft mud. Yet in this clay, and in many parts quite at the surface of it, we came upon the richest assemblage of remains that we have found in the entire cavern. We must therefore beware how we gauge a hyæna's or bear's ideas of comfort by our own.

After this long interval of lifeless beds it was with no little satisfaction that, at the base of the thick clay already referred to, we came upon evidence, scanty but yet sufficient, of an earlier occupation of the district. Two teeth of a small wolf, a canine and molar $\left(\frac{4}{1} \text{ and } \frac{4}{2}\right)$, were discovered resting on the surface of a yellow sandy clay. They were 7 feet from the commencement of the north cut, and $6\frac{1}{2}$ feet below the rocky roof. Unfortunately these are the only indications of life yet found relating to this time, which, judging by the thickness of barren beds between, was long prior to the age of the abundant life-assemblage of the hyæna-bed. Of one thing we may feel quite sure, that the presence of this carnivore implies the coexistence of other animals on which it could feed; and though at present we know not what they were, we may hope that further exploration will give us fuller information.

On the 10th of February, 1877, we succeeded in effecting, at the further end of the North Cut, an entrance into the further end of chamber B. Our cutting, however, though it kept to the limestone rock as a roof all the way, was found to be two feet below the bottom of the old shaft at the end of that chamber. We calculated that the cut would be about forty feet in length, and we found it forty-one and a half.

When we were obliged to leave off work we were clearing away the deposits on the left side of chamber A, consisting of large blocks of limestone in clay, and reducing that part to the same level as the right side of that chamber. Our object in doing this is that we may reduce the level of the whole of our present floor of working across the chamber to the depth necessary to disclose the old river-bed, which must have been the lowest level of the cave. Several indications lead us to suppose that we are not far off it, especially at the entrance. The arching of the right wall, and the occurrence of several grooves along it, apparently indicating old water-levels, are very suggestive that we are at last nearing the original bottom of the cave. When that is reached we can scarcely fail to meet with much that is interesting.

The present entire absence of conditions which could render the existence of a large stream possible in or near the cave as it now stands, taken in connexion with the fact of the present stream being 900 feet below us, suggests such an enormous interval of time necessary to effect these changes that we might almost stand aghast at it did we not remember how great and many are the vicissitudes which have occurred in that interval, and to which the cave and the surrounding district bear witness. From to-day to Romano-Celtic times is our first stage as we go back into the past, and that probably the shortest in the whole journey. The next takes us into the cloudland of Neolithic times. Then, after an unknown interval, we come to the submergence and emergence of parts of Lancashire to a depth of several hundred feet. A further step, probably a long one, shows us the north of England swathed in a great sheet of ice, which advanced and retired perhaps more than once. Again the scene changes, and the hyæna (that admirable historian) gives a record of his life and times. Further back, by a long period, the wolf takes up the story, and tells us, so far, comparatively little. But the bed of the old river which made the cave before the wolf haunted it should tell us a story which may fairly rival in interest any of the annals of cave-history.

The Committee are again indebted for kind assistance to Prof. Leith Adams and Mr. William Davies, of the British Museum.

Appendix.

Report on the Remains, by Prof. Busk.

I have gone over the Victoria collection as well as time would allow; but having been mostly out of town for some time, I have not been able to complete the task as fully as I should have wished, and have left a few doubtful specimens for further determination.

A large part of the collection consists of broken splinters and fragments, apparently mostly of bones of the Ox and Deer, and some probably of Rhinoceros from their thickness. Of about 180 determined specimens, about 46 belong to *Bos* of two distinct sizes—one probably being *Bos primigenius*, and the other, I should imagine, *B. longifrons*; amongst these are a few that appear to be comparatively recent. The next in frequency are teeth and bones of *Ursus*—so far as I can perceive, *U. ferox*. Amongst these are some indicating an individual or individuals of very large size; whilst others would indicate a form not larger than *U. arctos*. Some of the upper molars are very much like those of *U. spelæus*; but there is no clear indication of that species, and most of the teeth and bones are undoubtedly those of *U. ferox fossilis*.

Next comes *Hyæna spelæa*, with 30 specimens, which call for no remark, except that they show individuals of various ages, as usual.

Rhinoceros is represented by at least eleven well-marked specimens, all of which, are in my mind, clearly referable to *R. hemitœchus*. They are mostly teeth, but there is one well-marked fragment of a metatarsal.

I have noticed only three or four fragments of a molar of *Elephas antiquus*.

Fourteen specimens belong to *Cervus elephas*, though it is not impossible that some of the teeth may belong to *C. tarandus*; but there is no clear indication of that species.

A small ruminant, probably a Goat, is represented by sixteen specimens, some of which appear to be comparatively recent.

The Badger affords seven or eight specimens, mostly of teeth, and the Fox five or six teeth and bones.

Three or four specimens, but not very good ones, indicate the presence of a Wolf of small size, but not, I think, a Dog.

Besides these are bones of the Hare, and perhaps Rabbit, several Birds, *Arvicola*, &c., which I will examine when more at leisure.

(Signed) GEO. BUSK.

Summary of Bones and Teeth determined in the past year.

Bos	46
Cervus	14
Sheep or Goat	16
Hare	3 or 4
Fox	5
Bear	41
Canis lupus?	4
Hyæna	30
Rhinoceros	11
Elephant	3
Badger	7
	180

POSTSCRIPT. *By the Reporter.*

In the Report for 1876 reference was made to the existence of Goats' bones in the cave, to all appearance in the hyæna-bed, one of them bearing marks which could only be referred to human agency; but it was thought that, as many geologists and osteologists are of opinion that these animals were introduced into Europe at times not earlier than the Neolithic age, the matter could not be fully and fairly discussed without further and careful consideration. Your reporter, noticing that in some of the Belgian bone-caves Goats had been discovered with the remains of extinct Pleistocene animals, and reported on by Monsieur E. Dupont, the distinguished cave-explorer, wrote to him to inquire whether he was still of the same opinion that they were contemporaries. The result, so far as M. Dupont's opinion goes—and it is one of deserved weight—is strongly in the affirmative; but as his answer was not received until after the Association Meeting, the matter was not discussed in the Report. Your reporter now offers these remarks on his own responsibility.

M. Dupont writes as follows:—

"Bruxelles, le 24 août, 1877.

"MON CHER MONSIEUR,—Votre aimable lettre du 22 juillet dernier m'est arrivée pendant que j'étais occupé avec mes aides à lever le spécimen de la

Carte Géologique du royaume que notre Gouvernement veut faire exécuter. C'est cette absence qui m'a empêché de vous répondre plus tôt, et je profite pour le faire de la première suspension du travail.

"Depuis longtemps du reste je désirais vous écrire, tant pour vous remercier de l'envoi de vos très-intéressantes publications que pour avoir quelques renseignements sur la position définitive que vous assignez au dépôt ossifère de la Caverne Victoria. Vous prévenez obligeamment mes désirs en résumant dans votre lettre les résultats si curieux de vos recherches. Il est certainement peu de cavernes qui aient fourni des faits aussi positifs dans l'ordre géologique.

"La Chèvre de nos cavernes ne peut être distinguée de la Chèvre ordinaire. Elle y est associée au Mammouth, au *Rhinoceros tichorhinus*, à l'*Ursus spelæus*, etc. J'en maintiens absolument la coëxistence avec ces espèces perdues. Ces observations corroborent donc la vôtre, et je ne doute pas qu'elles ne soient constamment confirmées à l'avenir.

"Vous trouverez dans le compte-rendu du Congrès préhistorique de Bruxelles (1872) la discussion que M. Steenstrup a soulevée sur le même sujet. Il admettait aussi que la Chèvre, un petit Bœuf qui doit être le *Bos taurus* et d'autres espèces avaient dû être amenées dans le pays après l'extinction des espèces perdues. Je crois plutôt que ces espèces sont la souche indigène de plusieurs de nos espèces domestiques. Je regrette de devoir vous écrire en si grande hâte, et vous prie d'agréer l'assurance de mes sentiments très-distingués.

"E. Dupont."

Goats' bones appear to be not uncommon in the hyæna-layer; and an obvious inference by those who disbelieve in the antiquity of that species is that they have fallen from the upper beds of the Roman or Neolithic layer, and become accidentally mixed with an older fauna. But our method of working precludes such a supposition. The upper beds had been well worked away some time before these bones were uncovered, and no such accident could therefore arise. One rib of a small ruminant from the hyæna-bed, with artificial marks upon it $\left(\text{No. } \frac{2}{135}\right)$, has been already mentioned in the Report for 1875, p. 173.

On the 2nd of May, 1876, another bone—a small humerus, No. $\frac{3}{90}$—was found, bearing very evident tool-marks. It occurred in Parallel 17, at 17 feet right of the datum line and at a depth from the original surface of 15 feet. The marks are very clean cuts, as if made by a sharp instrument —so sharp, indeed, as almost to suggest that they may have been done with a metallic tool. The cuts, however, have evidently not been made subsequently to the discovery of the bone; for the surfaces therein exposed are of the same colour and have the same dark and ochreous staining and incrustation as the general surface of the bone. Its occurrence, moreover, at the depth of 15 feet in the hyæna-layer, surrounded by bones and teeth of the hyæna, bear, elephant, and rhinoceros, precludes us from assigning to it a modern origin in spite of the sharp nature of the cuts. The heel of a milk-tooth of *Elephas antiquus* was found within six inches of it. It may be a question whether a sharp flint-flake, properly hafted, may not be capable of producing in a bone of a freshly-slaughtered animal marks similar to these. In the absence of Prof. Busk it was forwarded to Mr. William Davies, of the British Museum, and he pronounced upon it as follows:—The humerus "is that of a very small goat, but evidently of an adult. It is smaller than the humerus of a true Shetland sheep with which I compared it, and besides the narrower *fossa*, which you refer to, there are other points in which it differs from the same bone in the sheep." Mr. Davies goes on to remark on the state of preservation of the bone, which leads him to think it must be of comparatively recent age. This, however, is the common condition of bones from the clay of the Victoria Cave, and has been already mentioned in a previous report*. Dr. Buckland found this also to be the case with bones of equal antiquity in Kirkdale Cave, which in many ways is comparable with the Victoria Cave. In this case he proved by experiments that "nearly the whole of their original gelatine has been preserved;" and cites other instances of preservation in stiff clay †. We cannot, therefore, take the condition of this bone to be any evidence against its antiquity, but rather the reverse; for, as a rule, the chief parts of the bones in the upper beds in the cave are much decayed.

The actual finding of remains of man or his works in the cave is, after all, a matter of little importance. It would, at most, only give completeness in this particular instance to the picture of the life of the period. That the fauna found there in beds beneath the glacial clay at the entrance was contemporary with man in other parts of Britain and Europe, is generally admitted without dispute. If there were an absence of evidence of his presence in the North of England at this time, it could not in any way invalidate the proofs of his coexistence with the same fauna, and presumably at the same time, in the South of England in days before the last great advance of cold conditions in the North ‡.

Report of the Committee, consisting of Sir W. THOMSON, *F.R.S.*, Major-General STRACHEY, *F.R.S.*, Captain DOUGLAS GALTON, *F.R.S.*, Mr. G. F. DEACON, Mr. ROGERS FIELD, Mr. E. ROBERTS, *and* Mr. JAMES N. SHOOLBRED (*Secretary*), *appointed for the purpose of considering the Datum Level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto.*

THIS Committee was appointed in 1875 at the Bristol Meeting to inquire into some uncertainties (alleged to exist by Mr. J. N. Shoolbred in his communication to the Association "On the Half-Tide Level at Liverpool") as to the exact position of the Datum Level of the Ordnance Survey of Great Britain.

It may be prefaced that the Ordnance datum is described in the 'Abstract of Levelling in England and Wales,' 1861, as follows:—"The datum level for Great Britain is the level of mean tide at Liverpool, as determined by our own observations; it is $\frac{8}{10}$ of an inch above the mean tidal level obtained from the records of the self-recording tide-gauge on the St. George's Pier, Liverpool."

The level of the sill (long ago removed) of the Old Dock at Liverpool is the datum to which the records in question of the gauge on the St.

* Third Report, 1875, p. 171.

† 'Reliquiæ Diluvianæ,' p. 13.

‡ See also "On the Age of the Hyæna-bed at the Victoria Cave, Settle, and its bearing on the Antiquity of Man," by the writer, 'Quart. Journ. Anthropol. Inst.' 1877.

George's Pier are referred. Being consequently the level to which the Ordnance Datum is referred, it is therefore of the greatest importance that its exact position should be clearly determined; and the primary object of this Committee is to set at rest the doubts which have hitherto existed on the subject.

The uncertainties appear to have arisen from the following causes:—

(1) The difference between the levels given in the Ordnance Book of Levels ('Abstract of Levelling in England and Wales,' with plates, 1861) and in the tracings of original levelling in Liverpool in 1843–44, sheet 29, as supplied by the Ordnance Department to the Borough Engineer's Office, Liverpool.

(2) The existence in Liverpool of two gauges, each purporting to be a reproduction of the Old Dock sill.

(3) A published statement under the authority of the Mersey Docks and Harbour Board as to the position of the Ordnance Datum with reference to the Old Dock sill.

1. (*a*) '*Abstract of Levelling in England and Wales.*'

At page V of this book occurs the above-quoted definition of the Ordnance Datum; and at page 2, in the list of levels, we find "Zero of the Tide-Gauge at George's Ferry Basin, near George's Baths, Liverpool. Altitude in feet above Mean Level of the Sea at Liverpool 4·670;" a minus sign (—) should evidently have been prefixed to this level, as the zero of the tide-gauge was below, not above, the mean sea-level. The zero of the tide-gauge was regarded as identical with that of the Old Dock sill; and, judging from the remarks on page 599 of the same volume, it was assumed to be so by the Ordnance Department.

These remarks * begin by saying that the mean-water datum plane depends upon the observations taken by the Ordnance Department in 1844. Then follows a statement showing that the Department were in possession of the records of the self-registering gauge for four years, from 1854 to 1857, and that the mean water during that period was 4·968 feet above the level of the Old Dock sill. Notwithstanding this fact, recourse was had (as is stated further on) to the tidal curves traced by the self-registering gauge between May 13th and June 14th, 1859 (one month); the mean water of which period is there announced as the true mean water at Liverpool, and that it differs but 0·068 foot (the $\frac{8}{10}$ of an inch of the definition) from the assumed Ordnance Datum plane.

The statement in the definition, "the mean tidal level obtained from the records of the self-recording tide-gauge," without any qualification as to the time during which the records were taken, might therefore be misapprehended, as it only refers to the mean obtained from one month's observations, and is not borne out by the records taken over longer periods.

The tidal curves, moreover, shown under the head of "Liverpool" in the volume of Plates issued with the Book of Levelling above named, would naturally be supposed to be those taken by the Ordnance Department for determining the mean level of the sea. The letter of Lieut.-Col. Clarke, R.E., Ordnance Department, Southampton, sent to the Secretary of this Committee, shows, however, that such is not the case †.

(*b*) *Tracings of original levelling in Liverpool*, 1843–44, *sheet* 29 (as supplied to the Borough Engineer's Office, Liverpool, by the Ordnance Department).

On this sheet, at a point near to the S.E. corner of the Canning Dock (the

* See Appendix.

† See Appendix for this and other letters from Lt.-Col. Clarke, R.E.

site of a gauge purporting to be a reproduction of the Old Dock sill), the following remark occurs:—"17·8 Bottom of 22nd figure on gauge." By examination of this gauge it appears that this would give 4·20 feet as the height of the Ordnance Datum above the zero of the Old Dock sill. Yet on page 2 of the 'Abstract of Levelling' above quoted, the difference is given as 4·67 feet. Both levels cannot, of course, be correct.

The Liverpool Borough Engineer's Office had ever since 1847, when the above tracings were supplied, observed the 4·20 feet difference for the levels throughout the town; while the Waterworks Office (until lately distinct from the former, though now combined with it) had made use of the 4·67 feet difference. It may here also be remarked (as will be seen further on) that the Engineer's Department of the Mersey Docks and Harbour Board made use of and published 5 feet as the difference between the Ordnance Datum and the Old Dock sill level.

2. *The existence of the two gauges, each purporting to be referred to the Old Dock sill.*

A few words as to the history of the Old Dock sill may not here appear inappropriate.

The Old Dock at Liverpool (whence the Old Dock sill datum takes its name) was opened on August 31st, 1715, and closed on August 31st, 1826. During this interval a "Dry Dock" had been added on the river side of the "Old Dock." This dock having been altered into a wet dock, and opened on December 12th, 1829, the level of the Old Dock sill, thenceforward covered with water, was transferred to the S.E. corner of the new dock; in 1832 this new dock assumed the name of the "Canning Dock." It was subsequently enlarged and reopened on May 9th, 1842. During this operation the Old Dock sill gauge must have been temporarily removed elsewhere, since the present eastern wall (near to the S.E. corner of which this gauge now stands) is considerably further inland than was the eastern wall of the "Dry Dock" against which it formerly stood.

In 1844 the approaches to the Canning Dock, having been enlarged, were opened under the name of the Canning Half-tide Dock, the two entrances from the river having between them the "Canning Island." To the river-face of this "Canning Island" was also transferred the level of the Old Dock sill by Mr. John B. Hartley, the Engineer to the Liverpool Dock Committee, and subsequently to the Mersey Docks and Harbour Board. Captain Graham H. Hills, R.N., the present Marine Surveyor to the Mersey Docks and Harbour Board, was informed in 1861, by Mr. J. B. Hartley, that this was the only trustworthy tide-gauge, as representing the Old Dock sill one. This gauge is placed in a conspicuous position facing the river, with the following heading in large letters over it, "Tidal datum, as transferred in 1843 from the Old Dock sill;" while the gauge at the S.E. corner of the Canning Dock (which must have been re-transferred there when the dock was enlarged, and during which process the error might have occurred) is placed unostentatiously in an obscure corner, where its existence is almost forgotten.

A series of check-levels*, taken under the direction of Mr. G. F. Deacon of Liverpool, whose attention was naturally drawn to the anomaly in 1871, when the Borough Engineer's and the Waterworks Departments were both placed under his charge, show that the zero of the Old Dock sill gauge at the Canning Island (the prominent one) is 4·66 feet below the Ordnance Datum (thus conciding nearly with the 4·67 feet of the Ordnance Book of Levels);

* See Appendix.

while the zero of the inner gauge at the Canning Dock is only 4·20 feet below the Ordnance Datum.

3. *Published statement of the Mersey Docks and Harbour Board.*

In an annual printed statement issued by this body there is given, among other matters, information as to the "Levels of Tides at Liverpool" *. This has been issued regularly for some years past. At the commencement, and for some time after, the "mean-tide level" was there given as "4 ft. 9 in. above the Old Dock sill." Towards the end of 1853 the self-registering tide-gauge was established. In 1864 the information derived from the ten completed years' observations (1854–63) of the self-registering gauge was tabulated, and the "Levels of Tides" were henceforth given as "derived" from that information. In this amended form the "mean-tide level" became "5 feet above O. D. S" (in lieu of the previous 4 ft. 9 in.). This information continued exactly in this form for some years, until in 1871 the words "(Ordnance Datum)" were inserted after the "mean-tide level" and before the "5 feet" †.

But the Ordnance Datum (as stated at p. 599 of the 'Abstract of Levelling,' see Appendix) depends upon tidal observations taken by the Ordnance Department in March 1844; and it has therefore nothing whatever to do with the 1854–63 observations of the Mersey Docks and Harbour Board.

Another very erroneous view of the Ordnance Datum, but one which hardly needs consideration in order to dispel it, is, that it continues to represent the mean tidal level at Liverpool. The mere mention of the facts that in 1844 the Ordnance Department considered the mean sea-level at that port to be 4·67 feet above the Old Dock sill, while the records of the self-registering tide-gauge from 1854–63 give it as 5·01 feet ‡ above that datum, and that the records of the succeeding decade, 1864–73, show it to have stood during that period at 5·24 feet over the same datum, clearly points out that the mean sea-level, at Liverpool at least, is a varying one, and therefore cannot *now* represent the Ordnance Datum.

In conclusion, the Committee are of opinion:—

1st. That of the two tide-gauges at Liverpool, now purporting to be referred to the level of the Old Dock sill, the zero of that fixed at the S.E. corner of the Canning Dock is about 5·54 inches above the zero of that on the river-face of the Canning Island, Liverpool.

2nd. That in order to reconcile the statement in the Ordnance Book of Levelling, that "the Datum Level for Great Britain is $\frac{8}{10}$ of an inch above the mean tidal level obtained from the records of the self-recording tide-gauge on the St. George's Pier, Liverpool," with the actual facts which the Committee have collected, it is necessary to bear in mind that the records of the self-recording gauge referred to were the observations of one month only taken in the year 1859, and that the mean tidal level of that month was 6·26 inches below the mean of the period from 1854 to 1873, taken by the same self-recording gauge.

3rd. That the difference of level between the Old Dock sill and the Ordnance Datum, given in the Ordnance Book of Levelling as 4·67 feet, is correct on the assumption that the zero of the gauge on the river-face of the

* See Appendix.

† [Since this report was presented to the Association, the engineer to the Mersey Docks and Harbour Board, on the matter being explained to him, has directed that the words "(Ordnance Datum)" be in future omitted, thus restoring the information as to the tides at Liverpool to its original form.—*Secretary of the Ordnance-Datum Committee.*]

‡ See Report of the British Association for 1875, Bristol, p. 164.

Canning Island, and not that of the gauge in the Canning Dock, be taken as the correct level of the Old Dock sill; and that, as is stated in the Ordnance Book of Levelling, the Ordnance Datum be taken at $\frac{8}{10}$ of an inch above the mean tidal level of the month of May 13 to June 14, 1859, as ascertained by the self-recording tide-gauge of the Mersey Docks and Harbour Board.

4th. It is thus apparent that the Ordnance Datum is an entirely arbitrary level, which could not be again obtained from tidal observations.

The Committee have further thought it advisable to take advantage of the present inquiry in order to obtain information as to some of the various local datum-marks in use in the British Isles, and to endeavour to ascertain the difference of each relatively to the Ordnance Datum, which would thus become a means of comparison between them. In order to enable the Committee to carry out this work, they request to be reappointed.

APPENDIX.

Extract from 'Abstract of Levelling in England and Wales,' 1861 (p. 599).

Tidal Observations.

This assumed mean water at Liverpool is the same imaginary plane to which all the heights in the preceding pages are referred. It depends upon tidal observations taken by this Department in March 1844. The error, however, is very small, as appears from the results shown by the self-registering tide-gauge at that Port.

The Tide-gauge at Liverpool in connection with the self-registering gauge is divided from zero in both directions. The zero corresponds with the level of the Old Dock sill.

By taking the annual means of H.W. and L.W. of self-registering gauge,

Mean H.W.	1854, 15·424 above zero.	Mean L.W.	1854, 5·544 below zero.
	1855, 15·425 "		1855, 5·570 "
	1856, 15·515 "		1856, 5·449 "
	1857, 15·478 "		1857, 5·532 "

These results are remarkably close, and give +15·460 as the mean of H.W. for four years and —5·524 as that of L.W. for the same period. If we assume the mean of these to represent mean water, we should have +4·968 as the reading of mean water. Mean water is, however, strictly speaking, not the mean of H.W. and L.W., but the mean of all heights recorded at indefinitely small intervals, and for as long a period as possible.

An examination of the curves traced by self-registering gauges, even for one month or less, affords an accurate means of determining the mean height, inasmuch as we can measure the heights at any intervals of time as small as we please. By this means we find from the curves traced between May 13th, 1859, to June 14th, 1859, that the true mean water at Liverpool reads 4·602 above the zero of the gauge. Now, by levelling, it appears that this zero is 4·670 feet (see page 2) below our assumed plane of difference. Consequently the true mean water at Liverpool is 0·068 foot *below* our assumed plane of reference.

If, therefore, we would strictly refer our heights to mean water at Liverpool, we should increase every quantity in the preceding pages by 0·068 foot.

Copies of Letters from Lieut.-Col. Clarke, R.E., Ordnance Survey Department.

H.M. Office of Works, &c.

Ordnance Survey Office,
Southampton, September 22, 1875.

The tidal observations taken at Liverpool in 1844, by which the mean level of the sea at that port was determined, have never been published.

The curves shown in the volume of Plates of the initial levelling for Liverpool are those of the self-registering tide-gauge for a selected period.

I do not think that Mr. Shoolbred has noticed page 599 of the volume of levelling*. I do not get mean tide by the formula $\frac{1}{2}$(high + low). And I used one month of the self-registering tide-gauge, viz. May 13 to June 14, 1859.

(Signed) A. K. Clarke, Lt.-Col.

H.M. Office of Works, &c.

Ordnance Survey Office,
Southampton, May 12, 1877.

Sir,—In answer to your letter to Colonel Bayley of May 3rd, which he has referred to me, I beg to say that the height of "bottom of 22nd figure on gauge" is not 22·00, but 22·265, which gives 22·265 − 17·8 = 4·46 (*date of his determination* 1843) against the 4·67 (*determined in* 1857).

I cannot explain this discrepancy of 0·21 foot; but it happens to correspond to some extent with the change you have observed in the mean tide.

Yours truly,
(Signed) A. K. Clarke, Lt.-Col. R.E.

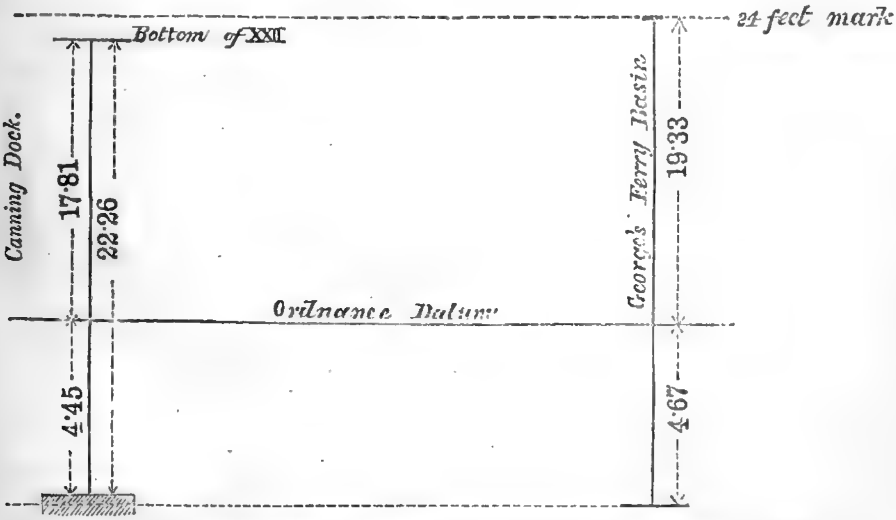
H.M. Office of Works, &c.

Ordnance Survey Office,
Southampton, May 16, 1877.

My Dear Sir,—Perhaps the enclosed diagram may help to clear up the mystery of the Ordnance Datum. The 22·265 feet has been measured (twice, I believe) from the surface of the stone to the lower edge of XXII. (Canning Dock). The 4·67 refers to a different place altogether (George's Ferry). There is no uncertainty whatever about our datum.

Yours truly,
(Signed) A. K. Clarke.

Perhaps I omitted to notice in my last letter that the 4·46 (your 4·20) and the 4·67 referred to different gauges.



* [See preceding.—*Secretary Ordnance-Datum Committee.*]

Extract from Tracings of Original Levelling Sheet 29 (1843–44) *supplied Ordnance Department to Borough Engineer of Liverpool.*

	feet.	
At Old-Dock Sill gauge, S.E. corner of Canning Dock ...	17·8	bottom of 22nd figure on gauge.
„ „ „	19·8	top of coping.

Copy of Results of Check-levels taken by Mr. G. F. Deacon, C.E., *Liverpool.*

Municipal Offices, Dale Street,
Borough Engineer's Department (entrance Crosshall Street),
Liverpool, 28 Aug., 1876.

Ordnance Datum and O. D. Sill.

DEAR SIR,—I am instructed by the Boro' Engineer to forward you the enclosed copy of the relative level of the Ordnance Datum and the Old Dock Sill on Canning Island.

I am, dear Sir,
Yours obediently,
(Signed) JOHN M. SADLER.

J. N. Shoolbred, Esq.,
Westminster Chambers, London.

Relative Level of Ordnance Datum and Old Dock sill transferred to river-face from Canning Island, marked

Tidal Datum as transferred in 1843 *from Old Dock Sill.*

	feet.	
Centre of copper bolt on face of river-wall opposite Victoria Dock	17·75	above Ordnance datum.
Fall to Old Dock sill at Canning Island	22·42	
	4·67	under „ „
Ordnance B.M., N.W. corner of St. Nicholas Churchyard	24·40	above Ordnance datum.
Fall to Old Dock sill at Canning Island	29·05	
	4·65	under „ „
Ordnance B.M. on house, Strand Street, corner of James Street	22·90	above Ordnance datum.
Fall to Old Dock sill at Canning Island	27·57	
	4·67	under „ „
Ordnance B.M., N.W. corner of Custom House	22·84	above Ordnance datum.
Fall to Old Dock sill at Canning Island	27·50	
	4·66	under „ „
Ordnance B.M., S.W. corner of Custom House	22·76	above Ordnance datum.
Fall to Old Dock sill at Canning Island	27·36	
	4·60	under „ „
This B.M. sunk	·05	
	4·65	under „ „

Mean level of Old Dock sill 4·66, say 4 feet 8 inches, under Ordnance datum.

Borough Engineer's Department,
Municipal Offices, Liverpool, 28 Aug., 1876.

Municipal Offices,
Liverpool, 7th Sept., 1876.

Dear Sir,—Enclosed I forward tracings showing relative heights of O.B.M. on Custom House, &c.

Ordnance Datum. Also copy of particulars 28th August, 1876.

I took observations this morning from O.B.M., north-west corner of Custom House to gauge on the east side of the Canning Dock, and find the bottom of the 22nd figure to be 17·78 feet (against 17·8 feet Ordnance, which is practically the same thing).

Their 22·0 feet bottom of figure on Gauge, = 17·8 feet Ordnance Datum,
gives 4·2 ,, the figure used in this Department since 1847.

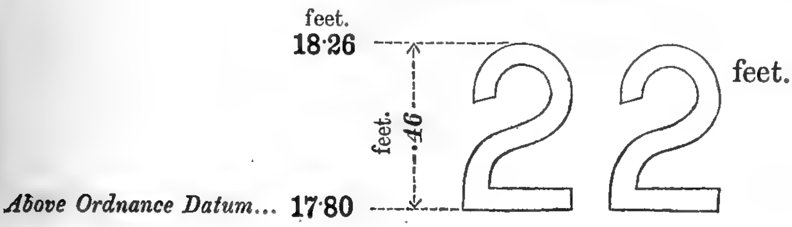
Also Tidal datum as transferred to river-face of Canning Island in 1843 from Old Dock sill (see observations taken Aug. 1876).

Sill 4·66 feet, say 4·8 feet, below Ordnance Datum.

You will observe these Datums do not agree.

Yours obediently,
(Signed) Thomas Hough.

P.S. *Figures on Gauge.*



Copy of Correspondence with the Engineer of the Mersey Docks and Harbour Board.

Dock Yard, Liverpool,
30th July, 1874.

Dear Sir,—I have your letter of the 28th instant making inquiry respecting the actual difference of level between the datum of the Old Dock sill and that of the Ordnance Survey, in reply to which I may say I have not by me the result of any critical examination of the relative levels; but I enclose a copy of that part of our tabular statement referring thereto, from which you will find that the Ordnance is called by us 5 feet above the level of the Old Dock sill.

Yours faithfully,
(Signed) George Fosbery Lyster,
per J. A. S.

J. N. Shoolbred, Esq.

Enclosure referred to in Mr. Lyster's letter, July 30th, 1874.

Levels of Tides at Liverpool.

Derived from the Record of the Self-registering Gauge at St. George's Pier, deduced from ten years' observations, 1854 to 1863.

Datum, Old Dock sill.

	ft.	in.	
An extraordinary high tide as marked on the Leasowe Lighthouse	25	0	Above datum.
An extraordinary high tide, 20th January, 1863	23	9	Above datum.
Average high-water mark of equinoctial spring-tides	21	1	Above datum.
Average high water of spring tides, including equinoctial tides	19	0½	Above datum.
Average high-water mark of ordinary spring tides, excluding the equinoctial tides	18	10	Above datum.
Mean high-water level	15	6	Above datum.
Highest high-water mark of neap tides	14	8	Above datum.
Average high-water mark of ordinary neap tides	11	7	Above datum.
Lowest high-water mark of neap tides	8	7	Above datum.
Mean-tide level (Ordnance Datum)	5	0	
Highest low-water mark of neap tides	4	1	Below datum.
Average low-water mark of ordinary neap tides	1	5	Below datum.
Lowest low-water mark of neap tides	3	10	Below datum.
Mean low-water level	5	6½	Below datum.
Average low-water mark of ordinary spring tides, exclusive of equinoctial tides	8	8	Below datum.
Average low-water mark of spring tides, inclusive of equinoctial tides	8	10	Below datum.
Lowest low-water mark of equinoctial spring tides	10	4	Below datum.

Report of the Committee, consisting of Prof. Huxley, Dr. Carpenter, Mr. Sclater, Mr. F. M. Balfour, Dr. M. Foster, Prof. E. Ray Lankester, *and* Mr. Dew-Smith, *appointed for the purpose of arranging with* Dr. Dohrn *for the occupation of a Table at the Zoological Station at Naples.*

The duty of your Committee seems not so much to report on the Zoological Station itself, which is now fully established and equipped, as to select fitting naturalists to proceed to Naples, and to occupy the Table engaged for the British Association.

Since the last report was made, three naturalists have occupied this Table, viz. Dr. W. B. Carpenter, F.R.S., Mr. Francis M. Balfour, and Mr. Arthur W. Waters.

These gentlemen are required by the Association to report the result of their work there. These reports will be found appended. We may say that the Institution is now thoroughly well established and is daily becoming an Institution of world-wide reputation.

Tables have been engaged by most of the Continental Governments, and many of the most eminent living naturalists have availed themselves of its advantages.

Your Committee would most strongly urge the desirability of renewing the grant, as such an Institution necessarily requires annual support, as it is in no way subsidized.

(Signed) PROF. HUXLEY,
P. L. SCLATER,
E. RAY LANKESTER,
MICHAEL FOSTER,
F. M. BALFOUR,
A. G. DEW-SMITH, *Secretary*.

University of London,
Burlington Gardens, W.
August 11, 1877.

DEAR SIR,

As I attended in person last year both at the Sectional Committee and at the Committee of Recommendations, and made a verbal report of my experiences at the Naples Zoological Station, on the strength of which the vote was passed *without any difficulty*, I do not see what more I have now to say. I found the arrangements entirely satisfactory; every facility being given in the supply of animals, the keeping them alive in special tanks, and the provision of apparatus, reagents, &c. for scientific investigation. And I hope in the course of the next year, by means of the information and material I there obtained, to complete my Memoir on *Antedon* (*Comatula*).

It seems to me that the *continuance* of the grant should rather be decided by its results during the *last* year.

I am sorry that I shall not be able to be at the Meeting of the British Association at Plymouth, as I had intended. The depressed state of health in which I am at present—partly depending on the severe bereavements I have sustained, and partly on the excessive wear and tear of official duties—makes it necessary for me to devote my vacation to bodily and mental refreshment.

Yours sincerely,
WILLIAM B. CARPENTER.

A. G. Dew-Smith, Esq.

Report by MR. FRANCIS M. BALFOUR, *on the Zoological Station at Naples.*

In accordance with the Regulations of the Committee appointed to report on the Zoological Station at Naples, I have the honour to lay before you the following.

I reached Naples on June 5th, and having given previous notice of my intended arrival, found every thing prepared for me.

My object in going to Naples was to work out the development of *Amphioxus*, and also to complete my researches on the development and anatomy of Elasmobranch fishes. An ample supply of *Amphioxus* was provided for me every morning; and since with a fair supply of fresh sea-water these animals live in a healthy condition, I had a continually increasing stock of them on hand. For the most part I kept them in small aquaria, which were daily examined to see if ova had been deposited. A considerable number of animals were also placed in one of the large tanks of the Aquarium, which was most liberally cleaned out for my special use. From time to time a surface-net was dragged through the tank with the hope of finding larvæ. In addition to these means of obtaining embryos I also employed the surface-net in those parts of the bay in which *Amphioxus* usually lives. All these means unfortunately proved ineffectual, and I failed to obtain any larvæ of *Amphioxus*; this was probably owing to the lateness of the season, since at the time I left Naples (July 1st) the majority of examples of *Amphioxus* were filled either with spermatozoa or ova. In any case the Zoological Station, so far from being in any way responsible for my failure, furnished me in a much more ample manner with all I required than any private individual could possibly have done for himself.

My researches on Elasmobranch fishes proved more fortunate. I obtained an ample supply of material, which I was partly able to investigate at Naples and partly to preserve for further study in England.

I may perhaps also be permitted to add a few words with reference to the present condition of the Station. Since the summer of 1875, when I last worked at Naples, considerable improvement has been effected in many of the departments. A carefully determined collection of the animals of the bay has been commenced, and has already attained considerable dimensions.

The department for supplying naturalists and museums with preserved specimens has now been fully organized; and I can answer for the very beautiful manner in which the specimens are preserved, under the direction of Dr. H. Müller, who has charge of the department.

The library has been steadily, not to say rapidly, increasing, and in most departments is fairly well supplied. There is still, however, a slight deficiency in systematic works. The greatest addition, however, has been made in the fishing department. Through the munificence of the Berlin Academy, Dr. Dohrn has been enabled to procure a steam launch made by Messrs. Thornycroft, of Chiswick, and specially designed for marine research. By means of this the area of fishing will be enormously extended, and will now include the adjoining bays of Salerno and Gaeta. It scarcely requires to be pointed out how greatly this will increase the number of forms to be procured as well as the constancy of the supply.

In conclusion, I would bear testimony to the unceasing kindness and willingness to assist naturalists displayed by the acting director, Dr. Hugo Eisig, and would strongly urge the desirability of renewing the grant of the Association.

August 1, 1877

Woodbrook, Adderley Edge,
Near Manchester,
August 15, 1876.

Dear Sir,

I promised to send you word as to the use I had made of the table at the Naples Zoological station, which was granted me by the British Association.

The pressure of business has prevented me from having any paper ready for the Glasgow meeting this year, but as far I can find time I shall still go on with the determination of the material I collected.

I took up the systematic study of the Bryozoa with the intention of comparing them with the Tertiary fossil forms from Italy, which I have from various horizons of the Tertiaries.

I have now determined fifty known species collected at Naples, and expect the number will be considerably added to, though I do not suppose I shall find as many species as I at one time expected, as by study I shall find specimens which I thought different to be the same species. Concerning new species I cannot form any idea until the completion of my work of determination.

I found the arrangements of the institution were thoroughly well adapted for any one wishing to follow up the systematic study of any group of smaller animals. I have already called attention in one or two places to the library, which although very good for embryology, is not at all satisfactory for those who wish to determine the fauna or flora on the spot, and it is to be hoped that it will receive such additions from authors as will make it much more complete.

I have also said that I should advise any naturalist who intends to study there, to previously obtain the catalogue that he may know what books that he is in the habit of using he had better bring with him.

After using the British Association table I became connected with the institution for a short time, and made a beginning for a museum by putting aside specimens from various groups for this purpose. Dr. Dohrn's report will probably give latest particulars as to what has been done in this direction. At the time that I left a good number of Crustacea, Tunicata, and other animals had been determined by Prof. Heller and others, and I completed a Catalogue of all the Echinodermata in the collection, which I had given some study to during my stay.

My experience gained during the few months I was in Naples makes me say in the most emphatic manner that this is a most useful institution, and if there are (as there doubtless always will be) zoologists who are anxious to avail themselves of it, then the grant of £75 by the British Association is one which it is to be hoped, in the interest of science, they will continue.

Yours truly,
ARTHUR WM. WATERS.

A. G. Dew-Smith, Esq.

Report of the Anthropometric Committee, consisting of Dr. BEDDOE, Lord ABERDARE, Dr. FARR, Mr. FRANCIS GALTON, Sir HENRY RAWLINSON, Colonel LANE FOX, Sir RAWSON RAWSON, Mr. JAMES HEYWOOD, Dr. MOUAT, Professor ROLLESTON, Mr. HALLETT, Mr. FELLOWS, *and* Professor LEONE LEVI.

THE Committee has met six times since the last general meeting at Glasgow. The following new members have been added to the Committee, viz. Dr. Lawson, Dr. Mouat, Capt. Dillon, and Mr. Redgrave.

A report on measurements of the 2nd Royal Surrey Militia at Guildford by Col. A. Lane Fox has been received, and has been published in the 'Journal of the Anthropological Institute;' a hundred copies of this paper have been retained for the use of the Committee.

Schedules of measurements filled in by Dr. Farr, Mr. Redgrave, and other observers have also been received by the Committee.

Mr. E. W. Brabook made a proposal to the Committee for carrying out the provisions of the vote of the Association in relation to typical photographs, and fifty copies have been printed in pamphlet form for the use of the Committee.

A series of photographs of natives taken at the Straits Settlements have been submitted by Mr. Francis Galton.

The results of the communications received and the measurements which have been taken have shown that more detailed instructions are necessary to enable the various observers to conduct their measurements upon a uniform plan, without which the returns are misleading, and the printed instructions have been modified accordingly.

With a view further to ensure uniformity in returning the colour of the hair and defining the terms to be employed in the descriptions, ten lithographed patterns of hair-colours corresponding to some of those used in M. Broca's tables have been printed, and three hundred copies have been bound up for distribution to the collectors of the statistics.

Coxeter's spirometer having been found too small to record the breathing capacity of large men, measures have been taken to ensure the improvement of the instrument. An additional set of instruments for measuring height, weight, and strength of arm have been obtained from Messrs. Tisley and Spiller, opticians.

It being the opinion of the Committee, as the result of their examination of the measurements already received, that the necessary uniformity is not likely to be obtained without trained observers, measures have been taken to secure the services of a non-commissioned officer of the army, by whom it is proposed to promulgate a uniform system of measurement in different localities. The arrangements for carrying out this experiment are still in progress.

Although the Committee has not yet obtained sufficient data to enable generalization to be formed, it is thought that the necessary preliminaries have been taken to secure accuracy, and that the measurements taken under the new instructions may be relied upon.

Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals, by a Committee consisting of WALTER NOEL HARTLEY, F.R.S.E., E. J. MILLS, D.Sc., F.R.S., *and* W. CHANDLER ROBERTS, F.R.S. *Drawn up by* W. N. HARTLEY, F.R.S.E.

IN a paper read before the Chemical Section of the British Association at the Glasgow Meeting, I described the method of determining the exact temperature at which the carbonic acid which is sometimes found enclosed in the cavities of rocks and minerals becomes gaseous. This temperature is called by Prof. Andrews the critical point, and has been determined by him, in the case of carbonic acid in as pure a state as it could be procured artificially, to be 30°·92 C.

The following Table shows the critical point of the carbonic acid enclosed in various minerals, and certain variations are apparent which may be accounted for, when the critical point is below the normal temperature, by the carbonic acid being mixed with some incondensible gas like nitrogen.

	Critical point.
Topaz	28° C.
Topaz	28° C. and 26°·5
Topaz	27°·55
Tourmaline	27°·27
Tourmaline	26°·9
Sapphire	between 30°·5 and 31°
Sapphire	between 25°·5 and 26°
Sapphire	29°·5
Rock crystal	30°·95
Rock crystal	30°·95
Rock crystal	32°·5
Rock crystal	33°·7
Rock crystal	29°
Rock crystal	30°·95
Beryl	30°·92
Rock crystal from India	30°·0 C.
Topaz, Aberdeen	29°·1
Oriental White Topaz	28°·2
Rock crystal	21°·0

It seemed to be very desirable to ascertain whether the presence of liquid carbonic acid in rocks was not of frequent occurrence, whether, in fact, the immense number of minute cavities dispersed through quartzite, granites, and porphyries, which are usually considered as containing water, may not often contain liquid carbonic acid, or whether the occurrence of liquid carbonic acid in rocks might not be characteristic of certain formations.

Method of Working, &c.—The microscopic observations of Bryson on the quartz porphyry of Arran, also of Zirkel on Labradorite, tend to show that if some means could be devised of readily recognizing minute quantities of this substance it would be frequently met with. The apparatus shown at the last meeting of the British Association was made use of. Its action raises the temperature of the specimen under examination to above the critical point of carbonic acid, and but for a single instant of time only if desirable. So marked is the change in appearance of cavities containing liquid carbonic acid when a current of warm air is blown upon them, that a layer of carbonic acid no larger than $\frac{1}{50,000}$ of an inch in diameter may be detected.

It has been necessary to examine a great variety of rocks, and very thin ections have been cut from about two hundred different specimens during the past year. These were polished but not covered with a thin glass, because a better examination may be made with high microscopic powers. A $\frac{1}{8}$-inch object-glass was made by Messrs. R. and J. Beck, after the pattern of one made according to Mr. Sorby's directions. Its definition is perfect at any depth in a reasonably well-cut rock-section. A considerable number of minerals were examined, including about 30 sapphires, a like number of zircons, 60 garnets from the Cape of Good Hope, several topazes and sections of fluor-spar, sulphate of baryta, and arksutite (a fluoride of aluminium, calcium, and sodium) from Greenland.

Motion of bubbles in fluid-cavities under the influence of heat.—Incidentally this inquiry has led to the discovery of curious facts concerning the motion of the bubbles in fluid-cavities when influenced by a source of heat. An extensive series of experiments were made, the details of which are fully recorded in the Proceedings of the Royal Society. The following is the summary of this part of the research:—

"1st. The bubbles in certain fluid-cavities approach a source of heat which is brought near them.

"2nd. The bubbles in certain fluid-cavities recede from the same source of heat.

"3rd. That a rise of 5° C. above the temperature of the specimen suffices to cause the apparent attraction.

"4th. That a rise of only $\frac{1}{2}$° C. will in some cases cause the apparent repulsion.

"5th. That in certain cases a bubble which receded from the source of heat at ordinary temperatures approached it when raised to 60° C., the source of heat always being from $\frac{1}{2}$° C. to 5° C. warmer than the specimen.

"6th. That this could occur in cavities containing liquid carbonic acid as well as water, but that it made no difference whether the carbonic acid was raised above its critical point or not."

This latter fact affords a means of controlling to some extent the conditions of the experiment, since we know that the tension of liquid carbonic acid when it has just passed the critical point amounts to 109 atmospheres.

Hence gas-bubbles enclosed in minute tubes containing water may be caused to recede from or approach a source of heat according as their temperature is below or above 60° C., and even when the gas is confined under enormous pressure. It was found that the warmth of the fingers is sufficient to propel even in a vertical direction a plug of water contained in a capillary tube open at both ends. The apparent attraction of bubbles by heat is evidently due to the same cause which occasions this movement. Professor Stokes assigns this apparent *repulsion* of the liquid to a diminution by heat of the surface-tension at one end of a plug of liquid in a tube, or side of a bubble in a cavity.

When *attraction* of the *liquid* takes place it may be because a slight rise of temperature effects a disengagement of gas from the water on the side of the bubble nearest to the source of heat, which increases the surface-tension at this side: the bubble is therefore propelled in the opposite direction.

This explanation is similar to that which Professor James Thomson gave of the cause of the "tears of wine," published in the Reports of the British Association (1855, Proceedings of Sections, p. 16).

On vibrating bubbles and the Brownian movement.—Mr. Sorby was the first to notice a remarkable vibration of minute bubbles in the fluid-cavities of minerals precisely of the nature of the Brownian movement.

This motion was repeatedly seen in some sections of granites, as, for instance, many specimens from Cornwall, quartzite from Snowdon, and granite from Shap Fell in Westmoreland. All the most minute cavities contain bubbles incessantly vibrating. It was found that all these bubbles approached a warm body, and that they ceased moving and clung for some time to the warmer side of a cavity. After repeated and varied experiments on these moving bubbles the following conclusion was arrived at. It is impossible to imagine a body which is not gaining or losing, or, at the same time, both gaining and losing heat; it is therefore impossible to imagine it entirely throughout at a uniform temperature. It is evident, then, that an easily movable particle which can be set in motion by exceedingly slight rises of temperature will make the transference of heat from one point to another plainly visible. The minute bubbles in fluid-cavities are such particles, and these vibratory motions afford an ocular demonstration of the continual passage of heat through solid substances.

A further continuation of this research was extended to the conditions under which minute solid particles exhibit the Brownian movement. It was found that solid particles are subject to the same influences and behave in the same way as minute bubbles, a fact which was anticipated. As to the cause of the movement there can be no doubt, since the very recent investigations of M. Delsaulx of Louvain, on the thermodynamic origin of the Brownian movement, lead to the same conclusion; but with regard to the *modus operandi* of this cause it will be well to reserve further statements until an exhaustive study of M. Delsaulx's views may warrant a decision.

General views concerning the occurrence of liquid carbonic acid in minerals.—Liquid carbonic acid is not of common occurrence in rocks and minerals, although occasionally met with.

The critical point is rarely to be found exactly the same as that determined by Professor Andrews, and it ranges from 32° C. in a sapphire to 21° C. in quartz.

The conditions of pressure under which the liquid carbonic acid exists are very varied: thus, in some cases the quantity of liquid in proportion to gas is so small that a rise of 5° or 6° C. above 16° causes it to disappear by evaporation. In other cases it may be made to expand and fill the cavity at or about its critical point; and in one instance, in the case of a piece of felstone from Snowdon, it was found that the liquid had expanded to the fullest extent possible at so low a temperature as 18° C.

Continuity of the gaseous and liquid states of matter exemplified in certain specimens.—In other instances noticed in large cavities in a white topaz, the liquid was in sufficient quantity to fill the cavity at 2° or 3° C. below its critical point.

Under such circumstances when the liquid was completely converted into gas it condensed on cooling *without undergoing any visible change.*

It may well be asked how the fact of this change of state was ascertained. The following description of experiments will explain all.

In a section of a colourless oriental topaz containing a large number of cavities, one of large size was easily studied with a magnifying-power of 40 diameters. A jet of warm air raised the liquid above its critical point. After waiting for a minute, during which no change of any kind was seen in the cavity, a very slight puff of warm air was directed on to the specimen, and immediately a *crowd of little bubbles made their appearance in its centre*; these instantly vanished, closed up in fact, but could be reproduced again and allowed to disappear as rapidly and as often as one could desire. The jet of air could be regulated so gently that only two or three bubbles were formed. It is evident, then, that the cavity is completely filled with liquid. When the jet of warm air was forcible no change was *seen* to take place, but a gentle warmth no longer caused the formation of bubbles therefore the cavity must have been filled with gas. It is evident, then, that in the first case the gas had passed into the liquid state without breach of continuity, and in the second the passage, in a reverse direction, from liquid to gas had taken place in like manner.

Thus one sees beautiful illustrations in natural specimens of Professor Andrews's famous law of continuity in the gaseous and liquid states of matter.

On the temperature of formation of rocks and minerals.—Regarding the proportions of gaseous and liquid carbonic acid, an important generalization has been arrived at.

In rock-crystal, in arksutite, in felstone from Snowdon, and in some topazes and beryls the carbonic acid is not contained in every cavity, though water is seen in them all. In one topaz it was noticed that nearly all the cavities contained merely a trace of water, but there was a sufficiency of liquid carbonic acid to occupy two thirds of their capacity at 16° C. One or two cavities, however, of large size were noticed which contained one third water, one third gaseous and one third liquid carbonic acid. I believe, for reasons I am about to state, that all these substances were formed by the action of a temperature below 340° C. In sapphires, in tourmalines, and in some other topazes the condition of things is different. Irregular though the cavities may be, it is easy to see that they have about the same proportion of gas, of liquid carbonic acid, and of water, and minute search shows that there is not a single cavity which does not contain in some proportion all of these substances. In a colourless and clear topaz there were discovered thousands of perfectly cylindrical tube-like cavities, round at each end. In the case of fifty-two cavities, as far as lineal measurement could decide, they each contained the same proportions of carbonic acid liquid, carbonic acid gas, and water. Hence at the time they were enclosed in the mineral these fluids must have existed in the state of a homogeneous vapour. This of necessity places the temperature of formation of the mineral somewhere above 342° C., the critical point of water. In other cases in which the cavities differ in the nature of their contents, the water at the time of the formation of the mineral must have been in the liquid state. It is possible to determine within certain limits the temperature which a rock or mineral has endured (and that, too, very easily) if liquid carbonic acid is found enclosed in it.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by Professor G. Carey Foster, *F.R.S., President of the Section.*

When any one fears that he has accepted a duty that is too difficult for him, or that he has allowed himself to be placed in a position, the responsibilities of which are greater than he can properly discharge, probably the very worst thing he can do is to proclaim his misgivings to the world. But though I fully believe in this rather obvious maxim, I cannot avoid saying that I enter upon my duties here to-day with very great diffidence, and that I feel the necessity of asking your indulgence at the outset for what I fear will be my inevitable shortcomings in discharging the functions of the honourable post that has been assigned to me. And I am sure that no one who calls to mind the names of some of those who, within recent years, have occupied the chair of this Section, and who knows—however imperfectly—what those names stand for in connexion with Mathematics and Physics, will be surprised that I should deprecate comparisons which might tend to degenerate into contrasts, or that I should shrink from having my performances measured by the standard of such predecessors. But I have neither the right nor the desire to detain you longer with this purely personal topic, and I therefore proceed to ask your attention to matters more closely connected with the business which has brought us here.

The periodically recurring character of these meetings unavoidably suggests, at each recurrence, a retrospect at the scientific work of the year, and an attempt to estimate the advances which have been the result of this work. At first sight nothing would seem to be more natural or appropriate than that each President of a Section should occupy the introductory remarks, which the custom of the Association demands from him, with an account of the chief forward steps made during the past year in the branches of science represented by his Section.

Very little consideration, however, is sufficient to show that, in the case at least of Section A, to give any thing like a general report of progress would be a task which few, if any, men could perform single-handed. To say nothing of the enormous *amount* of the material which is now the result of a year's scientific activity, the *variety*—or I might even say the unlikeness—of the subjects of which this Section takes cognizance is so great that, in most cases, it would be safe to conclude, from the mere fact of a man being able adequately to expound the recent advances in one of these subjects, that he must have given so much attention to this one as to have made it impossible for him to have followed carefully the progress of the rest.

But even supposing that all Presidents of Section A were able to discourse with full and equal knowledge of hyper-Jacobian surfaces, the influence of temperature on the capillary constant of dilute sulphuric acid, or the latest improvement in the construction of aneroid barometers, some consideration would still be due to their audience. And, long-suffering as British-Association audiences have often shown themselves to be, there is no doubt that before a tenth part could be read of a report on the year's work on the subjects included in this Section, the room would be cleared and most of those who came to hear about Mathematics and Physics would have gone to try whether they could not find in Section E or F something appealing more directly to the common sympathies of mankind.

But, although a serious report of progress would thus be both impossible and unsuitable in the form of an Address to the Section, it remains none the less true that such reports are in themselves of the utmost scientific value; and, as has been pointed out repeatedly, there are few ways in which the British Association could more effectually fulfil its function of promoting the Advancement of Science than by aiding in their preparation and publication. But when one tries to think out in detail the way in which the Association could do this, the practical difficulties of the scheme are seen to be neither few nor trifling. It may be sufficient to point out that there is no evident reason why help of this kind should be afforded to one branch of science rather than to another, and that the publication of reports upon all branches would completely overtax the resources of the Association.

In the case of some important sciences, however, the work of reporting recent advances has already, with more or less of help from this Association, been undertaken by other bodies; thus there are the 'Abstracts' published monthly in the Journal of the Chemical Society, and there are the Zoological Record, the Geological Record, and other publications of a like nature; but hitherto nothing of the kind has been done in this country for those departments of science with which this Section is specially concerned. But without attempting to commit the Association to any burdensome outlay, or to any larger scheme than it would be practicable to carry out, it seems to me possible that a systematic series of reports might be established in connexion with this Section which would have a very high value. In the early volumes of the British Association's Transactions we find, more frequently than in recent ones, reports, not merely on some special investigation, but on the recent progress and present state of some more or less comprehensive branch of Science. Thus in the first four volumes we find the following, among other reports, presented to this Section:—On the Progress of Astronomy, On the Present State of Meteorology, On the Present State of the Science of Radiant Heat, On the Progress of Optics, On the Magnetism of the Earth, On Capillary Attraction, On Physical Optics, On the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat. Now I venture to think that this form of the activity of the Association might with great advantage be revived and systematized. I would suggest, as a plan that seems to me worth consideration by the Committee of this Section, the appointment of Committees charged to report to the Section periodically on the advances made in each of the chief departments of Science of which we here take cognizance. For example, to confine my remarks to Physics, we might have a Committee on Optics, a Committee on Acoustics, one on Heat, one on Electricity, and so on. It would not be in accordance with the usages of the Association to nominate these as standing Committees, but they might be made virtually such by annual reappointment. I would suggest that they should not report annually, but at intervals of perhaps five or six years, the times being so arranged that different Committees should report in different years, the report in each case being a systematic account of all the work of any importance done on the subject and within the period to which it related. In order not to make the work too heavy, it would probably be needful to make each Committee comparatively numerous, so that individual members might each undertake to report upon some limited part of the general subject. Some one member of each Committee would also require to act as editor; his function would be not merely to put together the detached fragments sent in by his colleagues, but to distribute to them the materials on which they would have to report. For this purpose it would be needful that copies of all the important scientific periodicals relating to Physics should be supplied to the Committee; but, besides providing these and printing the Reports, I do not see that the Association need be put to any expense; and if it were thought well to sell the Reports independently of the yearly volumes of the Association, probably a good part even of this expense might be recovered.

The mutual relations subsisting between the two great groups of sciences which we discuss in this Section under the names Mathematics and Physics offer so many deeply interesting points for consideration, that, at the risk of reminding you how admirably and with what fulness of knowledge the same subject has been treated by more than one of my predecessors in this Chair, I venture to ask your attention once more to a few remarks on this topic.

The intimate connexion between Mathematics and Physics arises out of the fact that all scientific knowledge of physical phenomena is based upon *measurements*—that is to say, upon the discovery of relations of number, quantity, and position—of the same kind as those which form the subject-matter of mathematics. It is true that in studying physics we have to learn much about the quality of phenomena and of the conditions under which they occur, as well as about their purely quantitative relations; but even in the qualitative study of physical phenomena we find it impossible to determine what is really characteristic and to distinguish the essential from the accidental, except by the aid of measurements. In fact if we take the most elementary treatise upon any branch of physics that we can meet with (a book, it may be, which aims at giving a purely descriptive account of phenomena), we find, when we examine it, that numberless careful measurements have been required to establish the truth of the merely qualitative statements which it contains. To take a simple and well-known example, the old question, whether the ascent of water in a pump was due to the pressure of the atmosphere or to Nature's horror of a vacuum, was not conclusively settled by Torricelli's discovery that mercury would not rise beyond a certain height in a glass tube, even to prevent a vacuum being formed at the top of it, for the same thing was already known about the water in a pump. But when he measured the height of the mercury column in his tube and found that, if he multiplied it by the specific gravity of mercury, the product was equal to 32 feet, the height to which, as Galileo said (probably between jest and earnest) nature's abhorrence of a vacuum in a pump extended, it was clear that the ascent both of water and of mercury depended upon the particular depth of each liquid that was needed to produce some definite pressure; and when Pascal had persuaded his brother-in-law to carry a Torricelli's tube to the top of the Puy de Dome, and he had measured the height of the mercury column at the top of the mountain as well as at the foot, the proof was completed that the pressure which determined the height of both the water and the mercury was the pressure of the atmosphere.

Again, let us examine a still more familiar phenomenon, the falling of heavy bodies to the ground. So long as we consider this merely under its general or, as we may call them, its qualitative aspects, we might reasonably infer that it is the result of some inherent tendency of bodies; and, so far from its seeming to be true, as stated in Newton's First Law of Motion, that bodies have no power to alter their own condition of rest or of motion, we might infer that, however indifferent they may be as regards horizontal motion, they have a distinct tendency to move downwards whenever they can, and a distinct disinclination to move upwards. But when we measure the direction in which bodies tend to fall and the amount of the tendency in different places, and find that these vary in the way that they are known to do with geographical position and distance from the sea-level, we are obliged to conclude that there is no inherent tendency to motion at all, but that falling is the result of some mutual action exerted between the earth and the falling body; for if we suppose falling to be due to any internal cause, we must imagine something much more complicated than a mere tendency to motion in one direction, else how could a stone that has always fallen in one direction in England fall in almost exactly the opposite direction as soon as it is taken to New Zealand?

These two simple examples illustrate a principle that we meet with throughout Physics, namely that, in the investigation of the causes of physical phenomena, or, in other words, of the connexion between these phenomena and the conditions under which they occur, the really decisive guidance is afforded by the study of their measurable aspects.

The consequence is that from the very outset of his investigations the physicist has to rely constantly on the aid of the mathematician; for, even in the simplest cases, the direct results of his measuring operations are entirely without meaning until they have been submitted to more or less of mathematical discussion. And when in this way some interpretation of the experimental results has been arrived at, and it has been proved that two or more physical quantities stand in a definite relation to each other, the mathematician is very often able to infer, from the existence of this relation, that the quantities in question also fulfil some other relation that was previously unsuspected. Thus when Coulomb, combining the functions of experimentalist and mathematician, had discovered the law of the force exerted between two particles of electricity, it became a purely mathematical problem, not requiring any further experiment, to ascertain how electricity is distributed upon a charged conductor; and this problem has been solved by mathematicians in several cases.

It thus happens that a very large part of our knowledge of physics is due in the first instance to the mathematical discussion of previous results, and is experimental only in the second or perhaps still more remote degree.

Another way in which the mathematician cooperates in the discovery of physical truths is almost exactly the converse of that last mentioned. In very many cases the most obvious and direct experimental method of investigating a given problem is extremely difficult or, for some reason or other, untrustworthy. In such cases the mathematician can often point out some other problem more accessible to experimental treatment, the solution of which involves the solution of the former one. For example, if we try to deduce from direct experiments the law according to which one pole of a magnet attracts or repels a pole of another magnet, the observed action is so much complicated with the effects of the mutual induction of the magnets and of the forces due to the second pole of each magnet, that it is next to impossible to obtain results of any great accuracy. Gauss, however, showed how the law which applies in the case mentioned can be deduced from the deflections undergone by a small suspended magnetic needle when it is acted upon by a small fixed magnet placed successively in two determinate positions relatively to the needle; and, being an experimentalist as well as a mathematician, he showed likewise how these deflections can be measured very easily and with great precision.

It thus appears not only that mathematical investigations have aided at every step whereby the present stage in the development of a knowledge of physics has been reached, but that mathematics has continually entered more and more into the very substance of physics, or, as a physiologist might say, has been assimilated by it to a greater and greater extent.

Another way of convincing ourselves how largely this process has gone on would be to try to conceive the effect of some intellectual catastrophe, supposing such a thing possible, whereby all knowledge of mathematics should be swept away from men's minds. Would it not be that the departure of mathematics would be the destruction of physics? Objective physical phenomena would, indeed, remain as they are now, but physical science would cease to exist. We should no doubt still see the same colours on looking into a spectroscope or polariscope, vibrating strings would produce the same sounds, electrical machines would give sparks, and galvanometer-needles would be deflected; but all these things would have lost their meaning; they would be but as the dry bones—the *disjecta membra*—of what is now a living and growing science. To follow this conception further, and to try to image to ourselves in some detail what would be the kind of knowledge of physics which would remain possible supposing all mathematical ideas to be blotted out, would be extremely interesting; but it would lead us directly into a dim and entangled region where the subjective seems to be always passing itself off for the objective, and where I at least could not attempt to lead the way, gladly as I would follow any one who could show where a firm footing is to be found. But without venturing to do more than look from a safe distance over this puzzling ground, we may see clearly enough that mathematics is the connective tissue of physics, binding what would else be merely a list of detached observations into an organized body of science.

In my opinion, however, it would be a very serious misconception to suppose that on this account an elaborate apparatus of technical mathematics is in general needful for the proper presentation of physical truths. The ladders and ropes of formulæ are no doubt often essential during the building up of a newly discovered physical principle; but the more thoroughly the building is finished, the more completely will these signs that it is still in progress be cleared away, and easy ascents be provided to all parts of the edifice. In an address, delivered from the Chair of this Section four years ago, Prof. Henry Smith quotes the saying of an old French geometer, "that a mathematical theory was never to be considered complete till you had made it so clear that you could explain it to the first man you met in the street." Very likely Prof. Smith was right to call this "a brilliant exaggeration;" at any rate I know of no reason for disputing his opinion; but I believe the exaggeration would really be very small if the dictum were applied to the theories of physics instead of to those of pure mathematics. When a physical principle or theory is grasped with thorough clearness, I believe it is possible to explain it to the man in the street (only he must not be hurrying to catch a train); and it would, I think, be difficult to find a more wholesome maxim to be kept in mind by those of us whose business it is to teach physics, than that we should never think we understand a principle till we can explain it to the man in the street. I do not say that our modes of exposition should always be adapted to him, for, as a rule, he forms but a small part of our audience; but even when the conditions are such that a teacher is free to avail himself to the fullest extent of mathematical methods, I believe he would find his mathematical discussions gain marvellously in freshness and vigour if he had once made up his mind how he would treat his subject supposing all use of mathematical technicalities denied him.

So far, in considering the mutual relations of Mathematics and Physics, I have placed myself, as it was natural for me to do, at a physical point of view, and, starting from the fact that the existence and progress of the latter science are essentially dependent upon help derived from the former, I have tried to point out some of the ways in which this help is rendered. If we turn now to inquire in what light the relations between the two sciences appear from the side of mathematics, we find that mathematicians are not slow to admit the advantages which their science derives from contact with physics. It was a saying of Fourier that "a more attentive study of nature is the most fruitful source of mathematical discoveries;" and Prof. Henry Smith, in the Address I have already referred to, says that "probably by far the larger part of the accessions to our mathematical knowledge have been obtained by the efforts of mathematicians to solve the problems set to them by experiment." We may perhaps regard such expressions as equivalent to the statement that the law of inertia is not without application even to the mind of the mathematician, and that it, too, continues to move in a straight line "except in so far as it may be compelled by impressed forces" to change its direction; or, to put the matter a little differently, may we not look upon the fact as illustrating what is probably a general principle of mental action—namely, that the human mind has no more power to create an idea than the hand has to create matter or energy, our seemingly most original conceptions being in reality due to suggestions from without? But however this may be, the fact remains that the origin of many most important mathematical theorems and even entire departments of mathematics can be distinctly traced to the attempt to express mathematically the observed relations among physical magnitudes. By way of illustration of this statement, it may suffice to refer to the well-known cases of the theory of fluxions, to Fourier's theorem and the doctrine of harmonic analysis, to spherical harmonics, and to the theory of potential, out of which, in the hands of Riemann, there grew a general and most remarkable theory of mathematical functions.

The way in which physics reacts, so as to promote the advancement of a knowledge of mathematics, finds in many respects a close parallel in the influence exerted by the practical industrial arts on the progress of physics. This influence shows itself very distinctly, first, in the new conceptions and new points of view which practical pursuits supply to scientific physics, and, secondly, in the new subjects and new opportunities which they offer for physical investigation.

A very remarkable and important example of the former kind of influence is afforded by the idea of Work and the correlative one of Energy. These ideas, which have been found to have a most far-reaching significance and to have exerted a transforming effect upon every branch of physics, owe their recognition, not to the spontaneous growth of the science, but to their having been forced on the attention of physicists by the cultivators of practical mechanics*. Very much the same thing may also be said of the modern conceptions of the nature of heat and of the relation between thermal phenomena and those of other branches of physics. The notion of heat as a measurable magnitude, of which definite quantities could be given to or taken away from bodies, was fully established by the researches of Black and Wilke on Latent and Specific Heat. This was at the time when the idea of chemical composition was just taking its modern shape through the recognition of aeriform bodies as possible constituents of solids and liquids, and it was consequently natural that the new knowledge of the laws of heat should be embodied in the conception of a Matter of Heat or Caloric capable of entering into and being separated from combination like fixed air or dephlogisticated air. And in fact this conception not only took the place of philosophical speculations upon the nature of heat, such as those of Bacon and Locke, but it withstood the experimental onslaughts of Rumford and Davy, as well as the penetrating scientific criticism of Thomas Young. It is to the steam-engine, and to the attempt to find out the nature of the connexion obviously existing between the amount of heat supplied and the work done by the engine, that we must trace the downfall of the idea of the materiality of heat and the origin of our modern views†.

Probably it would be impossible to find a more remarkable instance of what I referred to just now, as the second way in which practice may react upon science so as to promote its advancement, than is presented to us in the case of electric telegraphy. This is an example of an industrial undertaking which is the direct offspring of scientific research, and could not have coexisted in its actual state of development with a less advanced condition of electrical science; but if it were possible to establish any common measure for such things, it may be doubted whether it would not be found that telegraphy has repaid to science benefits equal to those it has received. For instance, the discovery of earth-currents was a direct result of the large scale of the instrumental arrangements which are needed for telegraphic purposes, and is one which would probably have long remained unmade in the absence of some inducement to make experiments on a scale greater than that indicated by the visible wants of scientific inquiry. The same may be said of the discovery of the influence of electrostatic induction upon the transmission of electric currents through metallic conductors, and of the consequent additions to our knowledge of the specific inductive capacity of insulators and of the whole subject of electrostatic capacity. But by far the most important of the benefits conferred by electric telegraphy upon electrical science have resulted from the necessity under which the practical electrician found himself, of not only being able to produce certain results, but of producing them under definitely ascertained conditions as to the expenditure of time and material. When it was perceived that slight variations in the electrical conductivity, insulating power, or specific inductive capacity of certain materials might affect the pecuniary return upon investments reckoned in millions of pounds sterling, measuring instruments were devised which far surpassed in delicacy and accuracy those that had been previously made for purely scientific purposes, or the cost of which exceeded the means usually at the disposal of scientific investigators. The multiplication and wide diffusion of such instruments have led to the rapid accumulation of numerical data of great scientific importance, and have largely contributed to the spread of accurate conceptions as to the quantitative laws of electrical phenomena. But the further necessity experienced by practical electricians, that, besides being able to make accurate measurements, they should be able mutually to communicate and to understand each other's results, has probably done more than any thing else to hasten the introduction, for

* See on this point, Dühring, 'Kritische Geschichte der allgemeinen Principien der Mechanik' (Berlin, 1873), pp. 483–486.
† Conf. Dühring, *loc. cit.*

scientific purposes, of so-called "absolute" measurements, instead of mere comparisons of each quantity to be estimated with a standard magnitude of its own kind. The use of absolute measures constitutes one of the most characteristic differences between the Physics of to-day and that of the time when the British Association was instituted, and it may even be said to lie at the base of the doctrine of the Conservation of Energy, which implies the principle that every kind of Energy can be reduced to the same denomination.

Perhaps, after speaking as I have done of the necessity for the cooperation of mathematics in the advancement of physics, it is not inappropriate that I should, in conclusion, refer to the possibility that, by a too implicit reliance upon mathematical guidance, the physicist may be led away from the discovery of fresh truth or even into actual error. Mathematics is seen to be so indispensable and usually so powerful an aid in physical investigation, that there is a danger of forgetting that there are, after all, limits to its power. Partly from want of sufficient knowledge of the physical data on which mathematical discussion must be based, and partly from the imperfection of mathematical methods themselves, it happens that it is not possible to give a thoroughly complete mathematical account of even the simplest physical phenomenon. In all real cases, although some one effect may often predominate so greatly as alone to attract attention on a cursory view, the actual complexity is so great that it is only by deliberately leaving out of consideration what we believe to be the accidental accompaniments of a phenomenon, and confining our attention to what seems to be its essential and characteristic part, that it is possible to make it the subject of mathematical calculation. The consequence is that the problems treated of in mathematical physics are not the problems presented by nature, but are problems suggested by these and derived from them by a process of ideal simplification. There is therefore always a possibility that, in the simplifying process, some apparently trivial, but really important, feature of the actual phenomenon, to which the ideal one is meant to correspond, may have been overlooked. When this is the case, the fact will reveal itself sooner or later by the occurrence of discrepancies between the results of mathematical theory and those of experimental investigation. Such discrepancies are the finger-posts pointing to new discoveries; but the experimenter who forgets the inevitable limitation to the authority of theoretical conclusions, arising from the conditions I have alluded to, is apt to disregard them, and perhaps conscious of laziness and want of care in his method of experimenting, or sometimes from a want of proper self-confidence, he attributes all anomalous results to "the unavoidable errors of observation."

Two classes of experimenters are safe from falling into this danger. There are, first, those who, the first time they observe any thing that is not provided for in their text-books, conclude that the Law of Gravitation ought to be reconsidered; secondly, there are those who, with scrupulous care, take account of all the conditions which are known to be able to affect the phenomenon they are investigating, and are thus able to say, with well-founded confidence, when they meet with some unforeseen result, that it must indicate the operation of some unrecognized cause.

A brilliant example of this latter mode of working and of the discoveries to which it may lead has recently been afforded to us by the researches of Mr. Crookes, some of whose results, as embodied in the now well-known instrument which he has called the "Radiometer," have attracted much attention. It has appeared to me, however, that the surprising nature of these results has to some extent called off attention from the remarkable character of the scientific investigation which led to them; and it was at one time my intention to take advantage of the present opportunity for the purpose of trying, on the one hand, to render to Mr. Crookes the credit which I think his researches deserve, and, on the other hand, to give a connected account of the further investigations, both experimental and theoretical, to which these researches have given rise. There seemed to be the more reason for endeavouring to carry out the former part of my intention, inasmuch as an eminent and accomplished scientific man had published, within the last few months, an account of the discovery of the Radiometer, the unmistakable tendency of which was, either intentionally or unintentionally, to depreciate Mr. Crooke's merits, and to make it appear that he had put a wrong interpretation upon his own results. I found, however, that the time at my disposal would not enable me to make myself sufficiently master of the whole subject to treat it in the way that I wished, and I have therefore been obliged to content myself with merely making this allusion to it, as an illustration of the more general considerations to which I have ventured to ask your attention.

MATHEMATICS.

On the Calculation of Bernoulli's Numbers up to B_{62} *by means of Staudt's Theorem. By* Professor J. C. ADAMS, *M.A., F.R.S.*

Thirty-one of the numbers of Bernoulli are at present known to Mathematicians, and are to be found in a communication by Ohm in Crelle's Journal, vol. xx. p. 11. Of these numbers the first fifteen are given in Euler's 'Institutiones Calculi Differentialis,' part 2, chap. 5, and Ohm states that the sixteen following numbers were calculated and communicated to him by Professor Rothe of Erlangen. I find, however, that the first two of these had been already given by Euler in a memoir contained in the 'Acta Petropolitana' for 1781.

A remarkable theorem, due to Staudt, gives at once the fractional part of any one of Bernoulli's numbers, and thus greatly facilitates the finding of these numbers by reducing all the requisite calculations to operations with integers only.

The theorem may be thus stated:—

If $1, 2, a, a' \ldots . 2n$ be all the divisors of $2n$, and if unity be added to each of these divisors so as to form the series $2, 3, a+1, a'+1 \ldots . 2n+1$, and if from this series only the prime numbers $2, 3, p, p' \ldots .$ be selected, then the fractional part of the nth number of Bernoulli will be

$$(-1)^n\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{p}+\frac{1}{p'}+\ldots\right).$$

Having found, several years ago, a simple and elementary proof of this theorem, I was induced to apply the theorem to the calculation of several additional numbers of Bernoulli, and I ultimately obtained the values of the thirty-one numbers which are given in the present paper.

The method which has been employed affords numerous tests, throughout the course of the work, of the correctness with which the requisite operations have been performed, so that I feel entire confidence in the accuracy of the results.

I propose to publish some of the principal steps of these calculations in an Appendix to the twenty-second volume of the 'Cambridge Observations,' which is now in the press. In making them I have received very efficient aid from my Assistants, Mr. Graham and Mr. Todd.

The following is an outline of the method employed:—

Bernoulli's numbers B_1, B_2, &c. are defined by the equation

$$\frac{x}{\epsilon^x-1}=1-\frac{1}{2}x+\frac{B_1}{1.2}x^2-\frac{B_2}{1.2.3.4}x^4+\&c.+(-1)^{n-1}\frac{B_n}{\underline{|2n}}x^{2n}+\&c.$$

If we multiply by ϵ^x-1, and equate to zero the coefficient of x^{2n+1} on the right-hand side of the resulting equation, we shall find

$$(-1)^n C^n_n B_n+(-1)^{n-1}C^n_{n-1}B_{n-1}+\&c.+(-1)C^n_1 B_1+n-\tfrac{1}{2}=0,$$

in which C^n_r denotes the coefficient of x^{2r} in the expansion of $(1+x)^{2n+1}$.

This equation gives B_n when $B_1, B_2 \ldots . B_{n-1}$ are known.

Now let $$B_n = I_n + (-1) \ (f_n - 1),$$

where $(-1)^n f_n$ is the fractional part of B_n given by Staudt's Theorem, so that I_n is an integer.

Substituting in the above equation, and writing for simplicity C_r instead of C^n_r, as we may do without ambiguity, we have

$$\begin{aligned}(-1)^n C_n I_n + (-1)^{n-1} C_{n-1} I_{n-1} + \&c. + (-1) C_1 I_1 \\ + C_1 f_1 + C_2 f_2 + \&c. + C_n f_n \\ - C_1 - C_2 - \&c. - C_n + n - \tfrac{1}{2} = 0.\end{aligned}$$

Now by Staudt's Theorem the fraction $\frac{1}{2}$ occurs in each of the fractions f_n; hence the quantity arising from this fraction in $C_1 f_1 + C_2 f_2 + \&c. + C_n f_n$ will be

$$\tfrac{1}{2}(C_1 + C_2 + \ldots + C_n) = \tfrac{1}{2}(2^{2n} - 1).$$

Also, by the same Theorem, if $2r+1=p$ be an odd prime number, the fraction $\frac{1}{p}$ will occur in each of the fractions f_r, f_{2r}, f_{3r} &c.;

hence the part of $C_1 f_1 + C_2 f_2 + \&c. + C_n f_n$ which contains $\frac{1}{p}$ will be

$$\frac{1}{p}\{C_r + C_{2r} + C_{3r} + \&c.\}.$$

Also $C_n = 2n+1$; hence by substitution and transposition, we find

$$\begin{aligned}(-1)^{n-1}(2n+1) I_n = -\{C_1 I_1 + C_3 I_3 + \&c.\} + \{C_2 I_2 + C_4 I_4 + \&c.\} \\ -2^{2n-1} + n \\ + \tfrac{1}{3}(C_1 + C_2 + \&c. + C_n) + \tfrac{1}{5}(C_2 + C_4 + C_6 + \&c.) \\ + \tfrac{1}{7}(C_3 + C_6 + C_9 + \&c.) + \tfrac{1}{11}(C_5 + C_{10} + C_{15} + \&c.) \\ + \&c. + \frac{1}{p}(C_r + C_{2r} + {}_{3r} + \&c.) + \&c.,\end{aligned}$$

which gives I_n when $I_1, I_2 \ldots I_{n-1}$ are known.

In the above expression, p is supposed to include every odd prime number not exceeding $2n+1$.

It may be easily shown that all the quantities

$$\begin{aligned}&\tfrac{1}{3}(C_1 + C_2 + \&c. + C_n) \\ &\tfrac{1}{5}(C_2 + C_4 + C_6 + \&c.) \\ &\tfrac{1}{7}(C_3 + C_6 + C_9 + \&c.) \\ &\&c.\end{aligned}$$

are integers. Hence the right-hand side of the above equation is an integer which must be divisible by $2n+1$; and this supplies a test of the correctness of the work.

The reason why we assume

$$B_n = I_n + (-1)^n (f_n - 1),$$

instead of taking the simpler form

$$B_n = I_n + (-1)^n f_n,$$

is that with the above assumption the quantities I_1, I_2, I_3, I_4, I_5, I_8 all vanish, so that we have fewer quantities to calculate.

The numbers $C_r^n\, I_r$, which are required in order to find the value of $(2n+1)I^n$, can be readily derived from the numbers $C_r^{n-1}\, I_r$, which have been already employed in finding the value of the similar quantity $(2n-1)\, I_{n-1}$ which immediately precedes it. For since

$$C_r^n = \frac{(2n+1)2n}{(2n-2r+1)\,(2n-2r)}\, C_r^{n-1} = \frac{n(2n+1)}{(n-r)\,(2n-2r+1)}\, C_r^{n-1},$$

we have

$$C_r^n\, I_r = \frac{n(2n+1)}{(n-r)\,(2n-2r+1)}\, C_r^{n-1}\, I_r\,;$$

and a test of the correctness of the work is supplied by the divisions by $(n-r)$ and $2n-2r+1$ being performed without leaving any remainder.

I have proved that if n be a prime number, other than 2 or 3, then the numerator of the nth number of Bernoulli will be divisible by n.

This forms another excellent test of the correctness of the work.

I have also observed that if q be a prime factor of n, which is not likewise a factor of the denominator of B_n, then the numerator of B_n will be divisible by q. I have not succeeded, however, in obtaining a general proof of this proposition, though I have no doubt of its truth.

For the sake of convenience of reference, I include in the following Table the numbers of Bernoulli which have been previously calculated as well as those which have been added by myself.

Table of Bernoulli's Numbers expressed in Vulgar Fractions.

Numerator.	Denominator.	No.
1	6	1
1	30	2
1	42	3
1	30	4
5	66	5
691	2730	6
7	6	7
3617	510	8
43867	798	9
1 74611	330	10
8 54513	138	11
2363 64091	2730	12
85 53103	6	13
2 37494 61029	870	14
861 58412 76005	14322	15
770 93210 41217	510	16
257 76878 58367	6	17
26315 27155 30534 77373	1919190	18
2 92999 39138 41559	6	19
2 61082 71849 64491 22051	13530	20
15 20097 64391 80708 02691	1806	21
278 33269 57930 10242 35023	690	22
5964 51111 59391 21632 77961	282	23
560 94033 68997 81768 62491 27547	46410	24
49 50572 05241 07964 82124 77525	66	25
80116 57181 35489 95734 79249 91853	1590	26
29 14996 36348 84862 42141 81238 12691	798	27
2479 39292 93132 26753 68541 57396 63229	870	28
84483 61334 88800 41862 04677 59940 36021	354	29

				Numerator.						Denominator.	No.
	121	52331	40483	75557	20403	04994	07982	02460	41491	56786730	30
		123	00585	43408	68585	41953	03985	74033	86151	6	31
	10	67838	30147	86652	98863	85444	97914	26479	42017	510	32
1	47260	00221	26335	65405	16194	28551	93234	22418	99101	64722	33
	7877	31308	58718	72814	19091	49208	47460	62443	47001	30	34
1505	38134	73333	67003	80307	65673	77857	20851	14381	60235	4686	35
58279	54961	66994	41104	38277	24464	10673	65282	48830	18442		
60429	...	...	...	...	...	...	...	...	...	140100870	36
34152	41728	92211	68014	33007	37314	72635	18668	83077	83087	6	37
246	55088	82593	53727	07687	19604	05851	99904	36526	78288		
65801	...	...	...	...	...	...	...	...	...	30	38
41	48463	65575	40082	82951	79035	54954	20734	92199	37537		
24004	83487	...	...	...	...	...	...	...	...	3318	39
4	60378	42994	79457	64693	55749	69019	04684	97942	57872		
75128	89196	56867	...	...	...	...	...	...	...	230010	40
1	67701	41491	85145	83682	31545	09786	26990	02077	36027		
57025	34148	81613	...	...	...	...	...	...	...	498	41
20	24576	19593	52903	60231	13116	01117	31009	98991	73911		
98090	87728	10839	32477	...	...	...	...	...	...	3404310	42
660	71461	94176	78653	57384	78474	26261	49627	78306	86653		
33893	17619	96983	...	...	...	...	...	...	...	6	43
13114	26488	67401	75079	95511	42401	93118	43345	75027	55720		
28644	29691	98905	74047	...	...	...	...	...	...	61410	44
117	90572	79021	08279	98841	23351	24921	50837	75254	94966		
96471	16231	54521	57279	22535	...	...	...	...	...	272118	45
129	55859	48207	53752	79894	27828	53857	67496	59341	48371		
94351	43023	31632	68299	46247	...	...	...	...	...	1410	46
122	08138	06579	74446	96073	01679	41320	12039	58508	41520		
26966	21436	21510	52846	49447	...	...	...	...	...	6	47
2	11600	44959	72665	13097	59772	81098	24233	67304	39543		
89060	23415	06387	33420	05066	83499	87259	...	...	...	4501770	48
67	90826	06729	05495	62405	11175	46403	60560	73421	95728		
50448	75090	73961	24999	29470	58239	...	...	...	...	6	49
945	98037	81912	21252	95227	43306	94937	21872	70284	15330		
66936	13338	56962	04311	39541	51972	47711	...	...	...	33330	50
32040	19410	86090	70782	43020	78211	62417	75491	81719	71527		
17450	67900	25010	86861	53083	66781	58791	...	...	...	4326	51
31	95336	31363	83001	12871	03352	79617	42746	71189	60607		
82727	38327	10347	01628	49568	36554	97212	24053	...	...	1590	52
3637	39031	72617	41440	81518	20151	59342	71692	31298	64058		
16900	38930	81637	82818	79873	38620	23465	72901	...	...	642	53
34	69342	24784	78287	89552	08865	93238	52541	39976	67857		
60491	14687	00058	91371	50126	63197	24897	59230	65973	38057	209191710	54
7645	99294	04847	42892	24813	42467	24347	50052	87524	13412		
30790	66835	93870	75979	76062	69585	77997	79302	17515	...	1518	55
26508	79602	15509	97133	52597	21468	51620	14443	15149	91925		
09896	45178	84276	80966	75651	48755	15366	78120	35526	00109	1671270	56
217	37832	31936	91633	33310	76108	66529	91475	72115	66790		
90831	36080	61101	14933	60548	42345	93650	90418	86185	62649	42	57
30	95539	16571	84297	69125	13458	03384	14168	69004	12806		
43298	44245	50404	57210	08957	52457	19682	71388	19959	57547		
52259	...	...	...	...	...	...	...	...	...	1770	58
36	69631	19969	71311	15349	47151	58558	50066	84606	36108		
06992	04301	05944	06764	14485	04580	64618	89371	77635	45170		
95799	...	...	...	...	...	...	...	...	...	6	59
515	07486	53507	91090	61843	99685	78499	83274	09517	03532		
62675	21309	28691	67199	29747	49229	85358	81132	93670	77682		
67780	32820	70131	...	...	...	...	...	...	...	2328255930	60
49	63366	60792	62581	91253	26374	75990	75743	87227	90311		
06013	97703	09311	79315	06832	14100	43132	90331	13678	09803		
79685	64431	...	...	...	...	...	...	...	...	6	61
95876	77533	42471	28750	77490	31075	42444	62057	88300	13297		
33681	95535	12729	35859	33544	35944	41363	19436	10268	47268		
[illegible]0946	09001	...	...	...	...	...	...	...	...	30	62

It may be sometimes useful to have the values of Bernoulli's numbers expressed in integers and repeating decimals.

It readily follows from Staudt's theorem that if the fractional part of the nth number of Bernoulli be converted into a repeating decimal, then the number of figures in the repeating part will be either $2n$ or a divisor of $2n$, and the first figure of the repeating part will occupy the second place of decimals.

Table of Bernoulli's Numbers expressed in Integers and Repeating Decimals.

No.		No.
1	${\cdot}1\dot{6}$	1
2	${\cdot}0\dot{3}$	2
3	${\cdot}0\dot{2}380\ 9\dot{5}$	3
4	${\cdot}0\dot{3}$	4
5	${\cdot}0\dot{7}\dot{5}$	5
6	${\cdot}2\dot{5}311\ 3\dot{5}$	6
7	$1{\cdot}1\dot{6}$	7
8	$7{\cdot}0\dot{9}215\ 68627\ 45098\ 0\dot{3}$	8
9	$54{\cdot}9\dot{7}117\ 79448\ 62155\ 388\dot{4}$	9
10	$529{\cdot}1\dot{2}\dot{4}$	10
11	$6192{\cdot}1\dot{2}318\ 84057\ 97101\ 44927\ 53\dot{6}$	11
12	$86580{\cdot}2\dot{5}311\ 3\dot{5}$	12
13	$14\ 25517{\cdot}1\dot{6}$	13
14	$272\ 98231{\cdot}0\dot{6}781\ 60919\ 54022\ 98850\ 57471\ 264\dot{3}$	14
15	$6015\ 80873{\cdot}9\dot{0}064\ 23683\ 84303\ 86817\ 48359\ 16771\ \dot{4}$	15
16	$1\ 51163\ 15767{\cdot}0\dot{9}215\ 68627\ 45098\ 0\dot{3}$	16
17	$42\ 96146\ 43061{\cdot}1\dot{6}$	17
18	$1371\ 16552\ 05088{\cdot}3\dot{3}277\ 21590\ 87948\ 561\dot{6}$	18
19	$48833\ 23189\ 73593{\cdot}1\dot{6}$	19
20	$19\ 29657\ 93419\ 40068{\cdot}1\dot{4}863\ 26681\ \dot{4}$	20
21	$841\ 69304\ 75736\ 82615{\cdot}0\dot{0}055\ 37098\ 56035\ 43743\ 07862\ 67995\ 57032\ 11517\ 16\dot{5}$	21
22	$40338\ 07185\ 40594\ 55413{\cdot}0\dot{7}681\ 15942\ 02898\ 55072\ 46\dot{3}$	22
23	$21\ 15074\ 86380\ 81991\ 60560{\cdot}1\dot{4}539\ 00709\ 21985\ 81560\ 28368\ 79432\ 62411\ 34751\ 77304\ 9\dot{6}$	23
24	$1208\ 66265\ 22296\ 52593\ 46027{\cdot}3\dot{1}193\ 70825\ 25317\ 81943\ 54664\ 94290\ 02370\ 17884\ 07670\ 760\dot{6}$	24
25	$75008\ 66746\ 07696\ 43668\ 55720{\cdot}0\dot{7}\dot{5}$	25
26	$50\ 38778\ 10148\ 10689\ 14137\ 89303{\cdot}0\dot{5}220\ 12578\ 616\dot{3}$	26
27	$3652\ 87764\ 84818\ 12333\ 51104\ 30842{\cdot}9\dot{7}117\ 79448\ 62155\ 388\dot{4}$	27
28	$2\ 84987\ 69302\ 45088\ 22262\ 69146\ 43291{\cdot}0\dot{6}781\ 60919\ 54022\ 98850\ 57471\ 264\dot{3}$	28
29	$238\ 65427\ 49968\ 36276\ 44645\ 98191\ 92192{\cdot}1\dot{4}971\ 75141\ 24293\ 78531\ 07344\ 63276\ 83615\ 81920\ 90395\ 48022\ 59887\ 005\dot{6}$	29
30	$21399\ 94925\ 72253\ 33665\ 81074\ 47651\ 91097{\cdot}3\dot{9}267\ 41511\ 61723\ 87457\ 42183\ 07692\ 65988\ 72659\ 15822\ 23522\ 99560\ 12610\ \dot{6}$	30
31	$20\ 50097\ 57234\ 78097\ 56992\ 17330\ 95672\ 31025{\cdot}1\dot{6}$	31

No.		No.
32	2093 80059 11346 37840 90951 85290 02797 01847 ·09215 68627 45098 03	32
33	2 27526 96488 46351 55596 49260 35276 92645 81469 ·96540 58898 05630 23392 35499 52102 83983 80766 97259 04638 29918 72933 46929 94	33
34	262 57710 28623 95760 47303 04973 61582 02081 44900 ·03	34
35	32125 08210 27180 32518 20479 23042 64985 24352 19411 ·06167 30687 15322 23644 89970 12377 29406 74349 12505 33504 05463 08151 94195 47588 5	35
36	41 59827 81667 94710 91391 70744 95262 35893 66896 03011 ·34647 07892 24934 86300 26351 72786 57869 86190 73528 95096 22602 62909 14538 93184 246	36
37	5692 06954 82035 28002 38834 56219 12105 86444 80512 97181 ·16	37
38	8 21836 29419 78457 56922 90653 46861 73330 14550 89276 28860 ·03	38
39	1250 29043 27166 99301 67323 39829 70289 55241 77196 36444 84775 ·01115 12959 61422 54370 10247 13682 94153 10427 96865 58167 57082 57986 73899 93972 27245 3285	39
40	2 00155 83233 24837 02749 25329 19881 32987 68724 22013 28259 15915 ·20745 61975 56627 97269 68392 67857 91922 09034 38980 91387 33098 56093 21333 85504 97804 44328 5	40
41	336 74982 91536 43742 33396 67690 33387 53016 21959 89471 93843 67232 ·15461 84738 95582 32931 72690 76305 22088 35341 36	41
42	59470 97050 31354 47718 66049 68440 51540 84057 90715 65106 90499 04704 ·31085 21256 87731 14081 85506 02030 95487 77872 75541 88660 84463 51830 47372 30158 24058 32606 31376	42
43	110 11910 32362 79775 59564 13079 04376 91604 63051 14442 23148 86269 99497 ·16	43
44	21355 25954 52535 01188 65838 50190 41065 67897 32987 39163 46921 18045 90304 ·08804 75492 59078 32600 55365 57563 91467 18775 44373	44
45	43 32889 69866 41192 41961 66130 59379 20621 84513 68511 80910 91449 86557 88032 ·84801 07894 36935 44712 22043 37824 03222 13157 52724 92080 64148 64139 82169 49999 63251 23659 58885 48350 3	45
46	9188 55282 41669 32822 62005 55215 50189 71389 60388 91627 19959 59100 44871 13437 ·05460 99290 78014 18439 71631 20567 37588 65248 22695 03	46
47	20 34689 67763 29074 49345 50279 90220 02006 59751 40253 37827 70239 36918 42141 08241 ·16	47
48	4700 38339 58035 73107 85752 55535 00606 06545 96737 36975 90579 15139 76356 41204 83354 ·32224 63608 75833 28335 29922 67485 89999 04482 01485 19360 16278 04174 80235 55179 40721 09414 74131 28613 85632 76	48
49	11 31804 34454 84249 27067 51862 57733 93426 78903 65954 75074 79181 78993 54166 54911 76373 ·16	49
50	2838 22495 70693 70695 92641 56336 48176 47382 84680 92801 28821 28228 53171 44648 65111 07028 ·13414	50
51	7 40642 48979 67885 06297 50827 14092 09841 76879 73178 80887 06673 11610 03487 48532 84412 10855 ·01410 07859 45446 13962 08969 02450 30050 85529 35737 40175 68192 32547 38788 71937 12436 43088 30328 24780 39759 59315 765	51

No. No.

52 2009 64548 02756 60448 34656 19672 71536 31868 67270 82253 28766 24346 13019 52
89213 56500 97796 98883·05220 12578 6163

53 5 66571 70050 80594 14457 19346 03051 93569 61419 46828 75104 20621 38756 53
44521 52460 86197 22777 98400·15732 08722 74143 30218 06853 58255 45171
33956 38629 28348 9096

54 1658 45111 54136 21691 58237 13374 31991 23014 94962 61472 54647 27402 46681 54
55898 78137 71265 07431 49939·34194 64710 14554 06621 99281 22390 70085
52107 53810 46409 53506 23597 84716 13430 57045 61619 57851 96268 05479
05077 11801 7726

55 5 03688 59950 49237 74192 89421 91518 01548 12442 37426 49032 14141 52565 55
13225 28310 97674 29893 27917 85387·03227 93148 88010 54018 445

56 1586 14682 37658 18636 93634 01572 96643 87827 40978 41277 89638 80472 86451 56
42973 11365 09885 00683 12009 45121·13548 91788 87911 58819 34098 02126
52653 37138 82257 20559 81379 43001 43005 02013 43888 18084 45074 70366
84676 92234 04955 51287 344

57 5 17567 43617 54562 69840 73240 68250 71225 61240 84923 59305 50859 06216 57
69403 18108 29579 66515 49771 87766 32444·02380 95

58 1748 89218 40217 11733 96900 25877 61815 91451 41476 16182 65448 72627 34721 58
58762 12289 52384 00153 32666 64382 79521·05028 24858 75706 21468 92655
36723 16384 18079 09604 51977 40112 9943

59 6 11605 19994 95218 52558 24525 26426 41677 80767 72684 67832 00716 84324 59
01127 35747 50763 44103 14895 29605 90861 82633·16

60 2212 27769 12707 83494 22883 23456 71293 24455 73185 05498 77801 50566 60
55269 30277 36635 00257 26591 02528 03139 11549 56836·41706 43950 64162
89896 44622 10131 68427 75098 18261 25962 01999 15049 7

61 8 27227 76798 77096 98542 21062 45998 45957 31204 65051 84335 66283 84885 61
29885 84472 02350 07188 81721 85613 01633 96614 27405·16

62 3195 89251 11415 70958 35916 34369 18081 48735 26276 67109 91122 73184 50424 62
31195 31118 14531 48045 43981 20342 28242 29698 20300·03

On the Calculation of the Sum of the Reciprocals of the First Thousand Integers, and on the Value of Euler's Constant to 260 Places of Decimals. By Professor J. C. ADAMS, *M.A., F.R.S.*

If S_n denote the sum of the harmonic series

$$1+\frac{1}{2}+\frac{1}{3}+\&c.+\frac{1}{n},$$

n being an integer, and if R_n denote the value, defined in the usual way, of the semi-convergent series

$$\frac{B_1}{2n^2}-\frac{B_2}{4n^4}+\frac{B_3}{6n^6}-\&c.,$$

where B_1, B_2, B_3, &c. are the numbers of Bernoulli, then the value of Euler's constant E is given approximately by

$$E=S_n-\log_\epsilon n-\frac{1}{2n}+R_n.$$

Having computed the values of 31 of Bernoulli's numbers in addition to those previously known, I have been able to find a much more approximate value of E than has been before obtained.

In fact, by putting $n=1000$ in the above formula, the value of E is correctly found to more than 260 places of decimals.

In order to diminish as much as possible the number of decimal fractions which must be added together to form S_{1000}, I first resolved the reciprocal of every integer up to 1000 into ordinary fractions whose denominators were primes or powers of primes, and then combined the fractions corresponding to each of these primes into one sum, so that finally the number of decimal fractions to be added together was reduced to the number of prime numbers below 1000.

Also the value of $\log_\epsilon 1000$ or $3 \log_\epsilon 10$ was derived from the Napierian logarithms of $\frac{10}{9}$, $\frac{25}{24}$, and $\frac{81}{80}$, which may be found by extremely simple operations when the reciprocals of the successive integers are supposed to have been previously expressed in repeating decimals.

The following Table gives the results which I have thus obtained:—

R_{1000}	·00000	00833	33325	00000	39682	49801	59487	73237	84632	11743
	88611	32124	18782	98862	06644	51967	06850	04241	14869	65631
	43736	78499	44114	24665	37423	82138	50259	70190	89962	61572
	33894	07843	88131	36054	55889	69002	08034	44545	27898	47738
	31546	74821	27649	54293	18527	10448	88349	55931	43201	82238
	86978	52223	81562							
S_{1000}	7·48547	08605	50344	91265	65182	04333	90017	65216	79169	70880
	36657	73626	74995	76993	49165	20244	09599	34437	41184	50813
	96798	01438	22544	03715	81484	21958	84703	40431	40398	43368
	92966	39178	33827	35905	57913	00071	54692	68403	25933	79804
	87809	56515	86955	67800	24804	71415	08712	32350	00711	42865
	21027	95267	06455							
$\log_\epsilon 1000$	6·90775	52789	82137	05205	39743	64053	09262	28033	04465	88631
	89280	99983	70290	27178	29032	05744	07079	91615	26879	48950
	25903	35212	68587	45900	22857	63952	48420	26999	88621	07296
	34506	84487	21624	97666	40425	31399	68447	86995	95585	18051
	59268	96133	19788	65384	90098	66686	30946	59660	23963	10024
	23212	72982	31056							
E	·57721	56649	01532	86060	65120	90082	40243	10421	59335	93992
	35988	05767	23488	48677	26777	66467	09369	47063	29174	67495
	14631	44724	98070	82480	96050	40144	86542	83622	41739	97644
	92353	62535	00333	74293	73377	37673	94279	25952	58247	09491
	60087	35203	94816	56708	53233	15177	66115	28621	19950	15079
	84793	74508	56961							

The figures in the last two decimal places in each of these quantities are uncertain.

On a Simple Proof of Lambert's Theorem. *By* Professor J. C. Adams, *M.A., F.R.S.*

The following proof of Lambert's Theorem, which I find among my old papers, appears to be as simple and direct as can be desired.

Let a denote the semiaxis major and e the excentricity of an elliptic orbit, n the mean motion, and μ the absolute force.

Also let r, r' denote the radii vectores, and u, u' the excentric anomalies at the extremities of any arc, k the chord, and t the time of describing the arc.

Then

$$r=a(1-e\cos u), \quad r'=a(1-e\cos u'),$$

$$k^2=a^2(\cos u-\cos u')^2+a^2(1-e^2)(\sin u-\sin u')^2,$$

and

$$nt = \left(\frac{\mu}{a^3}\right)^{\frac{1}{2}} t = u - u' - e(\sin u - \sin u').$$

Or

$$\frac{r+r'}{2a} = 1 - \left(e \cos \frac{u+u'}{2}\right) \cos \frac{u-u'}{2},$$

$$\frac{k^2}{4a^2} = \sin^2 \frac{u+u'}{2} \sin^2 \frac{u-u'}{2} + (1-e^2) \cos^2 \frac{u+u'}{2} \sin^2 \frac{u-u'}{2}$$

$$= \sin^2 \frac{u-u'}{2} \left\{1 - e^2 \cos^2 \frac{u+u'}{2}\right\},$$

and

$$nt = u - u' - 2\left(e \cos \frac{u+u'}{2}\right) \sin \frac{u-u'}{2}.$$

Hence we see that if a, and therefore also n, be given, then $r+r'$, k, and t are functions of the *two* quantities

$$u - u' \text{ and } e \cos \frac{u+u'}{2}.$$

Let

$$u - u' = 2a \text{ and } e \cos \frac{u+u'}{2} = \cos \beta.$$

Then

$$\frac{r+r}{2a} = 1 - \cos a \cos \beta,$$

$$\frac{k}{2a} = \sin a \sin \beta;$$

therefore

$$\frac{r+r'+k}{2a} = 1 - \cos(\beta + a),$$

and

$$\frac{r+r'-k}{2a} = 1 - \cos(\beta - a);$$

also

$$nt = 2a - 2 \sin a \cos \beta,$$

$$= [\beta + a - \sin(\beta + a)] - [\beta - a - \sin(\beta - a)].$$

The first two of these equations give $\beta + a$ and $\beta - a$ in terms of $r+r'+k$ and $r+r'-k$, and the third equation is the expression of Lambert's Theorem.

An exactly similar proof may be given in the case of an hyperbolic orbit.

Let

$$\tfrac{1}{2}(\epsilon^u + \epsilon^{-u}) \text{ be denoted by csh}(u)$$

and

$$\tfrac{1}{2}(\epsilon^u - \epsilon^{-u}) \text{ by snh}(u),$$

which quantities may be called the hyperbolic cosine and hyperbolic sine of u.

Then we have

$$\text{csh}^2(u) - \text{snh}^2(u) = 1,$$

$$\text{csh}(u) + \text{csh}(u') = 2 \,\text{csh} \frac{u+u'}{2} \,\text{csh} \frac{u-u'}{2},$$

$$\text{csh}(u) - \text{csh}(u') = 2 \,\text{snh} \frac{u+u}{2} \,\text{snh} \frac{u-u'}{2},$$

$$\text{snh}(u) - \text{snh}(u') = 2 \,\text{csh} \frac{u+u'}{2} \,\text{snh} \frac{u-u}{2}.$$

The coordinates of any point in the hyperbola referred to its axes may be represented by

$$x=a \operatorname{csh}(u),$$

$$y=a\sqrt{e^2-1}\operatorname{snh}(u).$$

If u, u' denote the values of u corresponding to the two extremities of the arc, we have

$$r=a(e \operatorname{csh}(u)-1), \qquad r'=a(e \operatorname{csh}(u')-1),$$

$$k^2=a^2[\operatorname{csh}(u)-\operatorname{csh}(u')]^2+a^2(e^2-1)[\operatorname{snh}(u)-\operatorname{snh}(u')]^2;$$

or

$$\frac{r+r'}{2a}=\left(e \operatorname{csh}\frac{u+u'}{2}\right)\operatorname{csh}\frac{u+u'}{2}-1,$$

$$\frac{k^2}{4a^2}=\operatorname{snh}^2\frac{u-u'}{2}\left[e^2\operatorname{csh}^2\frac{u+u'}{2}-1\right].$$

Also twice the area of the sector limited by r and r'

$$=a^2\sqrt{e^2-1}[(e \operatorname{snh} u-u)-(e \operatorname{snh} u'-u')]$$

$$=a^2\sqrt{e^2-1}\left[2\left(e \operatorname{csh}\frac{u+u'}{2}\right)\operatorname{snh}\frac{u-u'}{2}-(u-u')\right],$$

and twice the area described in a unit of time is

$$\sqrt{\mu a(e^2-1)}.$$

Hence

$$t=\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}\left[2\left(e \operatorname{csh}\frac{u+u'}{2}\right)\operatorname{snh}\frac{u-u'}{2}-(u-u')\right];$$

and therefore if a be given, then $r+r'$, k, and t are functions of the *two* quantities $e \operatorname{csh}\frac{u+u'}{2}$ and $u-u'$.

Let $u-u'=2\alpha$, and $e \operatorname{csh}\frac{u+u'}{2}=\operatorname{csh}(\beta)$, which is always possible since e is greater than 1.

Then

$$\frac{r+r'}{2a}=\operatorname{csh}(\beta)\operatorname{csh}(\alpha)-1,$$

$$\frac{k}{2a}=\operatorname{snh}(\beta)\operatorname{snh}(\alpha);$$

therefore

$$\frac{r+r'+k}{2a}=\operatorname{csh}(\beta+\alpha)-1$$

and

$$\frac{r+r'-k}{2a}=\operatorname{csh}(\beta-\alpha)-1$$

Also

$$t=\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}[2 \operatorname{csh}(\beta)\operatorname{snh}(\alpha)-2\alpha],$$

$$=\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}[\operatorname{snh}(\beta+\alpha)-(\beta+\alpha)-\operatorname{snh}(\beta-\alpha)+\beta-\alpha].$$

As before, the first two of these equations give $\beta+\alpha$ and $\beta-\alpha$ in terms of $r+r'+k$ and $r+r'-k$, and the last equation is the expression of Lambert's theorem in the case of the hyberbola.

When the orbit is parabolic, a becomes infinite; and since $r+r'$ and k are finite, the quantities α and β become indefinitely small.

Hence

$$\frac{r+r'+k}{2a}=1-\cos(\beta+a)=\tfrac{1}{2}(\beta+a)^2 \text{ ultimately,}$$

$$\frac{r+r'-k}{2a}=1-\cos(\beta-a)=\tfrac{1}{2}(\beta-a)^2 \text{ ultimately;}$$

also

$$t=\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}\{\beta+a-\sin(\beta+a)-(\beta-a)+\sin(\beta-a)\}$$

$$=\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}\{\tfrac{1}{6}(\beta+a)^3-\tfrac{1}{6}(\beta-a)^3\} \text{ ultimately}$$

$$=\tfrac{1}{6}\left(\frac{a^3}{\mu}\right)^{\frac{1}{2}}\left\{\left(\frac{r+r'+k}{a}\right)^{\frac{3}{2}}-\left(\frac{r+r'-k}{a}\right)^{\frac{3}{2}}\right\} \text{ ultimately}$$

$$=\frac{1}{6\sqrt{\mu}}\{(r+r'+k)^{\frac{3}{2}}-(r+r'-k)^{\frac{3}{2}}\},$$

which is Lambert's theorem in the case of the parabola.

Suggestion of a Mechanical Integrator for the calculation of $\int(\mathrm{X}dx+\mathrm{Y}dy)$ *along an arbitrary Path. By* Professor CAYLEY.

I consider an integral $\int(\mathrm{X}dx+\mathrm{Y}dy)$, where X, Y are each of them a given function of the variables (x, y). $\mathrm{X}dx+\mathrm{Y}dy$ is thus not in general an exact differential; but assuming a relation between (x, y), that is, a path of the integral, there is in effect one variable only, and the integral becomes calculable. I wish to show how for any given values of the functions X, Y, but for an arbitrary path, it is possible to construct a mechanism for the calculation of the integral, viz. a mechanism such that a point D thereof being moved in a plane along a path chosen at pleasure, the corresponding value of the integral shall be exhibited on a dial.

The mechanism (for convenience I speak of it as actually existing) consists of a square block, or inverted box, the upper horizontal face whereof is taken as the plane of xy, the equations of its edges being $y=0$, $y=1$, $x=0$, $x=1$ respectively. In the wall-faces represented by these equations we have the endless bands A, A′, B, B′ respectively, and in the plane of xy a driving point D, the coordinates of which are (x, y), and a regulating point R, mechanically connected with D in suchwise that the coordinates of R are always the given functions X, Y of the coordinates of D*; the nature of the mechanical connexion will, of course, depend upon the particular functions X, Y.

This being so, D drives the bands A and B in such manner that to the given motions dx, dy of D corresponds a motion dx of the band A, and a motion dy of the band B; A drives A′ with a velocity-ratio depending on the position of the regulator R in suchwise that the coordinates of R being X, Y, then to the motion dx of A corresponds a motion $\mathrm{X}dx$ of A′; and similarly B drives B′ with a velocity-ratio depending on the position of R, in suchwise that to the motion dy of B corresponds a motion $\mathrm{Y}dy$ of B′. Hence to the motions dx, dy of the driver D there correspond the motions $\mathrm{X}dx$ and $\mathrm{Y}dy$ of the bands A′ and B′ respectively. The band A′ drives a hand or index, and the band B′ drives, in the contrary sense, a graduated dial, the hand and dial rotating independently of each other about a common centre;

* It might be convenient to have as the coordinates of R, not X, Y, but ξ, η, determinate functions of X, Y respectively.

the increased reading of the hand on the dial is thus $=Xdx+Ydy$; and supposing the original reading to be zero, and the driver D to be moved from its original position along an arbitrary path to any other position whatever, the reading on the dial will be the corresponding value of the integral $\int(Xdx+Ydy)$.

It is obvious that we might by means of a combination of two such mechanisms calculate the value of an integral $\int f(u)\,du$ along an arbitrary path of the complex variable $u,=x+iy$; in fact, writing $f(x+iy)=P+iQ$, the differential is now $(P+iQ)(dx+idy),=Pdx-Qdy+i(Qdx+Pdy)$; and we thus require the calculation of the two integrals $\int(Pdx-Qdy)$ and $\int(Qdx+Pdy)$, each of which is an integral of the above form. Taking for the path a closed curve, it would be very curious to see the machne giving a value zero, or a value different from zero, according as the path included or did not include within it a critical point; it seems to me that this discontinuity would really exhibit itself without the necessity of any change in the setting of the machine.

The ordinary modes of establishing a continuously variable velocity-ratio between two parts of a machine depend upon friction; and in particular this is the case in Prof. James Thomson's mechanical integrator: there is thus, of course, a limitation of the driving-power. It seems to me that a variable velocity-ratio, the variation of which is practically, although not strictly, continuous, might be established, by means of toothed wheels (and so with unlimited driving-power), in the following manner:—

Consider a revolving wheel A, which, by means of a link BC pivoted to a point B of the wheel A and a point C of a toothed wheel or arc D, communicates a reciprocating motion to D, the extent of this reciprocating motion depending on the distance of B from the centre of A, which distance, or say the half-throw, is assumed to be variable. Here, during a half-revolution of A, D moves in one direction, say upwards; and during the other half-revolution of A, D moves in the other direction, say downwards, the extent of these equal and opposite motions varying with the throw. Suppose, then, that D works a pinion E, the centre of which is not absolutely fixed, but is so connected with A that during the first half-revolution of A (or while D is moving upwards) E is in gear with D, and during the second half-revolution of A (or while D is moving downwards) E is out of gear with D; the continuous rotation of A will communicate an intermittent rotation to E, in such manner, nevertheless, that to each entire revolution of A, or rotation through the angle 2π, there will (the throw remaining constant) correspond a rotation of E through the angle $n\,.\,2\pi$, where the coefficient n depends upon the throw. And evidently if A be driven by a wheel A′, the angular velocity of which is $\frac{1}{\lambda}$ times that of A, then to a rotation of A′ through each angle $\frac{2\pi}{\lambda}$ there will correspond an entire revolution of A, and therefore, as before, a rotation of E through the determinate angle $n\,.\,2\pi$; hence, λ being sufficiently large, to each increment of rotation of A′ there corresponds in E an increment of rotation which is $n\lambda$ times the first-mentioned increment, viz. E moves (intermittently, or in beats as explained, and possibly also with some "loss of time" on E coming successively in gear and out of gear with D) with an angular velocity which is $=n\lambda$ times the angular velocity of A′: and thus the throw, and therefore n, being variable, the velocity-ratio $n\lambda$ is also variable.

We may imagine the wheel A as carrying upon it a piece L sliding between guides, which piece L carries the pivot B, of the link BC, and works by a rack on a toothed wheel a, concentric with A, but capable of rotating independently thereof. Then if α rotates along with A, as if forming one piece therewith, it will act as a clamp upon L, keeping the distance of B from the centre of A (that is, the half-throw) constant; whereas if α has given to it an angular velocity different from that of A, the effect will be to vary the distance in question—that is, to vary the half-throw, and consequently the velocity-ratio of A and E. And in some such manner, substituting for A and E the bands A and A′ of the foregoing description, it might be possible to establish between these bands the required variable velocity-ratio.

On the Values of a Class of Determinants *.
By J. W. L. GLAISHER, *M.A., F.R.S.*

On the Enumeration of the Primes in Burckhardt and Dase's Tables.
By J. W. L. GLAISHER, *M.A., F.R.S.*

Burckhardt's 'Tables des diviseurs' (1814–1817) give the least divisor of every number up to 3,036,000, and Dase's 'Factoren Tafeln' (1862–65) give the least divisor of every number from 6,000,000 to 9,000,000; there is thus left a gap of three millions for which there are no printed tables.

In 1871 I commenced the enumeration of the primes in the six millions over which the published tables extend. The work was performed in duplicate by two computers independently; the two enumerations were then read with one another and the discrepancies marked. All the doubtful numbers were then examined and brought into agreement; subsequently one of them was examined *de novo* with the original tables.

A short account of the enumeration, as far as it had then proceeded, together with an abstract of the results for two of the millions, was published in the British Association Report for 1872 ("On the Law of Distribution of Prime Numbers," Transactions of the Sections, pp. 19–21). I have there given tables showing the agreement of the number of primes counted with the theoretical numbers derived from the logarithm-integral formula of Tchebycheff and Hargreave for the second and ninth millions, arranged in groups of 50,000. Soon afterwards I became acquainted with the enumerations printed amongst the posthumous works of Gauss ('Werke,' t. ii. pp. 436–447, 1863), and I found many discrepancies between these results and my own. This, taken in conjunction with the great difficulty of attaining the certainty of accuracy in so troublesome an enumeration, led me to lay aside the work. In 1876, however, I recommenced the whole again, the work being carefully performed by a fresh computer, who had had no connexion with the previous enumerations. The primes in the first three millions and in the seventh million were enumerated *de novo*; but the results for the eighth and ninth millions were only examined. No errors were found in the values for the ninth million given in the 1872 paper, but several were found in the second million; they are as follows:—

Limits.	Number of Primes.	
	Value given in 1872.	True value.
1,000,000–1,050,000	3635	3636
1,350,000–1,400,000	3579	3581
1,400,000–1,450,000	3501	3502
1,600,000–1,650,000	3498	3508
1,700,000–1,750,000	3468	3467

and the total number of primes in the million is 70,433 instead of 70,420.

The number of primes in each quarter million of the six millions is shown in the following Table:—

* This paper is printed, under the title "On the Factors of a special form of Determinant," in the Quarterly Journal of Mathematics, vol. xv. pp. 347–356 (1878).

	First million.	Second million.	Third million.	Seventh million.	Eighth million.	Ninth million.
First quarter	22,045	17,971	17,150	15,967	15,851	15,712
Second quarter	19,494	17,682	16,991	15,941	15,772	15,652
Third quarter	18,700	17,455	16,922	15,950	15,768	15,746
Fourth quarter	18,260	17,325	16,822	15,941	15,767	15,650
Total	78,499	70,433	67,885	63,799	63,158	62,760

A preliminary account of the whole enumeration is published in the 'Proceedings of the Cambridge Philosophical Society,' vol. iii. pp. 17–23, 47–56 (1876 and 1877). Calling, for convenience of expression, the hundred numbers between $100n-1$ and $100\ (n+1)$ the $(n+1)$th century, then the enumeration was made by centuries—that is to say, the number of primes in each century was obtained by counting, and entered in its proper place upon a printed form. The results were then classified in tables; and those published in the Cambridge Phil. Soc. Proc. give the number of centuries, in each group of 100,000 in the six millions, which contain n primes, for n as argument. Thus, for example, the eighth column of the table for the third million shows that in the thousand centuries between 2,700,000 and 2,800,000 there is no century that contains no prime; 2 centuries, each of which contains one prime; 7 centuries, each of which contains two primes; and so on, there being 195 centuries containing six primes and one containing seventeen primes.

The following is a similar Table, in which each column has reference to a million:—

n.	Number of centuries, each of which contains n primes.					
	First million.	Second million.	Third million.	Seventh million.	Eighth million.	Ninth million.
0	0	1	1	6	4	4
1	3	16	25	28	30	34
2	29	72	97	173	171	178
3	140	257	338	482	541	570
4	372	667	775	1,049	1,066	1,078
5	801	1,253	1,408	1,603	1,691	1,742
6	1,362	1,743	1,878	1,948	1,993	1,966
7	1,765	2,032	1,997	1,916	1,754	1,788
8	1,821	1,612	1,526	1,366	1,394	1,278
9	1,554	1,182	1,036	840	787	778
10	1,058	691	558	374	360	390
11	592	311	227	156	155	143
12	316	113	98	46	40	38
13	122	39	28	10	10	11
14	32	7	6	3	2	2
15	20	3	1	0	2	0
16	8	1	0	0	0	0
17	3	0	1	0	0	0
21	1	0	0	0	0	0
26	1	0	0	0	0	0
Number of primes	78,499*	70,433	67,885	63,799	63,158	62,760

The number of primes in the first million has been obtained by Meissel ('Mathematische Annalen,' t. ii. 1870, pp. 636–642), and his results agree with my own.

* 1 and 2 are both counted as primes.

Meissel has given a list of errata in Gauss's first million; these I have confirmed; and I have given an errata list for the second and third millions.

I hope to give hereafter the results of the enumeration in more detail, adding the theoretical values for each group of 10,000 or 50,000 given by the li x formula, by Legendre's formula, and by Riemann's formula ('Mathematische Werke,' 1876, pp. 136–144).

Whenever there is no prime in a century, there must be a succession of at least 100 consecutive composite numbers; and whenever there is only one prime, there must be a succession of at least 50; but, of course, a 2-prime century or a 3-prime century need not indicate a long sequence. In order to find long successions of composite numbers I had all the instances in which there were 0, 1, 2, or 3 primes in a century looked out in the tables, and the cases noted down in which the sequence was fifty or upwards. These lists, for the six millions, were exhibited to the Meeting at Plymouth. I only here give, in the next Table, some of the longest sequences found in this manner, viz. those which exceed 110 in the first three millions, and those which exceed 120 in the other three millions.

Lower limit.	Upper limit.	Sequence.
	First million.	
370,261	370,373	111
492,113	492,227	113
	Second million.	
1,349,533	1,349,651	117
1,357,201	1,357,333	131
1,561,919	1,562,051	131
1,671,781	1,671,907	125
1,895,359	1,895,479	119
	Third million.	
2,010,733	2,010,881	147
2,637,799	2,637,911	111
2,898,239	2,898,359	119
	Seventh million.	
6,034,247	6,034,393	145
6,084,977	6,085,103	125
6,371,401	6,371,537	135
6,613,631	6,613,753	121
6,726,821	6,726,947	125
6,752,623	6,752,747	123
6,808,273	6,808,397	123
6,958,667	6,958,801	133
	Eighth million.	
7,129,877	7,130,003	125
7,230,331	7,230,479	147
7,621,259	7,621,399	139
7,743,233	7,743,371	137
	Ninth million.	
8,001,359	8,001,491	131
8,421,251	8,421,403	151
8,470,927	8,471,053	125
8,905,199	8,905,321	121
8,917,523	8,917,663	139

Thus the 111 numbers between 370,261, and 370,373 are composite, and so on, viz. the numbers in the first two columns are primes, and the numbers intermediate to the lower limit and the upper limit are all composite. It is to be noted that the above list is not complete, as the method pursued does not, of course, give all the sequences. The two long sequences in the first million seem to me very remarkable.

Lists of sequences of 79 and upwards in the first million, and of 99 and upwards for the other five millions, are given in the 'Messenger of Mathematics,' vol. vii. pp. 102–106 and 171–176 (November 1877 and March 1878), where also are to be found several other tables of a similar kind, including a *complete* list of sequences exceeding 50 between 1 and 100,000.

The following sequences that occur very early in the series of natural numbers deserve to be specially noted, viz.—

Lower limit.	Upper limit.	Sequence.
1,327	1,361	33
15,683	15,727	43
19,609	19,661	51
31,397	31,469	71

The next sequence, which is so large as 33, after that between 1327 and 1361, occurs between 8467 and 8501, where there is another sequence of 33.

It is known that any sequence of composite numbers, however long, must occur at a certain definite place in the series of natural numbers; for p and q being any two consecutive primes, the $q-2$ numbers immediately following $(2.3.5.7.11\ldots p)+1$ must be all composite; but the number $(2.3.5.7\ldots 109)+1$ (immediately following which there must be 111 composite numbers) contains 45 figures, whereas a sequence of 111 actually occurs at 370,261; so that long sequences are met with far earlier than this theorem requires them to happen.

On the Variation of the Modulus in Elliptic Integrals. *By* Dr. D. Bierens de Haan.

1. The following results can be easily verified:—

$$\frac{d}{d(p^2)}\mathrm{E}(p,x)=\frac{1}{2p^2}[\mathrm{E}(p,x)-\mathrm{F}(p,x)],$$

$$\frac{d}{d(p^2)}\mathrm{F}(p,x)=\frac{1}{2p^2(1-p^2)}\left[-\frac{1+(1-p^2)\sin^2 x}{\sqrt{(1-p^2\sin^2 x)}}p^2\sin x\cos x-(1-p^2)\mathrm{F}(p,x)+\mathrm{E}(p,x)\right];$$

these give the symbolic equations

$$\left[1-2p^2\frac{d}{d(p^2)}\right]\mathrm{E}(p,x)=\mathrm{F}(p,x),$$

$$\left[1+2p^2\frac{d}{d(p^2)}\right]\mathrm{F}(p,x)=\frac{1}{1-p^2}\left[\mathrm{E}(p,x)-\frac{1+(1-p^2)\sin^2 x}{\sqrt{(1-p^2\sin^2 x)}}p^2\sin x\cos x\right].$$

Hence, denoting the operation

$$(1-p^2)\left[1+2p^2\frac{d}{d(p^2)}\right]$$

by P, and

$$\left[1-2p^2\frac{d}{d(p^2)}\right]$$

by Q and by $\phi(x)$, a function of $\sqrt{(1-p^2\sin^2 x)}$,

$$[QPQ\ldots QPQ]\,E(p, x)=F(p, x)+\sin x\cos x\,\phi(x),$$
$$[PQP\ldots PQP]\,F(p, x)=E(p, x)+\sin x\cos x\,\phi(x),$$
$$[PQP\ldots QPQ]\,E(p, x)=E(p, x)+\sin x\cos x\,\phi(x),$$
$$[QPQ\ldots PQP]\,F(p, x)=F(p, x)+\sin x\cos x\,\phi(x).$$

Then, again,

$$\left[4p^2(1-p^2)\frac{d^2}{d(p^2)^2}+4(1-p^2)\frac{d}{d(p^2)}+1\right]E(p, x)=\frac{1+(1-p^2)\sin^2 x}{\sqrt{(1-p^2\sin^2 x)}},$$

$$\left[4p^2(1-p^2)\frac{d^2}{d(p^2)^2}+4(1-2p^2)\frac{d}{d(p^2)}-1\right]F(p, x)$$
$$=\frac{\sin x\cos x}{\sqrt{(1-p^2\sin^2 x\cos^2 x)}}[\sin^2 x-(1-p^2\sin^2 x)+2(1-p^2\sin^2 x)^2];$$

and generally

$$\left[4p^2(1-p^2)\frac{d^n}{d(p^2)^n}+4\{(n-1)-(2n-3)p^2\}\frac{d^{n-1}}{d(p^2)^{n-1}}+\{1-4(n-2)^2\}\frac{d^{n-2}}{d(p^2)^{n-2}}\right]E(p, x)$$
$$=-\frac{\sin^{2n-3}x\cos x}{(1-p^2\sin^2 x)^{n-\frac{3}{2}}}\,\frac{1^{n-3|2}}{2^{n-2}}\{1-(2n-5+p^2)\sin^2 x\},$$

$$\left[4p^2(1-p^2)\frac{d^n}{d(p^2)^n}+4(n-1)(1-2p^2)\frac{d^{n-1}}{d(p^2)^{n-1}}-\{4(n-1)(n-2)+1\}\frac{d^{n-2}}{d(p^2)^{n-2}}\right]F(p, x)$$
$$=-\frac{\sin^{2n-3}x\cos x}{(1-p^2\sin^2 x)^{n-\frac{3}{2}}}\,\frac{1^{n-3|2}}{2^{n-2}}[(2n-3)+\{(2n-3)(2n-5)-(2n-1)p^2\}\sin^2 x$$
$$+2p^4\sin^4 x].$$

If the modulus p is imaginary $=pi$, then

$$\int_0^x dx\sqrt{(1+p^2\sin^2 x)}=\sqrt{(1+p^2)}\left\{E\left(\frac{p}{\sqrt{(1+p^2)}}\right)-E\left(\frac{p}{\sqrt{(1+p^2)}},\ \tfrac{1}{2}\pi-x\right)\right\}$$
$$=\sqrt{(1+p^2)}\,E_1=E_2,$$

$$\int_0^x\frac{dx}{\sqrt{(1+p^2\sin^2 x)}}=\frac{1}{\sqrt{(1+p^2)}}\left\{F\left(\frac{p}{\sqrt{(1+p^2)}}\right)-F\left(\frac{p}{\sqrt{(1+p^2)}},\ \tfrac{1}{2}\pi-x\right)\right\}$$
$$=\frac{1}{\sqrt{(1+p^2)}}F_1=F_2,$$

E_1, E_2, F_1, F_2 being notations introduced for the sake of convenience. Then

$$\frac{d}{d(p^2)}E_2=\frac{1}{2p^2}(E_2-F_2),$$

$$\frac{d}{d(p^2)}F^2=-\frac{1}{2p^2(1+p^2)}\left[-\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}p^2\sin x\cos x+(1+p^2)F_2-E_2\right],$$

giving the symbolic equations

$$\left[1-2p^2\frac{d}{d(p^2)}\right]E_2=F_2,$$

$$\left[1+2p^2\frac{d}{d(p^2)}\right]F_2=\frac{1}{1+p^2}\left[\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}p^2\sin x\cos x+E_2\right].$$

Again,

$$\frac{d}{d(p^2)}E_1=\frac{1}{2p^2(1+p^2)}\{E_1-F_1\},$$

$$\frac{d}{d(p^2)}F_1=\frac{1}{2p^2(1+p^2)}\left[\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}p^2\sin x\cos x\sqrt{(1+p^2)}+(1+p^2)E_1-F_1\right];$$

whence

$$\left[1-2p^2(1+p^2)\frac{d}{d(p^2)}\right]E_1=F_1,$$

$$\left[1+2p^2(1+p^2)\frac{d}{d(p^2)}\right]F_1=\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}p^2\sin x\cos x\sqrt{(1+p^2)}+(1+p^2)E_1.$$

Thence, denoting the operation

$$(1+p^2)\left[1+2p^2\frac{d}{d(p^2)}\right] \text{ by } P_1,$$

$$\left[1-2p^2(1+p^2)\frac{d}{d(p^2)}\right] \text{ by } R,$$

$$\frac{1}{1+p^2}\left[1+2p^2(1+p^2)\frac{d}{d(p^2)}\right] \text{ by } S,$$

$$[P_1QP_1\ldots QP_1Q]E_2=E_2+\sin x\cos x\,\phi(x),$$

$$[QP_1Q\ldots PQP_1]F_2=F_2+\sin x\cos x\,\phi(x),$$

$$[QP_1Q\ldots QP_1Q]E_2=F_2+\sin x\cos x\,\phi(x),$$

$$[P_1QP_1\ldots P_1QP_1]F_2=E_2+\sin x\cos x\,\phi(x);$$

and in the same way

$$[SRS\ldots RSR]E_1=E_1+\sin x\cos x\,\phi(x),$$

$$[RSR\ldots SRS]F_1=F_1+\sin x\cos x\,\phi(x),$$

$$[RSR\ldots RSR]E_1=F_1+\sin x\cos x\,\phi(x),$$

$$[SRS\ldots SRS]F_1=E_1+\sin x\cos x\,\phi(x).$$

Then, again,

$$\left[4p^2(1+p^2)\frac{d^2}{d(p^2)^2}+4(1+p^2)\frac{d^2}{d(p^2)}-1\right]E_2=-\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}\sin x\cos x,$$

$$\left[4p^2(1+p^2)\frac{d^2}{d(p^2)^2}+4(1+2p^2)\frac{d}{d(p^2)}+1\right]F_2$$

$$=\frac{\sin x\cos x}{\sqrt{(1+p^2\sin^2 x)}}[-1+(1-p^2)(1+p^2\sin^2 x)+2p^2(1+p^2\sin^2 x)^2],$$

and

$$\left[4p^2(1+p^2)^2\frac{d^2}{d(p^2)^2}+4(1+p^2)(1+2p^2)\frac{d}{d(p^2)}+1\right]E_1$$

$$=-\frac{1+(1+p^2)\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}\sin x\cos x\sqrt{(1+p^2)},$$

$$\left[4p^2(1+p^2)\frac{d^2}{d(p^2)^2}+4p^2(1+p^2)\frac{d}{d(p^2)}+1\right]F_1$$

$$=p^2\sin x\cos x\sqrt{(1+p^2)}\left[\frac{\sin^2 x}{\sqrt{(1+p^2\sin^2 x)}}-\frac{1}{1+p^2\sin^2 x}+2\sqrt{(1+p^2\sin^2 x)}\right].$$

Thus, generally,

$$\left[4p^2(1+p^2)\frac{d^n}{d(p^2)^n}+4\{(n-1)+(2n-3)p^2\}\frac{d^{n-1}}{d(p^2)^{n-1}}+\{4(n-2)^2-1\}\frac{d^{n-1}}{d(p^2)^{n-1}}\right]E_2$$

$$=\frac{(-1)^n\sin^{2n-1}x\cos x}{(1+p^2\sin^2 x)^{n-\frac{3}{2}}}\;\frac{1^{n-3|2}}{2^{n-2}}[1-(2n-5-p^2)\sin^2 x],$$

$$\left[4p^2(1+p^2)\frac{d^n}{d(p^2)^n}+(n-1)4(1+2p^2)\frac{d^{n-1}}{d(p^2)^{n-1}}+\{4(n-1)(n-2)+1\}\frac{d^{n-2}}{d(p^2)^{n-2}}\right]F_2$$

$$=\frac{(-1)^{n-1}\sin^{2n-3}x\cos x}{(1+p^2\sin^2 n)^{n-\frac{1}{2}}}\;\frac{1^{n-3|2}}{2^{n-3}}[(2n-3)+\{(2n-3)(2n-5)+(2n-1)p^2\}\sin^2 x$$

$$+2p^4\sin^4 x],$$

and

$$\left[4p^2(1+p^2)^2\frac{d^n}{d(p^2)^n}+4(1+p^2)\{(2n-3)p^2+(n-1)(1+p^2)\}\frac{d^{n-1}}{d(p^2)^{n-1}}\right.$$

$$\left.+\{1+4(n-2)[(n-2)p^2+(2n-3)(1+p^2)]\}\frac{d^{n-2}}{d(p^2)^{n-2}}\right]E_1$$

$$=(-1)^{n-1}\Sigma_{h=0}^{h=n-2}\binom{n-2}{h}\frac{1^{h-1|2}\,1^{n-h-3|2}}{2^{n-2}(1+p^2)^{n-h-\frac{3}{2}}}\;\frac{1+(1-2h+p^2)\sin^2 x}{(1+p^2\sin^2 x)^{h+\frac{3}{2}}}\sin^{2h+1}x\cos x,$$

$$\left[4p^2(1+p^2)\frac{d^n}{d(p^2)^n}+4p^2\{(2n-3)(1+p^2)+(n-2)p^2\}\frac{d^{n-1}}{d(p^2)^{n-1}}\right.$$

$$\left.+\{1+4(n-2)[(n-2)(1+p^2)+(2n-5)p^2]\}\frac{d^{n-2}}{d(p^2)^{n-2}}\right]F_1$$

$$=(-1)^{n-1}\Sigma_{h=0}^{h=n-2}\binom{n-2}{h}\frac{1^{n-h-3|2}\,1^{h-1|2}\sin^{2n-2h-3}x\cos x}{2^{n-2}(1+p^2)^{h-\frac{3}{2}}(1+p^2\sin^2 x)^{n-h-\frac{1}{2}}}\{2+(2p-5)p^2\}[(2n-2k-3)$$

$$-\{(2n-2h-3)(2n-2h-5)+(2n-2h-1)p^2\}\sin^2 x+2p^4\sin^4 x].$$

3. If the integrals E_1, F_1, E_2, F_2 are taken between the limits 0 and $\frac{1}{2}\pi$, so that E and F become complete elliptic integrals, it is easily seen that the formulæ lose the terms $\sin x\cos x\,\phi(x)$, as the factor $\sin x\cos x$ vanishes at each limit, and the other factor is never infinite.

On Cubics of the Third Class with Three Single Foci.

By HENRY M. JEFFERY, *M.A.*

1. There are four cases for consideration, according as the number of foci at infinity is three, two, one, or none.

If three foci are real and at an infinite distance, the line at infinity ($\xi=\eta=0$) is an acubitangent.

Let the equation be written with polar tangential coordinates

$$p=a\cos(\theta+a)\cos(\theta+\beta)\cos(\theta+\gamma).$$

The position of the cusps is thus determined:—Since $\frac{d^2p}{d\theta^2}=0$,

$$\tfrac{3}{2}=\tan(\theta+\beta)\tan(\theta+\gamma)+\tan(\theta+\gamma)\tan(\theta+a)+\tan(\theta+a)\tan(\theta+\beta).$$

If the cusps form an equilateral triangle, the lines joining them with the satellite-point pass through the foci.

2. If two foci are at infinity, the line at infinity is a bitangent.

The cubics of this division may be thus expressed by oblique Boothian coordinates,

$$\lambda\xi\eta+(x\xi+y\eta-1)(\xi^2+\eta^2-2\xi\eta\cos\omega)=0.$$

If $$\lambda xy+x^2+y^2+2xy\cos\omega)=0,$$

the cubic is resolved into a point and a parabola,

$$(x\xi+y\eta)\left(\frac{\xi}{x}+\frac{\eta}{y}-\xi^2-\eta^2+2\xi\eta\cos\omega\right)=0.$$

If $\lambda=4\sin^2\frac{\omega}{2}$, or $-4\cos^2\frac{\omega}{2}$, the cubic is inflexional, and acubitangential or veribitangential, according as λ lies within or beyond these limits.

The exhibited figures were constructed for rectangular coordinates.

3. Let three single foci be collinear, and one of them at infinity.

Let the Boothian equation denote the group

$$\lambda\xi(1-b^2\xi^2)+(x\xi+y\eta-1)(\xi^2+\eta^2)=0,$$

so that the origin bisects the distance between the foci.

There are four critical lines, such that one of the coordinates is determined from a quartic

$$3b^4\xi^4-8b^2x\xi^3+(2b^2+4x^2+4y^2)\xi^2-1=0.$$

Write r^2 for x^2+y^2, and $3s^2$ for $2r^2+b^2$; the invariants are found to be

$$S=3s^4-3b^4;\ T=-s^6-3b^4s^2+4b^4x^2.$$

The condition that there are two coincident values of ξ, viz. $T^2=\left(\frac{S}{3}\right)^3$, determines the locus of the satellite-point (x, y), when the cubic is inflexional.

Its equation, when expanded, is an octavic,

$$r^6(4x^2-3r^2)-6r^4b^2(r^2-x^2)+3b^4(-3r^4+10r^2x^2-9x^4)+2b^6(7x^2-3r^2)-3b^8=0.$$

It denotes a unipartite curve whose asymptotes intersect at an angle 60°. For such a position of the satellite on this locus there are three critical values of the parameter, which yield inflexional, acubitangential, and veribitangential cubics. If the satellite lies within the bounding curve, there are four critical values; if beyond, two are real, and two imaginary.

4. Let one focus be at infinity, and the quadrantal pole of the line joining the other two.

Let the equation to class-cubics of this system be written,

$$\lambda\eta(1-b^2\xi^2)+(x\xi+y\eta-1)(\xi^2+\eta^2)=0.$$

There are five critical values, as may be proved by partial differentiation. The following quintic determines the critical values of ξ:—

$$x-(4x^2+4y^2+b^2)\xi+x(4x^2+4y^2+6b^2)\xi^2-2b^2(4x^2+b^2)\xi^3+5b^4x\xi^4-b^6\xi^5=0.$$

The discriminant of this quintic determines the locus of the satellite, when the cubic is inflexional.

$$x^4(x^2+y^2)^3(x^2-27y^2)-6b^2x^2y^2(x^2+y^2)^2(2x^2+9y^2)+3b^4y^4(16x^4-56x^2y^2-9y^4)$$
$$-64b^6y^6=0.$$

(In this equation x^2 is written to denote x^2-b^2.)

The curve is trinodal at the foci, and unipartite, with a pair of asymptotes through the origin, and the (y) axis for a third asymptote. If the satellite lie on either of the exterior loops of the bounding curve, there are four critic values, one of them inflexional; if the satellite fall within, five; if without, three critic values: if it lie on an interior loop, two critic values, one of them inflexional; if within, only one critic value, viz. the veribitangential.

For positions of the satellite along the (x) axis, the preceding quintic becomes

$$(b^2\xi-x)(b^2\xi^2-2x\xi+1)^2=0.$$

The first value resolves the cubic into a point and a parabola; the other pair of coincident values yields two bitangential and not inflexional cubics—four, if the satellite lie beyond the foci.

5. The case in which the focus at infinity has neither of the preceding positions, and all the cases where the foci are finite, remain for consideration.

On a Cubic Curve referred to a Tetrad of corresponding Points.

By HENRY M. JEFFERY, *M.A.*

1. A non-singular cubic consists of an infinite number of such tetrads; and if any one be drawn, the remaining tetrads may be obtained by transversals drawn from the several points of the cubic. Each tetrad ABCD yields three pairs of dyads, AB, CD; AC, BD; AD, BC; and each pair of dyad lines touches a separate Cayleyan class-cubic.

Let transversals through P on the cubic pass through A, B, C, D, and intersect it again in A′, B′, C′, D′; then, as has been stated, these points constitute a new tetrad; and if A′, B′, C′, D′ be joined in pairs with A, B, C, D, their points of intersection are three, and with P constitute a new tetrad.

These characteristic theorems, which are not new, may be simply obtained by the following proofs. It will also appear that the locus of the intersections of pairs of tangents drawn at the points where transversals through a fixed point on the cubic intersect it is a trinodal quartic, which passes through the first tetrad of corresponding points, the three other corresponding points of the second tetrad of which the fixed point is one, and through the coresidual or its own tangential point. The loci of the several points in which these concurrent transversals are divided—(1) Arithmetically, (2) Geometrically, (3) Harmonically—are (1) a crunodal cruciform curve (Newton's Species 7 or 8), whose asymptotes, three or one, are parallel to those of the primitive cubic, and at whose node the rectangular tangents are parallel to the asymptotes of its pole conic; (2) a central cubic, with asymptotes also parallel to those of the primitive cubic (Newton's Species 27); and (3) the pole conic, as is well known, a rectangular hyperbola.

2. If a system of conics be described about four common points, and if through a fixed point a series of transversals be drawn, the locus of the foci of the points in involution is a cubic.	2. If a system of conics be inscribed in four straight lines, and if from each point of a fixed line pairs of tangents be drawn to the conics, the envelop of the focal lines of the system in involution is a class-cubic.

This theorem (which is due to Prof. Cremona) is equally applicable to Plane and Spherical Geometry. Let the triangle of reference, A B C, be formed by the diagonal points of the quadrilateral constituted by the vertices; their coordinates are $\pm x$, $\pm y$, $\pm z$; and if the transversals concur in (f, g, h), the locus of the foci in involution will be denoted by the cubic,

$$\frac{x^2}{\alpha}(\beta h-\gamma g)+\frac{y^2}{\beta}(\gamma f-\alpha h)+\frac{z^2}{\gamma}(\alpha g-\beta f)=0.$$

It will be simpler, and not less general, to take the centre of the inscribed circle (1, 1, 1) as the origin of transversals; the cubic then becomes

$$\frac{x^2}{\alpha}(\beta-\gamma)+\frac{y^2}{\beta}(\gamma-\alpha)+\frac{z^2}{\gamma}(\alpha-\beta)=0.$$

3. The vertices of the quadrilateral ($\pm x$, $\pm y$, $\pm z$) constitute the first tetrad of corresponding points, of which the centre (1, 1, 1) is their common tangential point. A second tetrad of corresponding points is formed by the diagonal points of the quadrilateral A, B, C, and D, the centre (1, 1, 1); their common tangential point (x^2, y^2, z^2) is the conjugate pole of the first tangential (1, 1, 1) with respect to the system of conics (in § 2).

4. A transversal P D D′ intersects this cubic; the coordinates of P D D′ are thus connected.

Let (f, g, h), (1, 1, 1), (λF, λG, λH) denote them; they are thus related,

$$\frac{Ff}{x^2}=\frac{Gg}{y^2}=\frac{Hh}{z^2},$$

$$F+f=G+g=H+h=2r.$$

By the first property, the two points are conjugate poles with respect to the system of conics through the basis-points ($\pm x$, $\pm y$, $\pm z$).

5. Transversals through a point in the cubic (P) pass through the points of the second tetrad, A, B, C, D; the coordinates of the third points of intersections A′, B′, C′, D′ are

$$F, g, h;\ f, G, h;\ f, g, H;\ F, G, H.$$

6. If these four new corresponding points be joined in pairs with the four former points, the points of intersection are three, and correspond with P.

Thus

A′D and AD′, B′C and BC′ intersect in (Q) (f, G, H),

B′D and BD′, AC′ and A′C ,, in (R) (F, g, H),

C′D and CD′, AB′ and A′B ,, in (S) (F, G, h).

7. For the tangent to the cubic at a point (f, g, h),

$$\Sigma\alpha\left\{\frac{x^2}{f^2}(g-h)-\frac{z^2}{h}+\frac{y^2}{g}\right\}=0.$$

By the aid of the relations established in § 4, this becomes

$$\frac{\alpha}{f}(g-h)(f-F)+\frac{\beta}{g}(h-f)(g-G)+\frac{\gamma}{h}(f-g)(h-H)=0.$$

So the equation to the tangent at A′(F, g, h) is

$$\frac{\alpha}{F}(g-h)(F-f)+\frac{\beta}{g}(h-F)(g-G)+\frac{\gamma}{h}(F-g)(h-H)=0.$$

This and the tangents at B′, C′, D′ intersect in the common tangential point

$$\frac{\alpha(f-F)}{fF\{f(F+f)-HG-hg\}}=\frac{\beta(g-G)}{gG\{g(G+g)-FH-fh\}}=\frac{\gamma(h-H)}{hH\{h(H+h)-FG-fg\}}.$$

In like manner the tangents at P, Q, R, S are concurrent in

$$\frac{\alpha(f-F)}{fF\{f(F+f)-gH-Gh\}}=\frac{\beta(g-G)}{gG\{g(G+g)-Fh-fH\}}=\frac{\gamma(h-H)}{hH\{h(H+h)-fG-Fg\}}.$$

8. The equations to the tangents at P, D′, the extremities of a transversal through D, are

$$\Sigma\frac{a}{f}(g-h)(f-\mathrm{F})=0, \qquad \Sigma\frac{a}{\mathrm{F}}(g-h)(f-\mathrm{F})=0.$$

These intersect in the point

$$\frac{a(f-\mathrm{F})}{f\mathrm{F}}=\frac{\beta(g-\mathrm{G})}{g\mathrm{G}}=\frac{\gamma(h-\mathrm{H})}{h\mathrm{H}}.$$

Its locus is the trinodal quartic,

$$\frac{x^4}{a^2}(y^2-z^2)+\frac{y^4}{\beta^2}(z^2-x^2)+\frac{z^4}{y^2}(x^2-y^2)=0.$$

9. To investigate the three Cayleyan class-cubics (of § 1).
The equation to the chord A′B′ is

$$ah(g-\mathrm{G})+\beta h(f-\mathrm{F})+\gamma(\mathrm{FG}-fg)=0.$$

Let $\tau=f+\mathrm{F}=g+\mathrm{G}=h+\mathrm{H}$: the tangential coordinates of A′B′ are thus related,

$$\frac{p}{h}=2g-\tau;\quad \frac{q}{h}=2f-\tau;\quad \frac{2r}{\tau}=2\tau-2(f+g)=-\frac{p+q}{h}.$$

Now, since the equation to the cubic (of § 2) may be written as in § 4,

$$\frac{f(\tau-f)}{x^2}=\frac{g(\tau-g)}{y^2}=\frac{h(\tau-h)}{z^2},$$

$$\frac{1}{4x^2}\left(\tau^2-\frac{q^2}{h^2}\right)=\frac{1}{4y^2}\left(\tau^2-\frac{p^2}{h^2}\right)=-\frac{\tau^2}{4r^2z^2}(p+q)(p+q+2r)=\frac{(p^2-q^2)\tau^2}{4(p^2x^2-q^2y^2)}.$$

Hence the equation to one Cayleyan is

$$(p+q+2r)(p^2x^2-q^2y^2)+r^2(p-q)z^2=0,$$

where p, q, r represent ap, bq, cr; a, b, c, being sides of A B C.
The chord C′D′ is also a tangent to this Cayleyan.
Similarly the equations to the other two Cayleyans may be written by symmetry.
10. The loci of the several points in which concurrent transversals are divided Arithmetically, Geometrically, and Harmonically, form a system of cubics syzygetically connected with the primitive; and all pass through the tetrad of which the point of concurrence is their tangential point.
If $u_3=0$ be the cubic, and u_2 its pole conic, the equations to the loci are *in plano*

$$2u_3-ru_2=0;\ u_3-ru_2=0;\ u_2=0.$$

In spherics the equations must be modified:—

$$2u_3(6\mathrm{V})^2-ru_2\Sigma a(aa+b\beta\cos c+c\gamma\cos b)=0,$$

$$u_3(6\mathrm{V})^2-ru_2\Sigma a(aa+b\beta\cos c+c\gamma\cos b)=0.$$

$$u_2=0.$$

The factor of u_2 denotes the quadrantal polar of (D) (r, r, r) the centre of the inscribed circle.
These results might be anticipated by projecting the plane cubic and its associated cubics on the sphere, D being the pole of gnomonic projection.
[This memoir has been published *in extenso* with additions, since the meeting, in the 'Quarterly Journal for Mathematics,' vol. xv. pp. 198–223.]

On a Method of Deducing the Sum of the Reciprocals of the First 2^pn *Numbers from the Sum of the Reciprocals of the First* n *Numbers. By* F. G. LANDON, *M.A.*

Astronomy.

On some Recent Advances in the Lunar Theory.
By Prof. J. C. Adams, *F.R.S.*

On a new Method of Calculating the Absolute Duration of Geological Periods.
By Prof. Haughton, *F.R.S.*

The Solar Eclipse of Agathocles considered, in reply to Professor Newcomb's criticism on the Coefficient of Acceleration of the Moon's Mean Motion. By Prof. Haughton, *F.R.S.*

On the Tendency of a System of Heavenly Bodies to Centralize and Applanize, if subject to Resistance in their Motions. By F. G. Landon, *M.A.*

On a Meteor which passed over Bhawnpore, in India, in October 1873.
By Major G. N. Money.

While staying at the capital of the independent state of Bhawnpore, on the Sutlej, the author was aroused from sleep early one morning by a tremendous sound resembling the passage of several express trains, while the room was brightly illuminated, and this sound was followed by violent explosions which shook the building. He at first supposed an earthquake had occurred. After breakfast he heard that a shower of stones had fallen eighteen miles off to the north-east, and later in the day some pieces were brought in. The largest was an irregular mass, 3 ft. long by 1 ft. thick, still hot, blackened outside as by the action of fire, of a dark grey colour inside, and very heavy. The natives said there were many more—one as large as a bullock-cart. A second shower fell about thirty miles beyond the first. There could be no deception, as there were no other stones within a hundred miles of Bhawnpore, the soil being purely alluvial or sandy. The meteor, it appeared, was seen by a European who was superintending the erection of a palace for the Nawab. He described it as a huge ball of fire, as big as twenty moons, which passed with a roaring sound directly over his head in a north-easterly direction. It lit up the whole sky, the light being perfectly dazzling, and left behind it a flaming track of red, green, and yellow. Before passing out of sight two explosions in quick succession took place, at each of which a shower of sparks seemed to fall, but no alteration was apparent in the size or shape of the meteor itself. No attempt was made by the Government to collect information about this remarkable meteor. To give some idea of its magnitude it was stated that it was seen and heard at points quite 400 miles from Bhawnpore.

Light.

On a Method of showing the Sun's Rotation by Spectrum Photography.
By Captain Abney, *F.R.S.*

On a new Unit of Light for Photometry. By A. Vernon Harcourt, *F.R.S.*

On the Lower Limit of the Prismatic Spectrum. By Lord RAYLEIGH.

On a Binocular Microscope for High Powers. By J. TRAILL TAYLOR.

Some new Optical Illusions. By SILVANUS P. THOMPSON, *B.Sc., B.A.*

The relative motions of an object and a spectator may give rise to illusions in which motions differing in direction or character may be apparently produced. Some illusions of this class were brought forward by the late Sir D. Brewster in the 'Transactions' of the Brit. Assoc. for 1845, 1848, and 1861. The author has observed several other cases of illusory motion apparently due to a retinal compensation of the disturbance produced by the motion of images across the retina. Several of the illusions cited were observed in railway travelling. Thus, if from a rapid railway train objects from which the train is receding be watched, they seem to shrink as they are left behind, their images contracting and moving from the edges of the retina towards its centre. If after watching this motion for some time the gaze be transferred to an object at a constant distance from the eye, it seems to be actually expanding and approaching.

The author also drew attention to the following illusion:—A series of concentric circles of black and white are drawn upon a card. This is held firmly between the the thumb and finger, while a circular shaking motion is imparted to it by a movement of wrist and elbow, the circles appearing to rotate upon the card. It was held that the various effects of "compensation" to the movement of retinal images could be explained by supposing them to set up a secondary wave of nervous disturbance propagated in an opposite direction to that of the primary movement of the images.

On the Relative Apparent Brightness of Objects in Binocular and Monocular Vision. By SILVANUS P. THOMPSON, *B.Sc., B.A.*

It is a common idea that objects appear brighter when seen with the two eyes than with one. There appear, however, to be exceptions to this statement. The following is a method of submitting the question to photometric measurement. The comparison-photometer employed consists of a cardboard screen having an aperture divided into two equal portions. One half is covered with tissue-paper, and illuminated directly from behind. Behind the other half is set, at the polarizing angle, a mirror of black glass. Light from a second lamp falls upon a screen of tissue-paper, whose light is then reflected in the mirror. Thus the two halves of the aperture may be illuminated equally, but with light in one case wholly unpolarized, in the other wholly polarized. Let two Nicol prisms be now taken, having their principal sections placed parallel and perpendicular respectively to the plane of polarization of the mirror, and let one Nicol be placed in front of each eye. One eye only will receive the whole of the polarized light, while the unpolarized light will be equally distributed, half to each eye. The total amount of light received upon the retinal surface will be the same from each half of the aperture; but their apparent illuminations will be unequal, that of the polarized light appearing the greater. By comparing the distances at which the lamps must be placed it appears that light is more powerful in producing an effect when concentrated upon one eye than when equally distributed to the two, though according to what law experiments are not yet sufficiently numerous or exact to determine; but, on the other hand, the light so concentrated on one eye does not produce the sensation of twice as much illumination as the half of the light viewed by both eyes at once.

Electricity.

On the Viscosity of Dielectrics. By W. E. Ayrton *and* J. Perry.

On the Contact Theory of Voltaic Action. By W. E. Ayrton *and* J. Perry.

On Magnetic Induction as affecting Observations of the Intensity of the Horizontal Component of the Earth's Magnetic Force. By Charles Chambers, *F.R.S., Superintendent of the Colaba Observatory, Bombay.*

All our experiments for the measurement of the earth's magnetic force are necessarily made in the field of that force, consequently the magnets used in observations of deflection and vibration are subject to the inducing action of that force; and it is the universal practice of magnetic observatories, sanctioned by the most eminent writers on terrestrial magnetism, to apply corrections on account of induction both to the deflection and vibration observations. The object of this communication is to advance theoretical reasons—supported by experimental evidence—against the propriety of the particular correction applied to the vibration observation. This correction is based on the assumption that the vibration-magnet is susceptible of induction longitudinally but not transversely, or not so sensibly; and the assumption probably rests on what the writer regards as a false analogy between a permanent magnet and an induced magnet. The former, when removed from the influence of a strong magnetizing action, remains a magnet by virtue of its own internal forces, whilst the latter is a magnet by virtue of external forces alone; it does not therefore follow that because the power of a permanent magnet—measured by its magnetic moment—cannot be made by the same means nearly as great transversely as longitudinally, therefore the same may be said of an induced magnet. Indeed, in his treatment of the subject of the deviations of the compass, Sir George Airy gives to each elemental portion of a ship's iron as great a susceptibility to induction in one direction as in another; and in the more elaborate treatment of the same subject, in which Poisson's equations are taken as expressing the fundamental conception of the theory, terms representing transverse induction are still retained, as of comparable magnitude, in presence of others representing longitudinal induction.

Applying the Astronomer Royal's theory to the particular case of the vibration magnet, its induced magnetism becomes an assemblage of elementary magnets whose magnetic axes are all parallel to the magnetic meridian, and which, since they sensibly retain their parallelism to the meridian during the oscillation of the magnet, give rise to no moment of restitution; hence, according to this view, no correction would be required. According to Poisson's theory the amount of the correction is matter for experimental inquiry, and cannot be safely determined on *à priori* ground. It may be objected, however, that the swinging of a ship being a slow motion compared with the oscillation of a magnet, the theory of the deviations of the compass must be modified in its application to the case in question; and this is no doubt a correct view; for the theory regards the inductive action as being, at every moment considered, sensibly carried to its limit of effectiveness; whilst it is not only conceivable, but doubtless the fact, that where, as with the oscillating magnet, the motion is reversed every few seconds, the transverse inductive action only partially approaches its limit. On this account we should be prepared to expect, then, that even if the transverse induction were as great as the longitudinal, when time for full development of the induction was allowed, it would be in some degree in defect in the case of the vibrating magnet.

In the years 1873 and 1874, long before these views on the subject of induction first occurred to the writer, he had had made in Bombay a useful comparison of two Kew unifilar magnetometers, by means of practically contemporaneous observations. The result was to show a persistent difference in the values of the horizontal force yielded by the two instruments, far exceeding any probable errors of observation, and, after a careful examination of each single observational quantity, and of each constant entering into the computations, the writer came to the conclusion that no error of the magnitude of that in question could have its source anywhere but in connexion with the induction corrections. The values obtained for the horizontal force were (in British units of force):—

With magnetometer No. 17.	With magnetometer No. 23.
8·0701	8·0841
8·0698	8·0823
8·0762	8·0916
8·0764	8·0945
8·0694	8·0965
8·0707	8·0904
8·0757	8·0844
8·0756	8·0821
Mean = 8·0730	8·0902
	8·0858
	8·0905
	8·0880
	Mean = 8·0884

No. 23 showing an excess over No. 17 of ·0154 British units of force, or of ·0019 of the whole horizontal force.

We observe that the greatest value given by No. 17 is less than the least value given by No. 23, and infer that the difference between the two means cannot be attributed to probable error of observation, the value of which for a single determination (about ·001 of the whole force) is, moreover, much smaller.

If we now remove the corrections applied for induction to the vibration observations, the mean value yielded by No. 17 becomes ·0004 of the whole force, greater than the mean yielded by No. 23. It thus appears that a small correction, such as we have already seen reason to expect, is required for the vibration observation, but (on an average for the two instruments employed) only of about one sixth of the value of that which it is the custom of magneticians to apply; and as this small quantity scarcely exceeds the probable error of the mean determination of the horizontal force, it is yet premature to attribute it to any definite cause. Whilst, however, the experiments afford no sufficient reason for applying this small correction, they speak very distinctly in favour of no induction correction at all for the vibration observation as against the common practice.

To show that the error that we have been discussing is not of that minute order that is usually disregarded, we may mention that it would amount, in the case of the unifilar magnetometer used at the Kew Observatory, to about eight times the probable error of an observation.

On the Mode of stating some Elementary Facts in Electricity. By Prof. G. CAREY FOSTER, *F.R.S.*

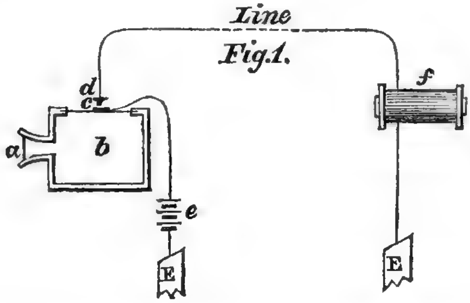
On the Telephone. By W. H. PREECE, *Memb. Inst. C.E., &c.*

In the following paper, instruments employed in the transmission of musical sounds are called tone telephones, and those employed in the transmission of the human voice, articulating telephones.

In the year 1837, Page, an American physicist, discovered that the rapid magnetization and demagnetization of iron bars produced what he called "galvanic music." Musical notes depend upon the number of vibrations imparted to the air per second. If these exceed sixteen we obtain distinct notes. Hence, if the currents passing through an electromagnet be made and broken more than sixteen times per second, we obtain "galvanic music" by the vibrations which the iron bar imparts to the air. The iron bar itself imparts these vibrations by its change of form each time it is magnetized or demagnetized.

De la Rive, of Geneva, in 1843, increased these musical effects by operating on long stretched wires which passed through open bobbins of insulated wire.

Philip Reiss, of Friedrichsdorf, in 1861, produced the first telephone which reproduced musical sounds at a distance. He utilized the discovery of Page by causing a vibrating diaphragm to rapidly make and break a galvanic circuit. The principal of his apparatus is shown in Fig. 1 annexed, in which the diagram (*b*) is a hollow wooden box into which the operator sings through the mouthpiece (*a*).



The sound of his voice throws the diaphragm (*c*) into rapid vibration, so as to make and break contact at the platinum points (*d*) at each vibration. This interrupts the current flowing from the battery (*e*) as often as the diaphragm vibrates, and therefore magnetizes and demagnetizes the electromagnet as often. Hence whatever note be sounded into the box (*a*) the diaphragm (*c*) will vibrate to the note, and the electromagnet *f* will similarly respond, and therefore repeat that note.

Musical sounds vary in tone, in intensity, and in quality. The tone depends on the number of vibrations per second only; the intensity on the amplitude or extent of those vibrations; the quality on the form of the waves made by the vibrating particles of air.

It is evident that in Reiss's telephone every thing at the receiving end remains the same, excepting the number of vibrations, and therefore the sounds emitted by it varied only in tone, and were therefore notes and nothing more. The instrument remained a pretty philosophical toy, and was of no practical value.

Cromwell Varley, in 1870, showed how sounds could be produced by rapidly charging and discharging a condenser.

Elisha Gray, of Chicago, in 1873 succeeded in producing tones from the finger when rubbing a dry sonorous body, such as an ordinary tin can, while the intermittent currents sent by a vibrating tuning-fork were passing through it; and by attaching an electromagnet to a hollow sounding-box, open at one end and closed at the other, he was able to reproduce the tones of the musical notes transmitted. His electromagnet had its armature rigidly fixed to one pole, and separated from the other by a space of $\frac{1}{64}$th of an inch. He called it a resonator. The vibrations of this armature are imparted to the sounding-box, and become, therefore, magnified. He constructed a keyboard, of two octaves compass, with steel reeds, each of which was tuned to its proper note and maintained in vibration by electromagnets. When the key corresponding to any note was depressed, its corresponding reed was connected to line and the proper number of currents transmitted to the distant station, where they operated the resonator and thus reproduced the note. In this way tunes were played, and the instrument became an electric organ. By attaching organ-pipes to his resonator he magnified the sounds, and was able to fill a large hall with music played at places from 90 to 208 miles away. More than that, he proved the practicability of transmitting chords and composite sounds to distant places. Gray also invented a method by which the intensity of the notes as well as their tones could be transmitted. Mr. Leonard Wray also introduced a capital receiver which emits the sounds received from a distance by means of Reiss's diaphragm.

It remained for Professor Graham Bell, of Boston, who has been working at this question with the true spirit of a philosopher since 1872, to make the discovery by which tone, intensity, and quality of sounds can all be sent. He has rendered it possible to reproduce the human voice with all its modulations at distant points. I have spoken with a person at various distances up to 32 miles; and through about a quarter of a mile I have heard Professor Bell breathe, laugh, sneeze, cough, and, in fact, make any sound the human voice can produce. Without explaining the various stages through which his apparatus has passed, it will be sufficient to explain it in its present form. Like Reiss he throws a diaphragm into vibration, but Professor Bell's diaphragm is a disk of thin iron (*a*), which vibrates in front of a soft iron core (*b*), attached to the pole of a permanent bar-magnet N S (see Fig. 2).

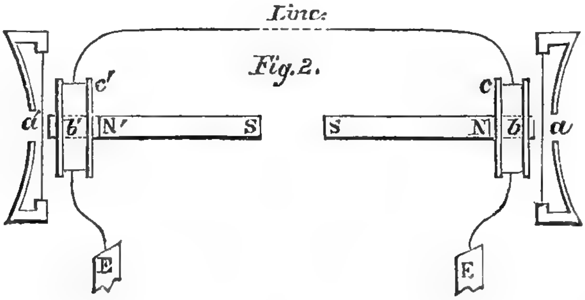


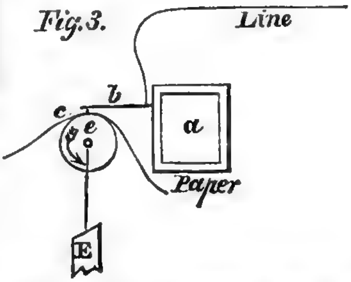
Fig. 2.

This core becomes magnetized by the influence of the bar-magnet N S, inducing all around it a magnetic field and attracting the iron diaphragm towards it. Around this core is wound a small coil (*c*) of No. 38 silk-covered copper wire. One end of this wire is attached to the line wire, the other is connected to the earth. The apparatus at each end is identically similar, so that it becomes alternately transmitter and receiver, first being put to the mouth to receive sounds and then to the ear to impart them. Now the operation of this apparatus depends upon the simple fact that any motion of the diaphragm *a* alters the condition of the magnet field surrounding the core *b*, and any alteration of the magnet field (that is, either strengthening or weakening) means the induction of a current of electricity in the coil *c*. Moreover, the strength of this induced current depends upon the amplitude of the vibration, and its form on the rate of vibration. The number of currents sent of course depends upon the number of vibrations of the diaphragm. Now each current induced in the coil *c* passes through the line wire to the coil *c'*, and then it alters the magnetization of the core *b'*, increasing or diminishing its attraction for the iron diaphragm *a'*. Hence the diaphragm *a'* is vibrated also, and every vibration of the diaphragm *a* must be repeated on the diaphragm *a'* with a strength and form that must vary exactly together. Hence, whatever sound produces the vibration of *a* is repeated by *a'*, because its vibrations are an exact repetition of those of *a*.

It is quite evident, however, that Bell's telephone is limited in its range. The currents operating it are very weak, and it is so sensitive to currents that, when attached to a wire which passes in the neighbourhood of other wires, it is subject to be acted upon by every current that passes through any one of those wires. Hence on a busy line it emits sounds that are very like the pattering of hail against a window, and which are so loud as to overpower the effects of the human voice.

Now Mr. T. A. Edison, of New York, has endeavoured to remedy those defects in Bell's by introducing a transmitter which is operated on by a battery-current, whose strength is made to vary directly with the quality and intensity of the human voice. In carrying out his investigations in this field, he has discovered the curious fact that the resistance of plumbago varies in some ratio inversely with the pressure brought to bear upon it. Starting from Reiss's transmitter he simply substitutes for the platinum point (*d*) a small cylinder of plumbago, and he finds that the resistance of this cylinder varies sufficiently with the pressure of the vibration of the diaphragm to cause the currents transmitted by it to vary in form and strength to reproduce all the varieties of the human voice. His receiver also is novel and peculiar. In 1874 he discovered that the friction between a platinum point and moist chemically prepared paper varied every time a current passed between the two, so that the rate with which the paper moved was altered at will. Now by attaching to a resonator (*a*) a spring (*b*), whose platinum face (*c*) rested on the chemically prepared paper (*d*), whenever the drum (*e*) was rotated and currents sent through the paper, the friction between *c* and *e* is so modified that vibrations are produced in the resonator (*a*), and these vibrations are an exact reproduction of those given out by the transmitter at the other station.

Fig. 3.



Edison's telephone, though not in practical use in America, is under trial. In some experiments made with it, songs and words were distinctly heard through 12,000 ohms, equal to the distance of 1000 miles of wire.

Bell's telephone is, however, in practical use in Boston, Providence, and New York. There are several private lines that use it in Boston, and several more are under construction. I tried two of them, and though we succeeded in conversing, the result was not so satisfactory as experiments led one to anticipate. The interferences of working wires will seriously retard the employment of this apparatus; but there is no doubt that scientific inquiry and patient skill will rapidly eliminate all practical defects.

To Professor Graham Bell must be accorded the full credit of being the first to transmit the human voice to distances beyond the reach of the ear and the eye by means of electric currents.

On an improved Lantern Galvanoscope. *By* S. P. Thompson.

With the view of making the movements of a galvonometer needle visible to large audiences, this instrument is constructed as a lantern-slide. The galvanometer, in which the needle turns upon a horizontal axis, resembles in miniature that of Becquerel. The scale behind the index is transparent in order that it may be projected upon the screen.

On the Effect of Transverse Stress on the Magnetic Susceptibility of Iron. *By* Sir W. Thomson, *F.R.S.*

On the Determination of Temperature-coefficients for insulating Envelopes. *By* T. T. P. Bruce Warren.

Sound.

On a new Method of Determining the Vibration-number of Tuning-Forks. *By* Prof. H. M'Leod.

On Binaural Audition. *By* Silvanus P. Thompson, *B.Sc., B.A.*

Two tuning-forks tuned nearly in unison when sounded together give rise to interference 'beats'. These 'beats' are heard also if the forks be held one to each ear, or if their sounds be conveyed separately to the ears with pipes. No combinational tone is heard, however, when two forks of an interval of a fifth, third, or fourth are held to the two ears and the intervals are harsh. A minor third produces thus an intensely disagreeable sound. When two tones in unison but differing 180° in phase are led to the two ears there does not appear to be any mutual destruction of the tones, and both are heard. As there is no physical decussation of the auditory nerves after leaving the fourth ventricle of the brain, the inference appears to be in favour of a means of comparison existing within the structures of the brain itself.

Meteorology.

On some Relations of Sea and Land Temperature in the South-west of England. By Dr. Barham.

The intention of the author was to furnish some materials for a correct estimate of the reciprocal influence of land and sea on the temperature of the air in the South-west of England, and inferentially on that of the more eastern districts. The physical geography of the promontory of Cornwall and the Scilly Isles rendered them interesting for their meteorology, and also as a scientific instrument from Nature's workshop, hardly to be equalled elsewhere for displaying, and to some extent measuring, the operation of most of the factors of climate. The stations of observation were St. Mary's (Scilly), Penzance, Helston, St. Agnes, Truro, Plymouth, Guernsey, and Greenwich, the latter as a generally recognized central standard. The observations extended over four years. The mean highest temperature was the same at Scilly and Penzance, namely, 71° Fahr.; at Guernsey, which came next, it rose to 72°·70; at Helston it approached 79°; at Truro it was nearly 78°; and at Plymouth 74°. The mean lowest temperatures were St. Mary and Penzance, again almost the same, 59°; Guernsey, 61°; Truro, 56·8°, nearly the same as Greenwich. The absolute highest temperatures at Scilly and Penzance were again much alike, namely, 74° and 75°; Helston and Truro, 86° and 85°; Guernsey, 78·5°, while at Greenwich it reached 91°·8, so that there was a difference of 16° between the extremes of Scilly and Greenwich, and of 12° between places almost adjacent, as Penzance and Helston. The absolute lowest summer temperature showed a similar relative equability. With regard to sea temperature, it was stated that the mean temperature of surface-water at Scilly and round the Cornish coast in the height of summer was 60°. Its influence was well shown in abstracting more than 8° from the average heat of hot days in the ten miles between Helston and the shores of Mount's Bay. There was scarcely any difference between Penzance and Scilly, in consequence of the almost island character of the peninsula; but immediately they got beyond the estuary, they got to a mainland climate, Helston being much higher in summer and much lower in winter. That was the great reason why Penzance was so suitable as a health resort, its climate, though not identical with that of Scilly, having still a great analogy to it. The extreme cold recorded at Penzance during 50 years was 23°; occasionally, but very rarely, it fell to 26°; and at Scilly it was rarely below 29°. The mean temperature of the sea in the winter months was 50°; and this, it was seen, penetrated the extreme of cold in winter in the same way as it did the extreme of heat in summer. In the course of further observations Dr. Barham showed how much further inland the influence of the westerly winds extended than that of the east winds.

Difference of Rainfall with Elevation. By G. Dines.

On the Measurement of the Height of Clouds. By A. Mallock.

On the Diurnal Variations of the Barometer and Wind in Mauritius. *By* C. MELDRUM, *F.R.S.*

On the Meteorology of Plymouth. *By* JOHN MERRIFIELD, *F.R.A.S.*

The deductions drawn in the paper are from observations taken daily at 8 A.M. for the past twelve years, viz. from 1865 to 1876, both inclusive.

I. *Atmospheric pressure.*—The average is 29·945 in.; the months of greatest pressure are June, 30·059, and July, 29·996; the months of least pressure are January and October, both being 29·868; these months correspond with a great and small rainfall. February and April to August have a mean pressure below the average, whilst the other six months have a pressure above it. The mean monthly range is 1·074 in., those of greatest range being January, February, November, and December, and those of least range are July and August. The greatest ranges correspond to the months of least pressure and *vice versâ.*

II. *Temperature.*—The coldest month is January, whose average is 42°·82 F., which is half a degree lower than December; but the nights of March are colder than those of February. The hottest month is July, whose average is 63°·56 F., which is about 1° F. higher than August. The lowest maximum I have recorded is 28° F. on 22nd December 1870, and the highest minimum 67° F. on 27th August 1869. The maximum temperature during the twelve years is 93° F. on 27th June 1866. The minimum is 14° F. on 27th December 1869. The mean daily range is 20°·74 F.; the greatest daily range was on 27th April 1865, when it was 44° F., with a maximum of 86° F. The least range was on 22nd December 1870, when it was 2° F., with a maximum of 28° F. The averages, according to the author's returns, agree with those published by the British Association from 1833–7, within *one tenth of a degree.*

III. *Wet and Dry Bulbs.*—The greatest difference between the bulbs is in June, 3°·79 F., and July, 3°·56 F. The least difference is in December, ·89, and January, ·94. The relative humidity for May, June, and July is 79°–77 and 79° respectively, whilst that for October is 93°. The greatest difference recorded by the author between the bulbs is 15° on June 22nd, 1865, when the dry bulb was 78° and the relative humidity was 41°; but this occurred after several days of continuous easterly winds.

IV. *Rainfall.*—January has the greatest rainfall, as well as the greatest number of rainy days, viz. 4·852 inches in 21·15 days. June has the least of each, viz. 1·375 inch in $9\frac{3}{4}$ days. September stands fifth in order of rainy days, but is second in order of rainfall; hence, if we neglect thunder-showers, our heaviest rains must occur in that month. We have nearly twice as much rainfall in the six months from September to February as during the remaining six months; whilst the number of rainy days is almost as 3 is to 2. We sometimes have heavy showers, as on 29th July, 1871, when in less than half an hour three-quarters of an inch of rain was registered; and sometimes, though rarely, suffer from want of rain, as, for example, from 18th March to 2nd July, 1870, when, if we omit a thunder-shower on 12th May, only 1·3 inches of rain fell in 106 days; but on the average we have rain amounting to more than ·1 inch every day.

V. *Winds.*—We get 195 westerly to 144 easterly winds in the year, or the days on which westerly winds and calms prevail are 20 per cent. more than those on which easterly ones blow. The months of July and August have the greatest number of westerly winds; March, April, and May have the greatest number of easterly winds. Winds of greatest violence blew in November, December, and January.

We get	20·49	per cent. of winds from		N. by E. to E.
	19·21	,,	,,	E. by S. to S.
	29·85	,,	,,	S. by W. to W.
	23·70	,,	,,	W. by N. to N.
and	6·75	,,	calms.	

VI. *Thunder-storms.*—Judging from newspaper reports, thunder-storms are rarer and less violent than in the Midlands. No doubt a large portion of the atmospheric electricity which is generated by the evaporation and friction of the waters of the sea is silently discharged through our damp atmosphere, and thus eludes observation.

MISCELLANEOUS.

Experiments illustrative of the Flight of Projectiles. By P. BRAHAM.

Suggestion for a new Polar Expedition, with a proposed Route. By Commander CHEYNE.

On the Tides of Port Louis, Mauritius, and Fremantle, Australia. By Captain EVANS, *F.R.S., and* Sir W. THOMSON, *F.R.S.*

Note on the Volumes of Solutions. By J. A. EWING *and* J. GORDON MACGREGOR, *M.A., D.Sc.*

In a paper by the authors, published in vol. xxvii. of the 'Transactions of the Royal Society of Edinburgh,' containing an account of experiments on the density and electrical conductivity of certain saline solutions, notice is directed to the fact that the density of very weak solutions of sulphate of copper and sulphate of zinc is greater than it would be on the hypothesis that the anhydrous part of the salt dissolves without increase of volume in the whole of the water present, including the water of crystallization. On the other hand, the density of comparatively strong solutions is less than this hypothesis would make it. From this it follows that if a small quantity of one of these salts in the anhydrous state were added to water it would cause contraction, while a large quantity of the salt would produce expansion. The amount of such contraction, however, as indicated by observations of density, was so small that the authors were unwilling to speak positively as to its existence until they had applied a direct volumetric test. They have now done so, with the result of confirming the deduction drawn from their earlier experiments.

The apparatus consisted of a large bottle 2744 c.cm. in capacity, through the cork of which projected a vertical tube of 0·66 cm. bore. The bottle, as well as part of the tube, was filled with distilled water, and the salt was introduced through the tube in quantities of 10 grammes at a time. The resulting change of volume was shown by the rise or fall of the liquid in the tube. In order to eliminate the effect of variations of temperature, a second precisely similar bottle and tube were prepared and filled with water, and the two were placed together in a large tub full of water. The second bottle acted as a thermometer, and the expansion or contraction due to the introduction of the salts into the first bottle was indicated by the difference between the changes of level in the two tubes. After the introduction of each dose of salt the bottle was rolled about for a time so as to secure thorough diffusion and solution, and then an interval of at least six hours elapsed before readings were taken, in order that the heat given out by the hydration of the salt might be dissipated.

The following results have been obtained in the case of anhydrous sulphate of copper. The maximum contraction occurs when the proportion of anhydrous salt to water is about 1 to 50, and the amount of contraction is then 0·00043 of the original volume of water. As more salt is added, the solution begins to expand, and with 1 part of salt to 18 of water the volume is equal to that of the water originally present. After this, any further addition of salt produces expansion beyond the original volume. The rate of expansion per unit quantity of salt appears to increase continually, but at first it is negative.

The above numbers are given subject to correction by more elaborate experiments which are now going on. The authors hope to extend the inquiry to other salts. They have already examined the behaviour of anhydrous sulphate of soda; but with that salt no contraction whatever has been observed, the solutions expand rapidly from the first.

On some Points connected with the Chemical Constituents of the Solar System. By Dr. J. H. Gladstone, *F.R.S., President of the Chemical Society.*

The discoveries of the spectroscope, and the general advance of knowledge of the heavenly bodies, have greatly confirmed the nebular theory of the creation of worlds. Assuming a nebulous mass of many chemical elements gradually condensing to a centre, how should we find these elements distributed? The least volatile would form the liquid or solid nucleus, while the others would arrange themselves according to their volatility, condensing into cloud at various distances from the intensely heated centre. Also, as Mr. Johnstone Stoney has shown, the gases would arrange themselves according to their relative density, the lightest gases being at the outside. In neither case, however, would the separation of the constituents be perfect; for mechanical movements and diffusion will always cause some portions of the less volatile bodies or denser gases to rise into the upper region. This is actually what is taking place in the sun at present.

Supposing the solar system to have been originally a great revolving nebula of this description condensing to a central sun, and forming from its outer portions smaller masses, such as the planets and their satellites, or the comets and meteorites, we may expect these to consist principally of the more volatile or the lightest elements with smaller portions of the less volatile or heavier ones. On arranging the elements of which the earth is composed according to the known or presumed density of their vapours, it is found that such is actually the case.

Non-metallic Elements.

Plentiful.		Not plentiful.	
Oxygen	16	Phosphorus	62
Silicon	28·5*	Fluorine	19*
Carbon	12*	Bromine	80
Hydrogen	1	Boron	11*
Sulphur	32	Iodine	127
Chlorine	35·5	Selenium	79*
Nitrogen	14	Average 63.	
Average 19·8			

Metals.

Plentiful.		Common.	
Aluminium	27·5*	Barium	137*
Calcium	40*	Zinc	32·5
Sodium	23*	Lead	207*
Magnesium	24*	Arsenic	150
Potassium	39	Copper	63·5*
Iron	56*	Antimony	122*
Manganese	55*	Silver	108*
Average 37·8		Tin	118*
		Chromium	52·5*
		Mercury	100
		Nickel	58·8*
		Average 104·5	

METALS (*continued*).

Rare.	
Cadmium	56
Cobalt	58·8*
Bismuth	208
Tungsten	184*
Gold	196·7*
Strontium	87·5*
Uranium	120*
Molybdenum	92*
Glucinum	14*
Titanium	50*
Average 106·7.	

Very rare.	
Platinum	197·4*
Palladium	106·5*
Iridium	198*
Osmium	199*
Rhodium	104*
Ruthenium	104*
Lithium	7*
Thallium	204*
Vanadium	137*
Cerium	92*
Lanthanum	92*
Didymium	96*
Yttrium	68*
Thorium	231·5*
Niobium	97·6*
Cæsium	133*
Rubidium	85*
Indium	74*
Tantalum	137·5*
Tellurium	128*
Zirconium	90*
Average 122·9.	

The plentiful elements, whether non-metallic or metallic, have always low atomic weights; the less plentiful ones are generally heavier, and the very rare ones have almost invariably high densities.

This is still more strikingly the case with reference to the meteoric stones, which are composed, almost without exception, of elementary substances which are light when in the gaseous condition, viz. iron, nickel, chromium, oxygen, sulphur, silicon, magnesium, calcium, sodium, carbon, hydrogen.

Among the circumstances which interfere with the universality of this rule are the great changes in density and volatility that are brought about by chemical combination; and the chemistry of the surface of our globe is but little guide to the compounds that exist at the high temperature at which meteorites, and probably our own earth, were formed.

Reasons were assigned for believing that the self-luminous heads of comets are not composed of carbon vapour, but rather of incandescent compounds of that substance.

[Printed *in extenso*, Phil. Mag. November 1877.]

Summary of the First Reduction of the Tidal Observations made by the recent Arctic Expedition. By Prof. HAUGHTON, *F.R.S.*

Physical Properties of Solids and Liquids in Relation to the Earth's Structure. By Prof. HENNESSY, *F.R.S.*

On the Molecular Changes which take place in Iron and Steel while Cooling. By A. MALLOCK.

On the Rate of Progression of Groups of Waves, and the Rate at which Energy is transmitted by Wind. By Prof. OSBORNE REYNOLDS, *F.R.S.*

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* Atomic weight.

On a new Form of Sprengel's Air-pump.
By C. H. Stearn *and* J. W. Swan.

Solutions of Laplace's Tidal Equation for certain special Types of Oscillation.
By Sir W. Thomson, *F.R.S.*

Diurnal and Semidiurnal Harmonic Constituents of the Variation of Barometric Pressure. *By* Sir W. Thomson, *F.R.S.*

On a Marine Azimuth Mirror and its Adjustments.
By Sir W. Thomson, *F.R.S.*

On the Possibility of Life on a Meteoric Stone falling on the Earth.
By Sir W. Thomson, *F.R.S.*

On a new Form of Apparatus to illustrate the Interference of Plane Waves.
By C. J. Woodward.

CHEMISTRY.

Address by Professor Abel, *F.R.S., President of the Section.*

The subject which my predecessor, in the honourable position of President of this Section, made the chief topic of his interesting and instructive Address, affords excellent illustrations of the operation of purely scientific research in creating and developing important branches of industry. Mr. Perkin, whose name has from the very commencement of the history of coal-tar colours been identified with their discovery and their scientific and technical history, referred to several series of researches, each one of which formed a link in a chain of discoveries in organic chemistry of the highest value as establishing, illustrating, or extending important chemical theories, but at the time, and for long afterwards, of value purely from a scientific point of view. These researches, undertaken and pursued by ardent and philosophical investigators under more or less formidable difficulties, and solely in the interests of science, resulted in the discovery of certain organic bodies which were produced originally only on a very small scale and at great cost, but which, after the lapse of years, have been readily manufactured from abundant sources, and have constituted important elements in the development of the industry of artificial colouring-matters. In fact this industry, which owes its origin to the discovery of mauve by Mr. Perkin about twenty years ago, and which is second to no branch of chemical industry in regard to the rapidity of its development and its influence upon other important branches of manufacture, affords more copious illustrations than any other of the immediate influence of pure science upon industrial progress. It therefore affords a topic which the chemist may well be excused for continually recurring to, with an interest bordering on enthusiasm, when illustrating the material advantages which accrue to communities from the promotion of scientific training and the encouragement of chemical research.

The iron-and-steel industry presents a great contrast to that of the artificial colours in regard to the extent of influence which the labours of purely scientific investigators have exerted upon its development. The efforts of scientific men to unravel such problems as, for instance, the true chemical constitution of steel, or the precise differences between the various combinations known as cast iron, and the conditions which determine their individual production or conversion from one to another, have hitherto been attended by results not at all proportionate to the patient experimental investigation of which from time to time they have been made the subject. Thus the protracted experiments and discussion carried on by Frémy and Caron, some years back, with reference to the dependence of the characteristics of steel upon the existence in it of nitrogen, cannot be said to have led to results of a more conclusive or even definite nature regarding the conditions which regulate the production, composition, and properties of steel than those arrived at by previous distinguished experimenters; and the same must be said, with respect to cast iron, of such experiments as those carried on for several years by Matthiessen (in which I also took some part) under the auspices of the Association, with the view to eliminate many existing points of doubt regarding the chemical constitution of cast iron, by preparing chemically pure iron and studying its combination with carbon and other elements occurring in cast iron.

The prosecution of purely scientific investigation may therefore of itself fail to bear *direct* fruit in regard to the development of new metallurgic achievements, or even to the elucidation of the comparatively complicated and numerous reactions which occur in furnaces, either simultaneously or in rapid and difficultly controllable succession, between materials composed of a variety of constituents in variable proportions. There can, however, be no question regarding the important benefits which have accrued from the application of chemical knowledge to the study and the perfection of furnace-operations by those who happily combine that knowledge with practical experience and with the power of putting to the test of actual practice the results of reasoning upon an intelligent observation of the phenomena exhibited in such operations, and upon the data which chemical analysis has furnished. In the hands of such men, the scientific results arrived at by Karsten, Berthier, Bunsen, Scheerer, Percy, and other eminent investigators acquire new value, and by them the fruits of the labours of the patient toiler at analytical processes meets with that appreciation which their solid and permanently valuable work does not always command at the hands of their numerous brother-workers in chemical science who follow the far more attractive paths of organic research.

Naturally, the brilliant results achieved from time to time by investigators in organic chemistry, the rapidity with which, by those results, theories are established or extended, types founded, their offspring multiplied, and their connexion with other families traced and developed, impart to organic research a charm peculiarly its own. This, and the general ease with which new results are obtained by the pursuit of methods of research comparatively simple in their nature and few in kind, have for many years not only secured to organic chemistry an overwhelming majority of workers; they also appear to have had a tendency to lead the younger labourers in the field of organic research to underestimate the value and importance, in reference to the advancement of science, of the labours of the plodding investigator of analysis. Yet no higher example can be furnished of the patient pursuit of scientific work, purely for its own sake, than that of the deviser or improver of analytical processes, who, undeterred by failure upon failure, indefatigably pursues his laborious work, probing to its foundation each possible source of error, carefully comparing the results he obtains with those furnished by other methods of analysis, and patiently accumulating experimental data till they suffice fully to establish the value and trustworthiness of the process which he then publishes for the benefit of his fellow-workers in science. Truly the results of such labours do not stand in unfavourable contrast, from whatever light they may be viewed, to those of the investigator of organic chemistry. It is not to be denied that the labourer at organic research may, so far as the analytical work which should fall to his share in the course of his investigations is concerned, be tempted to reduce this, the least attractive portion of his work, to within the smallest possible limits, and having, for example, by a boiling-point determination or a single analytical operation of the simplest kind, such as the examination of a platinum-salt, obtained a numerical result approximating to that which his theory demands, may hasten on to the further development of his airy structure, possibly not without risk to its stability. Unquestionably there are instances of frequent occurrence, in the pursuit of a particular line of organic research, in which more is not required than the identification of a particular product by some such simple means as above indicated. It is certain, moreover, that the labours of the organic investigator also not unfrequently afford bright examples of indomitable perseverance under formidable difficulties; and this alone should constitute a strong bond of union between the worker in organic research and his brother-worker in analytical chemistry, if one did not already exist in the active interest which each, if a true lover of science, must take in the work of the other.

It has been remarked by one of the most distinguished investigators, and, at the same time, one of the most brilliant lecturers and successful teachers of our time, that the contrivance of a new and good lecture experiment may rank in importance with the preparation of a new organic compound; and it may certainly be said with equal truth that the elaboration of a new and good method of analysis may rank in importance with a good research in organic chemistry, in reference both to the part it plays in the advancement of science and to its influence upon industrial progress.

An excellent illustration of this is afforded by reference to the Proceedings of the British Association when it met in this town thirty-six years ago. In a letter to Dr. Playfair, Liebig, who took a very active part in the proceedings of the Association in the earlier years of its existence, reports that Doctors Will and Varrentrapp have devised an excellent method for determining the amount of nitrogen in organic bodies, "very exact and easily performed." He then describes in a few lines the process so well known to chemists, which not only has been, and continues to be, invaluable to those engaged in organic research, but which, as may be testified by such researches as those of Lawes and Gilbert, has borne a most important and indispensable part in the advancement of agricultural chemistry. It is, I believe, but an expression of the unanimous conviction of chemists to say that the achievements in analytical chemistry of such men as Berzelius, Heinrich Rose, and Fresenius take equal rank with the brilliant researches and theoretical expositions of such chemists as Liebig, Laurent, Gerhardt and Berthelot, and that, of all the important contributions to the development of organic chemistry which we owe to Liebig, there is none which has exerted so great an influence on the progress of this branch of chemical science as his beautifully simple method of organic elementary analysis.

Reverting to the industry of iron and steel, which, in regard to some of its most important branches, cannot fail to be a subject of special interest in Plymouth and Devonport, it is not difficult to demonstrate that the labours of the analytical chemist have exercised, and continue to exert, an important influence on the very considerable advance which has in recent years been made, and still proceeds, towards securing complete control over the quality and character of the products obtained. The epoch is well within the recollection of chemists of my generation when the British ironmaster first awoke to the benefits which might accrue to him from an application of the labours of the analytical chemist in connexion with iron-smelting. When the last great stride was made in the manufacture of cast iron, by the introduction of the hot blast, the iron-smelter was naturally led to seek profit, to the fullest extent, with respect both to the great increase in the rate of production of pig-iron attainable thereby, and to the economy achievable in regard to the proportions and characters of the materials employed in the production of pig-iron. But after a time, the great falling off in the quality of a large proportion of the products of the blast-furnace, and the difficulties experienced in the production of malleable iron of even very moderate quality, aided by the great impetus to competition, in respect of quality, given by the first International Exhibition in 1851, directed the attention of our more enlightened ironmasters to the likelihood of their deriving important aid from chemical science, and more especially from the investigations of the analytical chemist.

Among the earliest to realize the importance of trustworthy and detailed information regarding the composition of the iron ores of the country was Mr. S. H. Blackwell, who, in presenting to the Royal School of Mines a very extensive and interesting series of British ores, which he had collected with great labour and expense for exhibition in 1851, placed at the disposal of Dr. Percy the requisite funds for engaging the services of competent analysts (Messrs. J. Spiller and A. H. Dick), who, under his direction and with subsequent pecuniary aid from himself and from Government funds, carried out a very careful and complete examination of this series, the results of which have been of great value for purposes of reference to those actively interested in the iron industry. It was, however, the first connexion of Messrs. Nicholson and D. S. Price and of Mr. E. Riley with two of the most important iron-works of this country, about a quarter of a century ago (*i.e.* at the time when the above investigation was commenced), that marked, I believe, the commencement of systematic endeavours to apply the results of analytical research to the improvement and regulation of the quality of the products of our iron-works.

It is, perhaps, but natural that the primary object sought by application of the knowledge of the analytical chemist should have been to eliminate or reduce the existing elements of uncertainty in obtaining the most abundant yield of pig-iron capable of conversion into railway bar sufficiently good to meet the minimum standard of quality, and to reduce still further the cost of production of such bar iron by utilizing materials concerning the composition of which (richness in iron, &c.) the iron-smelter was completely in the dark. The information accumulated by the analyst respecting the composition of the ores, fuel, and fluxes available at the works, and the composition of the pig-iron and slags (or cinders) produced under varied conditions, in regard to materials employed and to the proportions of ore, fuel, and flux used in the blast-furnace, could not, however, exist long without exerting a marked beneficial influence upon the quality of the iron produced, and generally upon the iron industry of the country.

Percy's invaluable work of reference on metallurgy furnishes abundant evidence of the scientifically interesting, as well as practically useful, nature of the results obtained at that time by the chemists above named, and others, working under Dr. Percy, with respect both to the elaboration of important analytical processes (in which direction Mr. Riley has continued to the present day to do valuable work) and to the elucidation of the reactions occurring in the processes of reduction and refining of the metal. It is needless to dwell upon the fact that the aid of the analyst has now long since become absolutely indispensable to the iron and steel manufacture; but I may perhaps be allowed briefly to refer to one or two recent illustrations of the indispensable part which analytical research has played and continues to play in the extension of our knowledge of the chemical reactions involved in the production of cast and wrought iron and of steel, and of the influences which the chief associates of iron in its mercantile forms exert upon its physical characters.

Among the many valuable communications made to that most important body, the Iron and Steel Institute of Great Britain, by men who combine great practical knowledge and experience in iron and steel manufacture with high attainments in mechanical science and such knowledge of chemical science as ensures a full appreciation of its value at their hands, one of the most interesting and suggestive to the chemist is that on the separation of carbon, sulphur, silicon, and phosphorus in the refining- and puddling-furnace, and in the Bessemer converter, contributed to the Transactions of the Institute's recent meeting by Mr. Lowthian Bell, whose valuable investigations in connexion with the iron industry are as interesting to the chemist as they are useful to the manufacturer. Mr. Bell has brought together the results of an extensive series of practical experiments on the treatment of different kinds of pig-iron of known composition in the finery, the puddling-furnace, and the Bessemer converter, and, by comparing the results of analytical investigation of the products of those experimental operations with each other and with those of the materials operated upon, he has obtained valuable confirmation of the views already held by metallurgic chemists regarding the succession in which carbon, silicon, sulphur, and phosphorus are attacked when pig metal is submitted to the above purifying processes, and the extent to which these foreign associates of iron are abstracted, or resist removal, by the more or less thorough application of those several modes of treatment. He has also thrown new light on the reason why the most difficultly assailable impurity, phosphorus, obstinately resists all attempts to effect even a slight diminution in its amount, by application of the Bessemer treatment. The earnestness with which Mr. Bell wages war against this enemy of the ironmaster, in one of its most favourite haunts, the Cleveland District, not simply with the old British pluck which acknowledges not defeat, but systematically on scientific principles, calling to his aid all the resources which the continual advances in applied mechanical and chemical research place within his reach, cannot fail to contribute importantly, if it does not of itself directly lead, to the complete subjection of this most intractable of the associates to which iron becomes linked in the blast-furnace. Indications have lately not been wanting that the existence of phosphorus in very notable proportions in iron may not of necessity be inimical to its conversion into steel of good quality; and it may be that this element, which is now turned to useful account to impart particular characteristics to the alloys of copper and tin, is even destined to play a distinctly useful part in connexion with the production of steel possessed of particular characters, valuable for some special purposes.

In the great development which steel manufacture has received within the last few years, one most prominent feature has been the production with precision, upon a large scale, of steel of desired characteristics, in regard to hardness &c., by first adding to fluid cast iron of known composition the requisite proportion of a rich iron ore (with or without the addition of scrap iron) to effect a reduction of the carbon to the desired amount, concurrent with a refining of the metal by the oxidizing action of the ore, and then giving to the resulting steel the desired special qualities by the addition of suitable proportions of iron compounds of known composition, rich in manganese and carbon (Spiegeleisen and the similar product called ferro-manganese). The germ of this system of producing steel-varieties of predetermined characteristics exists in crucible processes like that of Uchatius, which have been in more or less extensive use for many years past; but it is to such invaluable arrangements as are most prominently represented in the Siemens-Martin furnace, wherein several tons of metal may be fused and maintained at a very high temperature with as little liability to change from causes not under control as if the operation were conducted in a crucible, that we are indebted for the very great expansion which the direct application of the analytical chemist's labours to the development of the steel industry is now receiving.

The production of steel upon the open hearth, to the elaboration of which Dr. C. W. Siemens has so largely contributed, since he first established the process at Llandore in 1868, has, in fact, become assimilated in simplicity of character and precision of results to a laboratory operation, and may be justly regarded as a triumph of the successful application of chemical principles, and of the power of guidance and control afforded by utilizing analytical research, to the attainment of prescribed results upon a stupendous scale, with an accuracy approaching that which the experienced chemical operator secures in the laboratory upon a small scale, under conditions which he can completely control. The production of steel by a large number of small separate operations in pots has now become supplanted with great advantage by the Siemens-Martin system of working at some of our largest establishments at Sheffield; this system has also secured a footing at highly renowned continental works, which are formidable competitors with us in the manufacture of steel, such as those of Essen, Creusot, and Térrenoire. It is specially interesting to notice that, in the hands of those who, on the Continent at least equally with ourselves, have learned to combine the results of practical experience with the teachings of chemical science, the facilities now existing for dealing in a single receptacle with large masses of fluid steel have greatly facilitated the application of chemical means to the production of *solid* masses of considerable size, thereby reducing, if not altogether dispensing with, the necessity for submitting large steel castings to costly mechanical operations, with the object of closing up cavities caused by the escape of occluded gas as the liquid metal cools. The success i this direction which appears to have attended the addition of silicon, in combination with iron and manganese, to the steel before casting, in preventing the formation of so-called *blow-holes,* and in contributing at the same time to the production of the particular character of steel required, bids fair to be of special importance in connexion with the application of steel to the production of projectiles for use against armour plates, as affording ready and comparatively very economical means of ensuring the production of perfectly sound castings, which, in compactness of structure, will, it is asserted, compete successfully with carefully forged castings, and even with the magnificent material which Whitworth produces by submitting the fluid metal to powerful pressure.

The part which silicon plays, by its comparatively high susceptibility to oxidation, in promoting the production of sound steel castings is readily intelligible; but the functions of the manganese compounds, which are an indispensable adjunct to the Bessemer process, and the application of which has become an integral part of steel manufacture, are still far from being thoroughly understood; and there is ample scope for chemical research, in co-operation with practical experiment, in the further study of the influence not only of manganese in the production and upon the properties of steel, but also of elements such as titanium, tungsten, and boron, and of chromium, which exists, associated in considerable quantities with iron, in a very abundant Tasmanian ore, to which prominent attention has lately been directed. The achievements of the mechanical engineer have so facilitated the handling and perfected the means of production and the mechanical treatment of malleable iron and of steel, that the full advantage may now be reaped of any improvement of a chemical nature which may be effected in the production of those materials; and it must be a source of pride to the chemist to observe with what success the teachings of his science are being applied by practical men of the present day in the construction of furnaces capable of withstanding the high temperatures required for the production and working of iron and steel in large masses, and in combining the perfect consumption and consequent great economy of fuel with the attainment of those high temperatures and with a thorough control over the character of the gaseous agents to which the fluid metal is exposed in the furnace. I need not quote the names of those men who have already rendered themselves prominent by their services in this particular direction, but may refer, in special illustration of the results achieved by purely practical men, to the success in applying very simple furnace-arrangements to the attainment of the above results which has recently attended the labours of Mr. William Price, a principal Foreman in the Royal Gun Factories at Woolwich.

A few of the experiments made in the early days of the application of armouring to ships and forts appeared to demonstrate, on the one hand, that steel was quite incapable of competing with malleable iron, of even very moderate quality, as a material for armour plates, and, on the other hand, that the penetrative power of projectiles made of chilled iron, upon the Palliser system, could not be surpassed, or even attained, with any degree of certainty, by projectiles of steel, produced at comparatively very great cost. But some recent results obtained on the Continent, and especially in the course of the important experiments instituted by the Italian Government at Spezzia, have afforded decisive indications that steel, the application of which to the construction of ordnance has since that time been very greatly extended, may now be looked to hopefully as capable of affording greater protection against the enormous projectiles of the present day than can be secured by proportionately large additions to the stupendous iron-armouring of the most modern ironclads, and also as applicable, at a cost very moderate when compared with that of ten years ago, to the production of projectiles of large dimensions superior in point of penetrative power, and of uniformity in this respect, to those of chilled iron, the difficulties in the production of which are very greatly increased by the formidable increase which has lately been made in their size. Promising results have also quite recently been obtained at Shoeburyness with a new system of applying steel in conjunction with malleable iron, by which a perfect union of masses of the two materials at one of their surfaces is effected by the aid of heat.

The superiority of soft and very homogeneous steel over wrought iron of the best quality, in regard to lightness combined with strength and toughness, is leading to its very advantageous employment in the construction of a particular class of vessels for the Navy; and the perfect confidence which can be placed in the uniformity, in structure and strength, of steel of such character as is produced by the Whitworth system of manufacture has greatly facilitated the production of air-chambers of small weight, but capable of being quite safely charged with sufficient air, under a pressure of 1000 lb. on the square inch, to carry the Whitehead torpedo through water to the distance of a thousand yards in little more than a minute and a half.

Thus the results of the recent development of the steel-industry, to which the labours of the chemist have not unimportantly contributed, give promise of exerting a great influence upon the resources of nations for defence and attack. Although the necessity for the continual expansion of such resources cannot but be deeply deplored, there can be no doubt that the problems which it presents, and the special requirements to which it gives rise, must operate, and perhaps as importantly as the demands created by peaceful industries and commercial enterprise, in encouraging the metallurgist, the chemist, and the engineer to continue their combined work in following up the successes, to the achievement of which the results of scientific research have greatly though indirectly contributed.

If it were necessary to add to the illustrations which Mr. Perkin gave in his Address last year of the practical fruits of research in *organic* chemistry, I might be tempted to dilate upon the important results which have, especially during the last ten years, grown out of the discovery and study of the products of the action of nitric acid upon cellulose and glycerine. During the six years which have elapsed since I had the honour of bringing before the members of the British Association the chief points of scientific interest and practical importance presented by the history of those remarkable bodies, their application to technical and war purposes has been greatly developed. Nitroglycerine and gun-cotton may now be justly classed among the most interesting examples of the practical importance frequently attained by the results of chemical research, while the history of the successive steps by which their safe manipulation and efficient application have been developed affords more than one striking illustration of the achievements effected, by combined physical and chemical research, in the solution of problems of high scientific interest and practical importance, and in the vanquishment of difficulties so formidable as, for a time, to appear fatal to the attainment of permanently practical success.

It is to a careful study of the influence which the *physical* characters of gunpowder (its density, hardness, &c.) and its *mechanical* condition (*i. e.* form and size of the masses and condition of their surfaces) exert upon the rapidity of the explosion under confinement that we chiefly owe the very important advance which has been made of late years in controlling its explosive force, in its application as a propelling agent, and the consequent simple and effectual means whereby the violence of action of the enormous charges now used in siege- and ship-guns is effectually reduced to within their limits of endurance, without diminution of the total explosive force developed. But, concurrently with these important practical results, the application of combined chemical and physical research to a very extended and comprehensive investigation of the action of fired gunpowder has furnished results which possess considerable interest from a purely scientific point of view, as in many respects modifying, in others supplementing, the conclusions based upon earlier experiments and theoretical considerations with respect to the nature and proportions of the products formed, the heat developed by the explosion, the tension of the products of combustion and the conditions which regulate it, both when the explosion is brought about in a close vessel and when it occurs in the bore of a gun. The results of these physico-chemical researches have, moreover, already acquired practical importance in regard to the light they have thrown upon the influence exerted by variable conditions of a mechanical nature upon the action of, and pressure developed by, fired gunpowder in the bore of a gun, and in demonstrating that modifications in the *composition* of gunpowder, not unimportant from an economical point of view in dealing with the very large charges now employed, may importantly contribute to render the storing of the maximum of work in the projectile, when propelled from a gun, compatible with a subjection of the gun to comparatively very moderate and uniform strains.

Other interesting illustrations of the intimate manner in which physical and chemical research are linked together, and of the important extent to which some of our most illustrious workers in chemistry have contributed to demolish the semblance of a barrier which existed in past times between the two branches of Science, are furnished and suggested by the recently published list of grants of money which the Government has made to scientific men, on the recommendation of the Royal Society, from the fund which, for the first time last year, was added to the very modest sum previously accorded from national resources in support of research. The perusal of that list, representing as it does a most carefully considered selection by the highest representatives of science in the country, from a very large number of applications, affords important evidence, on the one hand, of the active pursuit of science in Great Britain and, on the other, of the very wide range of subjects of interest and importance, the full investigation of which demands the provision of adequate resources. That the necessity for such resources needs but to be thoroughly made known to ensure their provision, even from other than national sources, has been demonstrated by the success which, in a comparatively brief space of time, has attended the efforts of the Chemical Society to establish, upon the foundation patriotically laid by one of its original members, Dr. Longstaff, a special Fund, to be administered by the Society, for the advancement of Chemical Science. An inspection of the list of contributors to this special Fund in aid of chemical research, which, in about two years, has reached the sum of four thousand pounds, and from the proceeds of which the first applications for grants have recently been met, is suggestive of two observations: one is, that the proportion and amount of contributions hitherto received are comparatively small from the source whence the greatest support of such a Fund may naturally be looked for, namely, from those who most directly benefit by the results of chemical research. It is to be hoped that there are many prominent representatives of the Chemical and Metallurgic Industries in this country who still intend to give practical effect to their natural desire to aid in the advancement of Chemical Science, and to the appreciation which they can hardly fail to entertain of the usefulness of this Fund. On the other hand, it is a matter well meriting special notice that a very prominent section of the contributors to the Fund is composed of some of the most ancient corporate bodies of the City of London. Most welcome evidence is thereby afforded of the readiness with which the City Companies are prepared to respond to appeals for the substantial support of measures well calculated to promote progress in science. This evidence, and the combined action which they are even now contemplating for promoting the application of scientific research to the advancement of industry and commerce, by establishing an Institution for technical education upon a scale worthy to serve as a monument of the true usefulness of wealthy confederations, must be cordially hailed as very substantial proofs that these representatives of our national wealth and commercial supremacy are entering upon a new sphere of activity which will more than restore their ancient prestige, by according them a new rank, more elevated than any which their civil importance could, in the past or future, confer upon them—a rank high among the chief promoters of our national enlightenment.

On the Formation of the Black Oxide of Iron on Iron Surfaces, for the Prevention of Corrosion. By Professor BARFF.

On the Explosive Character of a Mixture of Magnesium and Potassium Chlorate. By P. Braham.

On Hydrogen Peroxide and some Uranium Compounds. By T. Fairley.

On the Thermo-chemistry of Oxygen. By T. Fairley.

On some Candles altered by long Exposure to Sea-water. By Professor J. H. Gladstone, *F.R.S.*

Mr. Latimer Clark had sent the author some specimens of candles recovered from the wreck of a vessel sunk off the Spanish coast in 1702. They had remained submerged till 1875, a period of 173 years.

The wick has rotted away, leaving scarcely any trace of its existence, while the fatty portion has become a friable heavy substance of a dull white colour. The candles bore evidence of having been made by dipping, for the concentric layers were easily separated from one another. Both the outer and inner portions still contain some of the fat apparently unchanged; they are unctuous to the touch and have a fatty odour. The fat can be easily separated from the rest by treating the altered candles with ether.

After combustion there remained a strongly alkaline white ash, consisting of carbonate and chloride of calcium and sodium, with traces of magnesium and potassium. From the details of the analysis it appears that the fat has been converted in great measure into calcium and sodium salts, doubtless by the slow replacement of the triatomic group C_3H_5 in the stearine by 3 atoms of the metal, with the simultaneous production of glycerine. Though the calcium in sea-water is far less abundant than the sodium, it appears to have had a much greater effect; and it is of course impossible to say whether the one salt has not been made by double decomposition from the other. The author pointed out as a most interesting fact, that whereas the fat has been in contact with a practically unlimited amount of sea-water for 173 years, and a chemical change between them has been possible, the double decomposition has proceeded so extremely slowly that the reaction is only about half completed at the present time.

On the Application of a new Unit of Light to the Examination of Coal-gas. By A. Vernon Harcourt, *M.A., F.R.S.*

After pointing out the variations to which the unit of light now in use—a sperm candle burning 120 grains of sperm per hour—is liable, and the irrelevance, for the purpose of estimating the value of illuminating gas, of tests affected by any other portions of the force radiating from a flame besides those which produce vision, the author explained the application of the new unit of light to the examination of coal-gas. By making a mixture in a small gasholder of the most volatile spirit from American petroleum, which distilled at 50° C., with ordinary air, in the proportion of one of the liquid to 600 of air, or seven of the vapour to twenty of air, he prepared a gas which was scarcely at all soluble in water, and was permanent at ordinary temperatures and pressures. This gas was burnt at a pair of burners, corresponding to the two candles commonly used in photometry, each consisting of a brass tube surmounted by a plate through which the standard gas issued at the rate of half a cubic foot per hour, through an opening one quarter of an inch across. The illuminating power of the gas and the rate of burning were so adjusted that each burner gave the average light of one candle. Photometric results obtained with the same sample of coal-gas showed that successive observations made with standard gas gave closely corresponding results.

On Hederic Acid and Resin of Scammony. *By* CHARLES T. KINGZETT, *F.C.S.*

In a paper "On some new Reactions in Organic Chemistry and their Ultimate Bearings"*, the author, in conjunction with Dr. H. W. Hake, has described a number of instances in which bodies (for instance, camphor) give with strong sulphuric acid and sugar a violet-coloured product. Other bodies give this colour with sulphuric acid without the addition of sugar; and by means of these reactions the constitution of many substances may be in a measure predicted.

Hederic acid $C_{16}H_{26}O_4$ (Possett; also Davies), a constituent of ivy-leaves, gives this colour-test with sulphuric acid; also in a less degree does resin of scammony. In the present paper the author has described the processes by which he has isolated glucose from the respective substances, thus confirming the hypothesis given in his original paper above alluded to. Incidentally it is shown that the root of *Convolvulus scammonia* contains no alkaloid; and some information is given regarding a volatile oil obtained below 90° C. on distillation of scammony resin.

Preliminary Account of the Alkaloids from Japanese Aconite.
By B. H. PAUL, *Ph.D., F.C.S., and* C. T. KINGZETT, *F.C.S.*

The authors have isolated from Japanese Aconite an alkaloid of the formula $C_{29}H_{43}NO_9$, which is crystalline, but does not form crystallizable salts. It is further shown that when the alkaloidal principle is extracted by means of Duquesnel's process, it is accompanied by the salt of an alkaloid, perhaps aconitrate of aconitine; and from this it is suggested that the so-called aconitine obtained and analyzed by Wright and others has never been obtained absolutely pure, being probably a variable mixture of the alkaloid with the above salt.

Albumen of Commerce. *By* C. T. KINGZETT, *F.C.S., and* M. ZINGLER.

In the patent process described by the authors, albumen solutions are bleached and preserved by passing a current of air through them in presence of oil of turpentine at a temperature of about 40° C. Under these conditions, the turpentine oxidizes, forming peroxide of hydrogen, camphoric acid, &c., the former of which bodies effects, as it forms, the bleaching of blood, serum, or other albuminous solutions, while the camphoric acid &c. preserves them in the liquid state entirely free from putrescible or other changes.

On an Improved System of Alkali Manufacture. *By* JAMES MACTEAR, *F.C.S.*

The author claims for this system these advantages:—1. By its use the output of the furnaces had been increased from 50 to 70 per cent. 2. That there is a large saving both during lixiviation and in coal. 3. That there is a much reduced quantity of waste. 4. That there is a considerably increased yield of alkali from a given amount of sulphate of soda. 5. That there is a considerable saving in wages. This new process has been widely adopted in Great Britain, and is also very successfully used in France.

On a new Mechanical Furnace used in the Alkali Manufacture and for Calcining Purposes generally. *By* JAMES MACTEAR.

Regeneration of Sulphur employed in the Alkali Manufacture by the Mactear Process. *By* JAMES MACTEAR.

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* Pharm. Journ., May 12, 1876.

On some Properties of Gallium. By Dr. ODLING, *F.R.S.*

Note on Benzine Derivatives. By Dr. ODLING, *F.R.S.*

Note on Dr. W. Gibb's Researches on Cobaltamines. By Dr. ODLING, *F.R.S.*

On the Constitution of Mellitic Acid. By S. E. PHILLIPS.

On the Principle of Uric Acid Genesis. By S. E. PHILLIPS.

Note on some recent Changes of Gold Surfaces. By T. A. READWIN.

On some recent Gold Pseudomorphs. By T. A. READWIN.

On the Oxidation of Colophony. By Dr. D. C. ROBB.

On some Circular Tables for Analysis. By S. P. THOMPSON.

These tables, designed by Prof. Denis Monnier, of Geneva, exhibited in a compact form the results of all the chief reactions used in chemical analysis. The reactions of the several bases and acids were grouped in sectors around the circumference of two disks of card provided with indicators.

On the Action of various Fatty Oils upon Copper. By WILLIAM H. WATSON, *F.C.S.*

This communication enumerates a number of experiments showing the extent to which ten different oils act upon copper. The conclusions arrived at are that paraffin oil and castor oil have the least action upon copper, while the action of sperm oil and seal oil is but slight. The rest of the oils examined (linseed, olive, almond, colza, sesame, and neat's-foot) all acted considerably upon copper, and the action of linseed oil was especially great.

The author concludes, from experiments, that the comparative action of different oils cannot, in all cases, be correctly decided upon from the *appearances* of the oils after exposure to copper plates, though minute quantities of the metal may be easily *detected* in *most* oils from the colour produced.

On Pyrocatechin as a Derivative of certain Varieties of Tannic Acid. By Dr. JOHN WATTS.

On the Arctic Coal brought home by the late Expedition. By T. WILLS, *F.C.S.*

A seam of coal was discovered by the late Expedition on the west side of Robeson Channel, in Grantland, lat. 81° 44′ N., long. 65° 3′ W., about two miles from the winter-quarters of the second ship of the Expedition, H.M.S. 'Discovery.' The coal occurs in the side of a narrow mountain-gorge in the form of a slight saddleback, thickest in the centre, and becoming continually smaller towards each end; the seam was exposed on the N.W. side of the gorge for a considerable distance; the thickness of the seam at the deepest visible portion was 25 feet. Neither the bottom of the seam nor the underlying strata were visible at any place; the height, from the top of the seam to the surface of the ground above the gorge, was about 30 feet. Above the coal was a shale containing numerous impressions of Miocene plants. The seam is almost uniform in character and free from clayey veins. The prevailing rock of the surrounding district is a shingly clay-stone, somewhat similar to the red Miocene rock of the Disco Coal-beds.

The coal has a bright shiny appearance, looking somewhat of a pitchy character; it is very brittle, but possesses a slight cleavage, sometimes having a conchoidal fracture. When finely powdered it is of a brown colour, which is the case with most bituminous coals. Here and there small particles of iron pyrites were observable. The following is the result of several analyses:—

Specific gravity	1·29
Moisture	2·38
Ash	6·21
Sulphur	·96
Carbon	76·95
Hydrogen	5·43
Oxygen and Nitrogen by difference	8·07
	100·00

These figures indicate a coal of very good quality, and of very much the same character as the coal from some of the English coal-fields.

The Arctic coal gives about 65 per cent. of coke, which exhibits a very slight amount of caking. The ash is white and bulky, and contains silica and alumina, with a little free lime, present no doubt in the coal as carbonate, also a very small quantity of iron. The calorific value is high. The coal can readily be obtained by the process of quarrying; and the author points out the probable use which would be made of it by any future expedition.

It is probable that this coal is one of those which, although in reality Miocene, approach in their character very nearly to true Carboniferous coals. For the details regarding the position in which the coal is found the author is indebted to Dr. Coppinger, late of H.M.S. 'Discovery.'

Contributions to Chemical Dynamics. By Dr. C. R. Alder Wright.

On the Aconite Alkaloids. By Dr. C. R. Alder Wright.

GEOLOGY.

Address by W. Pengelly, *F.R.S., F.G.S., President of the Section.*

When, as long ago as 1841, the British Association made its only previous visit to Plymouth, some of us, now amongst its oldest members, thought ourselves too young to take any part in its proceedings. If the effects of that meeting are still traceable in this district, it will be admitted, of course, that the seed then sown was of excellent quality and that it fell on good soil. Be this as it may, the hope may be cherished that thirty-six years will not again be allowed to elapse between two consecutive visits to the capital of the two south-western counties.

One effect of this wide hiatus is the loss of almost all the human links whose presence on this occasion would have pleasantly connected the present with the past. A glance at the lists of Trustees and the General, Sectional, and Local officers in 1841 will show that the presence of scarcely one of them can be hoped for on this occasion; and there is but little probability that any of those who prepared Reports or Papers for the last Plymouth Meeting will have done so for that which is now assembled.

Nor are these the only changes. In 1841 Section C embraced, as at the beginning, the Geographers as well as the Geologists; but ten years later the geographers were detached, whether to find room for themselves, or to make room for the students of an older geography, it is not necessary to inquire.

Some years afterwards came an innovation which, until entering on the preparation of this address, I always regarded as a decided improvement. The first Presidential Address to this Section was delivered at Leeds in 1858 by the late Mr. Hopkins, so well known to geologists for his able application of his great mathematical powers to sundry important problems in their Science; and from that time to the present, with the exception of the Meetings of 1860 and 1870 only, the President of this Section has delivered an address.

None of the local geological papers read in 1841 appear to have attracted so much attention as those on Lithodomous Perforations, Raised Beaches, Submerged Forests, and Caverns (see 'Athenæum' for 7th to 28th of August, 1841); and, as an effort to connect the present with the past, I have decided on taking up one of these threads, and devoting the remarks I have now to offer to the History of Cavern-Exploration in Devonshire. I am not unmindful that there were giants in those days; and no one can deplore more than I do our loss of Buckland and De la Beche, amongst many others; nor can I forget the enormous strides opinion has made since 1841, when, in this Section, Dr. Buckland "contended that human remains had never been found under such circumstances as to prove their contemporaneous existence with the hyænas and bears of the Caverns," and added that "in Kent's Hole the Celtic knives........were found in holes *dug by art*, and which had disturbed the floor of the cave and the bones below it" ('Athenæum,' 14th Aug. 1841, p. 626). This scepticism, however, did the good service of inducing cavern explorers to conduct their researches with an accuracy which should place their results, whatever they might prove to be, amongst the undoubted additions to human knowledge.

The principal Caverns in South Devon occur in the limestone districts of Plymouth, Yealmpton, Brixham, Torquay, Buckfastleigh, and Chudleigh; but as those in the last two localities have yielded nothing of importance to the Anthropologist or the Palæontologist, they will not be further noticed on this occasion. In dealing with the others it seems most simple to follow mainly the order of chronology; that is to say, to commence with the Cavern which first caught scientific attention, and, having finished all that the time at my disposal will allow me to say about it, but not before, to proceed to the next, in the order thus defined; and so on through the series.

Oreston Caverns.—When Mr. Whidbey engaged to superintend the construction of the Plymouth Breakwater, Sir Joseph Banks, President of the Royal Society, requested him to examine narrowly any caverns he might meet with in the limestone-rock to be quarried at Oreston, near the mouth of the river Plym, not more than two miles from the room in which we are assembled, and have the bones or any other fossil remains that were met with carefully preserved (see Phil. Trans. 1817, pp. 176–182). This request was cheerfully complied with, and Mr. Whidbey had the pleasure of discovering bone-caves in November 1816, November 1820, August and November 1822, and of sending the remains found in them to the Royal Society.

It is, perhaps, worthy of remark that, though Cavern-researches received a great impulse from the discoveries in Kirkdale, Yorkshire, and especially from Dr. Buckland's well-known and graphic descriptions of them, such researches had originated many years before. The request by Sir Joseph Banks was made at least as early as 1812 (see Trans. Devon. Assoc. v. pp. 252, 253), and a paper on the Oreston discoveries was read to the Royal Society in February 1817, whereas the Kirkdale Cavern was not discovered until 1821. British Cave-hunting appears to have been a science of Devonshire birth.

The Oreston Caverns soon attracted a considerable number of able observers; they were visited in 1822 by Dr. Buckland and Mr. Warburton; and in a comparatively short time became the theme of a somewhat voluminous literature. Nothing of importance, however, seems to have been met with from 1822 until 1858, when another cavern, containing a large number of bones, was broken into. Unfortunately, there was no one at hand to superintend the exhumation of the specimens; the work was left entirely to the common workmen, and was badly done; many of the remains were dispersed beyond recovery; the matrix in which they were buried was never adequately examined; and we are utterly ignorant, and must for ever remain so, as to whether they did or did not contain indications of human existence. I visited the spot from time to time, and bought up every thing to be met with; but other scientific work in another part of the county occupied me too closely to allow more than an occasional visit. The greater part of the specimens I secured were lodged in the British Museum, where they seem to have been forgotten, whilst a few remain in my private collection.

Some difference of opinion has existed respecting the character of the successive caverns, and much mystery has been imported into the question of the introduction of their contents. Mr. Whidbey, it is said, "saw no possibility of the cavern of 1816 having had any external communication through the rock in which it was enclosed" (Phil. Trans. 1817, pp. 176–182); but Dr. Buckland was of opinion that they were all at first fissures open at the top, and "that the openings had been long filled up with rubbish, mud, stalactite, or fragments of rock cemented, as sometimes happens, into a breccia as solid as the original rock, and overgrown with grass" (Phil. Trans. 1822, pp. 171–240).

The conclusion I arrived at, after studying so much of the roof of the cavern of 1858 as remained intact, was that Dr. Buckland's opinion was fully borne out by the facts; that, in short, the Oreston caverns were *Fissure Caverns*, not *Tunnel Caverns*.

The Cavern of 1858 was an almost vertical fissure, extending a length of about 90 feet from N.N.E. to S.S.W. It commenced at about 8 feet below the surface of the plateau, continued thence to the base of the cliff, but how much further was not known, and its ascertained height was about 52 feet. It was 2 feet wide at top, whence it gradually widened to 10 feet at bottom. The roof, judging from that part which had not been destroyed, was a mass of limestone-breccia, made up of large angular fragments, cemented with carbonate of lime, and requiring to be blasted as much as ordinary limestone. The Cavern was completely filled with deposits of various kinds.

The uppermost 8 feet consisted of loose angular pieces of limestone, none of which exceeded 10 lb. in weight, mixed with a comparatively small amount of such sand as is common in dolomitized limestone districts, but without a trace of stalagmite or fossil of any kind. The 32 feet next below were occupied with similar materials, with the addition of a considerable quantity of tough, dark, unctuous clay. Between this mass and the outer wall of the cavern was a nearly vertical plate of stalagmite, usually about 2 feet thick, and containing, at by no means wide intervals, firmly cemented masses of breccia identical in composition with the adjacent bed just mentioned. The bones the cavern yielded were all found within these 32 feet; and were met with equally in the loose and the coherent breccia, as well as in the stalagmite. A somewhat considerable number of ellipsoidal balls of clay, from 1·5 to 2·5 inches in greatest diameter, occurred in the clay of this bone-bed, but not elsewhere. Still lower was a mass of dark, tough, unctuous clay, containing a very few, small, angular stones, but otherwise perfectly homogeneous, and known to be 12 feet deep, but how much more was undetermined.

The osseous remains found at Oreston prior to 1858 have been described by Sir E. Home, Mr. Clift, Dr. Buckland, Professor Owen, Mr. Busk, and others. The animals represented were *Ursus priscus*, *U. spelæus*, Weasel (?), Wolf, Fox, Cave Hyæna, Cave Lion, *Rhinoceros leptorhinus*, *Equus fossilis*, *E. plicidens*, *Asinus fossilis*, *Bison minor*, *Bos longifrons*, and, according to the late Mr. Bellamy, Mammoth and Hippopotamus (see Nat. Hist. of S. Devon, 1839, p. 82). With regard to Hippopotamus, I can only say that I have never met with satisfactory evidence of its occurrence in Devonshire; but the Mammoth was certainly found at Oreston in 1858; and, unless I am greatly in error, remains of *Rhinoceros tichorhinus* were also met with then, and lodged by me in the British Museum. It may be added that the skull and other relics of Hog were exhumed on that occasion, and now belong to my collection. There was nothing to suggest that the cavern had been the home of the Hyæna; and whilst I fully accept Dr. Buckland's opinion that animals had fallen into the open fissures and there perished, and that the remains had subsequently been washed thence into the lower vaultings (Reliq. Dil. 2nd ed. 1834, p. 78), I venture to add that some of the animals may have retired thither to die; a few may have been dragged or pursued there by beasts of prey; whilst rains, such as are not quite unknown in Devonshire in the present day, probably washed in some of the bones of such as died near at hand on the adjacent plateau. Nothing appears to have been met with suggestive of human visits.

Kent's Hole.—About a mile due east from Torquay harbour and half a mile north from Torbay, there is a small wooded limestone hill, the eastern side of which is, for the uppermost 30 feet, a vertical cliff, having at its base, and 54 feet apart, two apertures leading into one and the same vast cavity in the interior of the hill, and known as Kent's Hole or Cavern. These openings are about 200 feet above mean sea-level, and from them the hill slopes rapidly to the valley at its foot, at a level of from 60 to 70 feet below.

There seems to be neither record nor tradition of the discovery of the Cavern. Richardson, in the 8th edition of 'A Tour through the Island of Great Britain,' published in 1778, speaks of it as "perhaps the greatest natural curiosity" in the county; its name occurs on a map dated 1769; it is mentioned in a lease dated 1659; visitors cut their names and dates on the stalagmite from 1571 down to the present century; judging from numerous objects found on the floor, it was visited by man through mediæval back to pre-Roman times; and, unless the facts exhumed by explorers have been misinterpreted, it was a human home during the era of the Mammoth and his contemporaries.

In 1824, Mr. Northmore of Cleve, near Exeter, was led to make a few diggings in the Cavern, and was the first to find fossil bones there. He was soon followed by Mr. (now Sir) W. C. Trevelyan, who not only found bones, but had a plate of them engraved. In 1825, the Rev. J. MacEnery, an Irish Roman Catholic priest residing in the family of Mr. Cary, of Tor Abbey, Torquay, first visited the Cavern, when he, too, found teeth and bones, of which he published a plate. Soon after, he made another visit, accompanied by Dr. Buckland, when he had the good fortune to discover a flint implement—the first instance, he tells us, of such a relic being noticed in any cavern (see Trans. Devon. Assoc. iii. p. 441). Before the close of 1825, he commenced a series of more or less systematic diggings, and continued them until, and perhaps after, the summer of 1829 (ibid. p. 295). Preparations appear to have been made to publish the results of his labours; a prospectus was issued, numerous plates were lithographed, it was generally believed that the MS. was almost ready, and the only thing needed was a list of subscribers sufficient to justify publication, when, alas! on 18th February, 1841, before the printer had received any "copy," before even the world of Science had accepted his anthropological discoveries, before the value of his labours was known to more than a very few, Mr. MacEnery died at Torquay.

After his decease his MS. could not be discovered, and its loss was duly deplored. Nevertheless, it was found after several years, and, having undergone varieties of fortune, became the property of Mr. Vivian, of Torquay, who, having published portions of it in 1859, presented it in 1867 to the Torquay Natural-History Society, whose property it still remains. In 1869, I had the pleasure of printing the whole, in the 'Transactions of the Devonshire Association.'

Whilst Mr. MacEnery was conducting his researches, a few independent diggings, on a less extensive scale, were undertaken by other gentlemen. The principal of these was Mr. Godwin-Austen, the well known geologist, whose papers fully bore out all that MacEnery had stated. (See Trans. Geol. Soc. Lond. 2nd series, vi. p. 446.) In 1846, a sub-committee of the Torquay Natural-History Society undertook the careful exploration of very small parts of the Cavern, and their Report was entirely confirmatory of the statements of their predecessors—that undoubted flint implements did occur, mixed with the remains of extinct mammals, in the cave-earth, beneath a thick floor of stalagmite. The sceptical position of the authorities in geological science remained unaffected, however, until 1858, when the discovery and systematic exploration of a comparatively small virgin cavern on Windmill Hill, at Brixham, led to a sudden and complete revolution; for it was seen that whatever were the facts elsewhere, there had undoubtedly been found at Brixham flint implements commingled with remains of the Mammoth and his companions, and in such a way as to render it impossible to doubt that Man occupied Devonshire before the extinction of the cave mammals.

Under the feeling that the statements made by MacEnery and his followers respecting Kent's Hole were perhaps, after all, to be accepted as verities, the British Association, in 1864, appointed a Committee to make a complete, systematic, and accurate exploration of the Cavern, in which it was known that very extensive portions remained entirely intact. This Committee commenced its labours on 28th March, 1865; it has been reappointed, year after year, with sufficient grants of money, up to the present time; the work has gone on continuously throughout the entire thirteen years; and the result has been, not only a complete confirmation of Mr. MacEnery's statements, but the discovery of far older deposits than he suspected—deposits implying great changes of, at least, local geographical conditions; changes in the fauna of the district; and yielding evidence of men more ancient and far ruder than even those who made the oldest flint tools found in Kent's Hole prior to the appointment of the Committee.

The Cavern consists of a series of chambers and passages, which resolve themselves into two main *Divisions,* extending from nearly north to south in parallel lines, but passing into each other near their extremities, and throwing off branches, occasionally of considerable size.

The successive deposits, in descending order, were:—

1st, or uppermost. Fragments and blocks of limestone from an ounce to upwards of 100 tons weight each, which had fallen from the roof from time to time, and were in some instances cemented with carbonate of lime.

2nd. Beneath and between these blocks lay a dark-coloured mud or mould, consisting largely of decayed leaves and other vegetable matter. It was from 3 to 12 inches thick, and known as the *Black Mould.* This occupied the entire Eastern Division, with the exception of a small chamber in its south-western end only, but was not found in the other, the remoter, parts of the Cavern.

3rd. Under this was a Stalagmitic Floor, commonly of granular texture and frequently laminated, from less than an inch to fully 5 feet in thickness, and termed the *Granular Stalagmite.*

4th. An almost black layer, about 4 inches thick, composed mainly of small fragments of charred wood, and distinguished as the *Black Band,* occupied an area of about 100 square feet, immediately under the Granular Stalagmite, and, at the nearest point, not more than 32 feet from one of the entrances to the Cavern. Nothing of the kind has occurred elsewhere.

5th. Immediately under the Granular Stalagmite and the Black Band lay a light red clay, containing usually about 50 per cent. of small angular fragments of limestone, and somewhat numerous blocks of the same rock as large as those lying on the Black Mould. In this deposit, known as the *Cave-earth,* many of the stones and bones were, at all depths, invested with thin stalagmitic films. The Cave-earth was of unknown depth near the entrances, where its base had never been reached; but in the remoter parts of the Cavern it did not usually exceed a foot, and in a few localities it "thinned out" entirely.

6th. Beneath the Cave-earth there was usually found a Floor of Stalagmite having a crystalline texture, and termed on that account the *Crystalline Stalagmite.* It was commonly thicker than the Granular Floor, and in one instance but little short of 12 feet.

7th. Below the whole occurred, so far as is at present known, the oldest of the Cavern deposits. It was composed of subangular and rounded pieces of dark red grit, embedded in a sandy paste of the same colour. Small angular fragments of limestone, and investing films of stalagmite, both prevalent in the Cave-earth, were extremely rare. Large blocks of limestone were occasionally met with; and the deposit, to which the name of *Breccia* was given, was of a depth exceeding that to which the exploration has yet been carried.

Except in a very few small branches, the bottom of the Cavern has nowhere been reached. In the cases in which there was no Cave-earth, the Granular Stalagmite rested immediately on the Crystalline; and where the Crystalline Stalagmite was not present, the Cave-earth and Breccia were in direct contact. Large isolated masses of the Crystalline Stalagmite, as well as concreted lumps of the Breccia, were occasionally met with in the Cave-earth, thus showing that the older deposits had, in portions of the Cavern, been partially broken up, dislodged, and redeposited. No instance was met with of the incorporation in a lower bed of fragments derived from an upper one. In short, wherever all the deposits were found in one and the same vertical section, the order of superposition was clear and invariable; and elsewhere the succession, though defective, was never transgressed.

Excepting the overlying blocks of limestone, of course, all the deposits contained remains of animals, which, however, were not abundant in the Stalagmites.

The Black Mould, the uppermost bed, yielded teeth and bones of Man, Dog, Fox, Badger, Brown Bear, *Bos longifrons*, Roedeer, Sheep, Goat, Pig, Hare, Rabbit, and Seal—species still existing, and almost all of them in Devonshire. This has been called the *Ovine* bed, the remains of Sheep being restricted to it. In it were also found numerous flint flakes and "strike-lights;" stone spindle whorls; fragments of curvilineal pieces of slate; amber beads; bone tools, including awls, chisels, and combs; bronze articles, such as rings, a fibula, a spoon, a spear-head, a socketed celt, and a pin; pieces of smelted copper; and a great number and variety of potsherds, including fragments of Samian ware.

The Granular Stalagmite, Black Band, and Cave-earth, taken together as belonging to one and the same biological period, may be termed the *Hyænine* beds, the Cave Hyæna being their most prevalent species and found in them alone. So far as they have been identified, the remains belong to the Cave Hyæna, *Equus caballus*, *Rhinoceros tichorhinus*, Gigantic Irish Deer, *Bos primigenius*, *Bison priscus*, Red Deer, Mammoth, Badger, Cave Bear, Grizzly Bear, Brown Bear, Cave Lion, Wolf, Fox, Reindeer, Beaver, Glutton, *Machairodus latidens*, and Man—the last being a part of a jaw with teeth, in the Granular Stalagmite. In the same beds were found unpolished *ovate* and *lanceolate* implements made from *flakes*, not *nodules*, of flint and chert; flint flakes, chips, and "cores;" "whetstones;" a "hammer-stone;" "dead" shells of *Pecten*; bits of charcoal; and bone tools, including a needle or bodkin having a well-formed eye, a pin, an awl, three harpoons, and a perforated tooth of Badger. The artificial objects, of both bone and stone, were found at all depths in each of the Hyænine beds, but were much more numerous below the Stalagmite than in it.

The relics found in the Crystalline Stalagmite and the Breccia, in some places extremely abundant, were almost exclusively those of Bear, the only exceptions being a very few remains of Cave Lion and Fox. Hence these have been termed the *Ursine* beds. It will be remembered that teeth and bones of Bear were also met with in both the Hyænine and the Ovine beds; and it should be understood that this biological classification is intended to apply to Kent's Cavern only. The Ursine deposits, or rather the Breccia, the lowest of them, also yielded evidences of human existence; but they were exclusively tools made from *nodules*, not *flakes*, of flint and chert.

Ansty's-Cove Cavern.—About 3 furlongs from Kent's Hole towards N.N.E., near the top of the lofty cliff forming the northern boundary of the beautiful Ansty's Cove, Torquay, there is a cavern where, simultaneously with those in Kent's Cavern, Mr. MacEnery conducted some researches, of which he has left a brief account (see Trans. Devon. Assoc. vi. pp. 61–69). I have visited it several times, but it seems to be frequently kept under lock and key, as a tool and powder house, by the workmen in a neighbouring quarry. It is a simple gallery, and, according to Mr. MacEnery, 63 feet long, from 3 to 9 feet high, and from 3 to 6 feet broad. Beneath some angular stones he found a stalagmitic floor 14 inches thick, and in the deposit below remains of Deer, Horse, Bear, Fox, Hyæna (?), Coprolites, a few marine and land shells, one white flint tool with fragments of others, a Roman coin, and potsherds.

In a letter to Sir W. C. Trevelyan, dated 16th December, 1825, Dr. Buckland states that Mr. MacEnery had found in this Cave "bones of all sorts of beasts, and also flint knives and Roman coins; in short, an open-mouthed cave, which has been inhabited by animals of all kinds, quadruped and biped, in all successive generations, and who have all left their exuviæ one upon another" (ibid. p. 69).

Yealm-Bridge Cavern.—About the year 1832 the workmen broke into a bone-cavern in Yealm-Bridge quarry, about one mile from the village of Yealmpton, and eight miles E.S.E. from Plymouth; and through their operations it was so nearly destroyed that but a small arm of it remained in 1835, when it was visited by Mr. J. C. Bellamy, who at once wrote an account of it, from which it appears that, so far as he could learn, the Cavern was about 30 feet below the original limestone surface, and was filled to within from 1 foot to 6 feet of the roof (see Nat. Hist. S. Devon, 1839, pp. 86–105). In the same year, but subsequently, it was examined by Captain (afterwards Colonel) Mudge, who states that there were originally three openings into the Cave, each about 12 feet above the river Yealm; that the deposits were, in descending order:—

1. Loam with bones and stones	3·5	feet.
2. Stiff whitish clay	2·5	„
3. Sand	6·0	„
4. Red clay	3·5	„
5. Argillaceous sand	6 to 18·0	„

and that, where they did not reach the roof, the deposits were covered with stalagmite.

On the authority of Mr. Clift and Professor Owen, Capt. Mudge mentions relics of Elephant, Rhinoceros, Horse, Ox, Sheep, Hyæna, Dog, Wolf, Fox, Bear, Hare, and Water-Vole. The bones, and especially the teeth, of the Hyæna exceeded in number those of all the other animals, though remains of Horse and Ox were very abundant. Mr. Bellamy, whilst also mentioning all the foregoing forms, with the exception of Dog only, adds, Deer, Pig, Glutton, Weasel, and Mouse. He also speaks of the abundance of bones and teeth of Hyæna, but seems to regard the Fox as being almost as fully represented; and next in order he places Horse, Deer, Sheep, and Rabbit or Hare; whilst the relics of Elephant, Wolf, Bear, Pig, and Glutton are spoken of as very rare. The bones, he says, were found in the uppermost bed only. They were frequently mere fragments and splinters, some being undoubtedly gnawed, and all had become very adherent through loss of their animal matter. Those of cylindrical form were without their extremities; there was no approach to anatomical juxtaposition; and the remains belonged to individuals of all ages. Reliquiæ of Carnivorous animals greatly exceeded those of the Herbivora, and teeth were very abundant. Coprolites occurred at some depth below the stalagmite, in the upper bed, which also contained granitic and trappean pebbles, and lumps of breccia made up of fragments of rock, bones, pebbles, and stalagmite. The bones found prior to 1835 had been removed as rubbish, and some good specimens were recovered from materials employed in making a pathway. Nothing indicating the presence of man appears to have been found.

The Ash-Hole.—On the southern shore of Torbay, midway between the town of Brixham and Berry Head, and about half a mile from each, there is a cavern known as the *Ash-Hole.* It was partially explored, probably about, or soon after, the time Mr. MacEnery was engaged in Kent's Hole, by the late Rev. H. F. Lyte, who, unfortunately, does not appear to have left any account of the results. The earliest mention of this Cavern I have been able to find is a very brief one in Bellamy's 'Natural History of South Devon,' published in 1839 (p. 14). During the Plymouth Meeting in 1841, Mr. George Bartlett, a native of Brixham, who assisted Mr. Lyte, described to this Section the objects of interest the Ash-Hole had yielded (see Report Brit. Assoc. 1841, Trans. Sections, p. 61). So far as was then known the

Cave was 30 yards long and 6 yards broad. Below a recent accumulation, 4 feet deep, of loam and earth, with land and marine shells, bones of the domestic fowl and of Man, pottery, and various implements, lay a true Cave-earth, abounding in the remains of Elephant. Professor Owen, who identified, from this lower bed, relics of Badger, Polecat, Stoat, Water-Vole, Rabbit, and Reindeer, remarks, that for the first good evidence of the Reindeer in this island he had been indebted to Mr. Bartlett, who stated that the remains were found in this Cavern (see Brit. Foss. Mam. 1846, pp. 109–110, 113–114, 116, 204, 212, 479–480). I have made numerous visits to the spot, which, when Mr. Lyte began his diggings, must have been a shaft-like fissure, accessible from the top only. A lateral opening, however, has been quarried into it; there is a narrow tunnel extending westward, in which the deposit is covered with a thick sheet of stalagmite, and where one is tempted to believe that a few weeks labour might be well invested.

Brixham Cavern.—Early in 1858 an unsuspected Cavern was broken into by quarrymen at the north-western angle of Windmill Hill at Brixham, at a point 75 feet above the surface of the street almost vertically below, and 100 feet above mean tide. On being found to contain bones, a lease in it was secured for the Geological Society of London, who appointed a Committee of their members to undertake its exploration; funds were voted by the Royal Society, and supplemented by private subscriptions; the conduct of the investigation was intrusted to Mr. Prestwich and myself; and the work, under my superintendence, as the only resident member of the Committee, was begun in July 1858 and completed at midsummer 1859.

The Cavern, comprised within a space of 135 feet from north to south, and 100 from east to west, consisted of a series of tunnel galleries from 6 to 8 feet in greatest width, and 10 to 14 feet in height, with two small Chambers and five external entrances.

The deposits, in descending order, were:—

1st, or uppermost. A Floor of Stalagmite, from a few inches to a foot thick, and continuous over very considerable areas, but not throughout the entire Cavern.

2nd. A mass of small angular fragments of limestone, cemented into a firm concrete with carbonate of lime, commenced at the principal entrance, which it completely filled, and whence it extended 34 feet only. It was termed the *First Bed.*

3rd. A layer of blackish matter, about 12 feet long, and nowhere more than a foot thick, occurred immediately beneath the First Bed, and was designated the *Second Bed.*

4th. A red, tenacious, clayey loam, containing a large number of angular and subangular fragments of limestone, varying from very small bits to blocks a ton in weight, made up the *Third Bed.* Pebbles of trap, quartz, and limestone were somewhat prevalent, whilst nodules of brown hematite of iron and blocks of stalagmite were occasionally met with in it. The usual depth of the bed was from 2 to 4 feet, but this was exceeded by 4 or 5 feet in two localities.

5th. The Third Bed lay immediately on an accumulation of pebbles of quartz, greenstone, grit, and limestone, mixed with small fragments of shale. The depth of this, known as the *Fourth* or *Gravel Bed,* was undetermined; for, excepting a few feet only, the limestone bottom was nowhere reached. There is abundant evidence that this bed, as well as a stalagmitic floor which had covered it, had been partially broken up and dislodged before the introduction of the Third Bed.

Organic remains were found in the Stalagmitic Floor and in each of the beds beneath it, with the exception of the Second only; but as 95 per cent. of the whole series occurred in the Third, this was not unfrequently termed the *Bone Bed.*

The Mammals represented in the Stalagmite were Bear, Reindeer, *Rhinoceros tichorhinus,* Mammoth, and Cave Lion.

The First Bed yielded Bear and Fox only.

In the Third Bed were found relics of Mammoth, *Rhinoceros tichorhinus,* Horse, *Bos primigenius, B. longifrons,* Red Deer, Reindeer, Roebuck, Cave Lion, Cave Hyæna, Cave Bear, Grizzly Bear, Brown Bear, Fox, Hare, Rabbit, *Lagomys spelæus,* Water-Vole, Shrew, Polecat, and Weasel.

The only remains met with in the Fourth Bed were those of Bear, Horse, Ox, and Mammoth.

The Human Industrial Remains exhumed in the Cavern were flint implements and a hammer-stone, and occurred in the Third and Fourth Beds only. The pieces of flint met with were 36 in number. Of these, 15 are held to show evidence of having been artificially worked, in 9 the workmanship is rude or doubtful, 4 have been mislaid, and the remainder are believed not to have been worked at all (see Phil. Trans. vol. 163, 1873, pp. 561, 562). Of the undoubted tools, 11 were found in the Third and 4 in the Fourth Bed. Two of those yielded by the Third Bed, found 40 feet apart, in two distinct but adjacent galleries, and one a month before the other, proved to be parts of one and the same *nodule*-tool; and I have little or no doubt that it had been washed out of the Fourth Bed and redeposited in the Third.

The Hammer-Stone was a quartzite pebble, found in the upper portion of the Fourth Bed, and bore distinct marks of the use to which it was applied.

Speaking of the discovery of the tools just mentioned, Mr. Prestwich said in 1859:—"It was not until I had myself witnessed the conditions under which flint implements had been found at Brixham, that I became fully impressed with the validity of the doubts thrown upon the previously prevailing opinions with respect to such remains in caves" (Phil. Trans. 1860, p. 280); and according to Sir C. Lyell, writing in 1863:—"A sudden change of opinion was brought about in England respecting the probable coexistence, at a former period, of man and many extinct mammalia, in consequence of the results obtained from the careful exploration of a Cave at Brixham. . . . . The new views very generally adopted by English geologists had no small influence on the subsequent progress of opinion in France" (Antiquity of Man, pp. 96, 97).

Bench Cavern.—Early in 1861 information was brought me that an ossiferous cave had just been discovered at Brixham, and, on visiting the spot, I found that, of the limestone quarries worked from time to time in the northern slope of Furzeham Hill, one known as Bench Quarry, about half a mile due north of Windmill-Hill Cavern, and almost overhanging Torbay, had been abandoned in 1839, and that work had been recently resumed in it. It appeared that in 1839 the workmen had laid bare the greater part of a vertical dyke, composed of red clayey loam and angular pieces of limestone, forming a coherent wall-like mass, 27 feet high, 12 feet long, 2 feet in greatest thickness, and at its base 123 feet above sea-level. In the face of it lay several fine relics of the ordinary Cave Mammals, including an entire left lower jaw of *Hyæna spelæa* replete with teeth, but which had nevertheless failed to arrest the attention of the incurious workmen who exposed it, or of any one else.

Soon after the resumption of the work in 1861, the remnant of the outer wall of the fissure was removed, and caused the fall of an incoherent part of the dyke, which it had previously supported. Amongst the débris the workmen collected some hundreds of specimens of skulls, jaws, teeth, vertebræ, portions of antlers, and bones, but no indications of Man. Mr. Wolston, the proprietor, sent some of the choicest specimens to the British Museum, and submitted the remainder to Mr. Ayshford Sanford, F.G.S., from whom I learn that the principal portion of them are relics of the Cave Hyæna, from the unborn whelp to very aged animals. With them, however, were remains of Bear, Reindeer, Ox, Hare, *Arvicola ratticeps*, *A. agrestis*, Wolf, Fox, and part of a single maxillary with teeth not distinguishable from those of *Canis isatis*. To this list I may add Rhinoceros, of which Mr. Wolston showed me at least one bone.

From the foregoing undesirably, but unavoidably, brief descriptions, it will be seen that the Devonshire Caverns, to which attention has been now directed, belong to two classes,—those of Oreston, the Ash-Hole, and Bench being *Fissure Caves*; whilst those of Yealm Bridge, Windmill Hill at Brixham, Kent's Hole, and Ansty's Cove are *Tunnel Caves*.

Windmill-Hill and Kent's Hole Caverns have alone been satisfactorily explored; and besides them none have yielded evidence of the contemporaneity of Man with the extinct Cave Mammals.

Oreston is distinguished as the only known British Cavern which has yielded remains of *Rhinoceros leptorhinus* (Quart. Journ. Geol. Soc. xxvi. p. 456).

Yealm-Bridge Cavern, if we may accept Mr. Bellamy's identification in 1835, was the first in this country in which relics of Glutton were found (South Devon Monthly Museum, vi. pp. 218–223; see also Nat. Hist. S. Devon, 1839, p. 89). The same species was found in the Caves of Somerset and Glamorgan in 1865 (Pleist. Mam., Pal. Soc. pp. xxi, xxii), in Kent's Hole in 1869 (Rep. Brit. Assoc. 1869, p. 207), and near Plas Heaton, in North Wales, in 1870 (Quart. Journ. Geol. Soc. xxvii. p. 407).

Kent's Hole is the only known British Cave which has afforded remains of Beaver (Rep. Brit. Assoc. 1869, p 208), and, up to the present year, the only one in which the remains of *Machairodus latidens* had been met with. Indeed, Mr. MacEnery's statement, that he found in 1826 five canines and one incisor of this species in the famous Torquay Cavern, was held by many palæontologists to be so very remarkable as, at least, to approach the incredible, until the Committee now engaged in the exploration exhumed, in 1872, an incisor of the same species, and thereby confirmed the announcement made by their distinguished predecessor nearly half a century before (Rep. Brit. Assoc. 1872, p. 46). In April last (1877) the Rev. J. M. Mello was able to inform the Geological Society of London that Derbyshire had shared with Devon the honour of having been a home of *Machairodus latidens*, he having found its canine tooth in Robin-Hood Cave in that county, and that there, as in Kent's Hole, it was commingled with remains of the Cave Hyæna and his contemporaries (Abs. Proc. Geol. Soc. No. 334, pp. 3, 4).

The Ash Hole, as we have already seen, afforded the first good evidence of a British Reindeer.

In looking at the published Reports on the two famous Torbay Caverns it will be found that they have certain points of resemblance as well as some of dissimilarity:—

1st. The lowest known bed in each is composed of materials which, whilst they differ in the two cases, agree in being such as may have been furnished by the districts adjacent to the Cavern-hills respectively, but not by the hills themselves, and must have been deposited prior to the existing local geographical conditions. In each, this bed contained flint implements and relics of Bear, but in neither of them those of Hyæna. In short, the *Fourth Bed* of Windmill-Hill Cavern, Brixham, and the *Breccia* of Kent's Hole, Torquay, are coeval, and belong to what I have called the *Ursine* period of the latter.

2nd. The beds just mentioned were in each Cavern sealed with a sheet of stalagmite, which was partially broken up, and considerable portions of the subjacent beds were dislodged before the introduction of the beds next deposited.

3rd. The Great Bone Bed, both at Brixham and Torquay, consisted of red clayey loam, with a large percentage of angular fragments of limestone; and contained *flake* implements of flint and chert, inosculating with remains of Mammoth, the tichorhine Rhinoceros, and Hyæna. In fine, the *Cave-earth* of Kent's Hole and the *Third Bed* of Brixham Cavern correspond in their materials, in their osseous contents, and in their flint tools. They both belong to what I have named the *Hyænine* period of the Torquay Cave.

But, as already stated, there are points in which the two Caverns differ:—

1st. Whilst Kent's Hole was the home of Man, as well as of the contemporary Hyæna during the absences of the human occupant, there is no reason to suppose that either Man or any of the lower animals ever did more than make occasional visits to Brixham Cave. The latter contained no flint chips, no bone tools, no utilized *Pecten*-shells, no bits of charcoal, and no coprolites of Hyæna, all of which occurred in the Cave-earth of Kent's Hole.

2nd. In the Torquay Cave relics of Hyæna were much more abundant in the Cave-earth than those of any other species. Taking the teeth alone, of which vast numbers were found, those of the Hyæna amounted to about 30 per cent. of the entire series, notwithstanding the fact that, compared with most of the Cave-mammals, his jaws, when furnished completely, possess but few teeth. At Brixham, on the other hand, his relics of all kinds amounted to no more than 8·5 per cent. of all the osseous remains, whilst those of the Bear rose to 53 per cent.

3rd. The entrances of Brixham Cavern were completely filled up and its history suspended not later than the end of the Palæolithic era. Nothing occurred within it from the days when Devonshire was occupied by the Cave and Grizzly Bears, Reindeer, Rhinoceros, Cave Lion, Mammoth, and Man, whose best tools were unpolished flints, until the quarryman broke into it early in A.D. 1858. Kent's Cavern, on the contrary, seems to have never been closed, never unvisited by Man, from the earliest Palæolithic times to our own, with the possible exception of the Neolithic era, of which it cannot be said to have yielded any certain evidence.

Though my *History of Cavern Exploration in Devonshire* is now completed, so far as the time at my disposal will allow, and so far as the materials are at present ripe for the historian, I venture to ask your further indulgence for a few brief moments whilst passing from the region of Fact to that of Inference.

That the Kent's-Hole men of the Hyænine period—to say nothing at present of their predecessors of the Breccia—belonged to the Pleistocene times of the Biologist, is seen in the fact that they were contemporary with Mammals peculiar to, and characteristic of, those times. This contemporaneity proves them to have belonged to the *Palæolithic* era of Britain and Western Europe generally, as defined by the Archæologist; and this is fully confirmed by their unpolished tools of flint and chert. That they were prior to the deposition of even the oldest part of the Peat Bogs of Denmark, with their successive layers of Beech, Pedunculated Oak, Sessile Oak, and Scotch Fir, we learn from the facts that even the lowest zone of the bogs has yielded no bones of mammals but those of recent species, and no tools but those of *Neolithic* type; whilst even the Granular Stalagmite, the uppermost of the Hyænine beds in Kent's Hole, has afforded relics of Mammoth, *Rhinoceros tichorhinus*, Cave Bear, and Cave Hyæna.

That the men of the Cave Breccia, or Ursine period, to whom we now turn, were of still higher antiquity is obvious from the geological position of their industrial remains. That the two races of Troglodytes were separated by a wide interval of time we learn from the sheet of Crystalline Stalagmite, sometimes 12 feet thick, laid down after the deposition of the Breccia had ceased, and before the introduction of the Cave-earth had begun, as well as from the entire change in the materials composing the two deposits. But, perhaps, the fact which most emphatically indicates the chronological value of this interval is the difference in the faunas. In the Cave-earth, as already stated, the remains of the Hyæna greatly exceed in number those of any other mammal; and it may be added that he is also disclosed by almost every relic of his contemporaries—their jaws have, through his agency, lost their condyles and lower borders; their bones are fractured after a fashion known by experiment to be his; and the splinters into which they are broken are deeply scored with his teeth-marks. His presence is also attested by the abundance of his droppings in every branch of the Cavern. In short, Kent's Hole was one of his *homes*; he dragged thither, piecemeal, such animals as he found dead near it; and the well-known habits of his representatives of our day have led us to expect all this from him. When, however, we turn to the Breccia a very different spectacle awaits us. We meet with no trace whatever of his presence, not a single relic of his skeleton, not a bone on which he has operated, not a coprolite to mark as much as a visit. Can it be doubted that had he then occupied our country he would have taken up his abode in our Cavern? Need we hesitate to regard this entire absence of all traces of so decided a cave-dweller as a proof that he had not yet made his advent in Britain? Are we not compelled to believe that Man formed part of the Devonshire fauna long before the Hyæna did? Is there any method of escaping the conclusion that between the era of the Breccia and that of the Cave-earth it was possible for the Hyæna to reach Britain?—in other words, that the last continental state of our country occurred during that interval? I confess that, in the present state of the evidence, I see no escape; and that the conclusion thus forced on me compels me to believe also that the earliest men of Kent's Hole were *interglacial*, if not *preglacial*.

KENT'S CAVERN.			PERIODS.				
Deposits.	*Bones.*	*Implements.*	*Archæological.*	*Danish-Bog.*	*Biological.*	*Geographical.*	*Climatal.*
Black Mould.	Ovine.	Iron,	Iron.	Beech.	Recent.	Insular.	Post-Glacial.
		Bronze, and (?)	Bronze.	Pedunculated Oak.			
				Sessile Oak.			
		Neolithic.	Neolithic.	Scotch Fir.			
Granular Stalagmite.	Hyænine.	Palæolithic Flakes.	Palæolithic.		Pleistocene.	Continental.	Glacial and Inter-Glacial.
Black band.							
Cave-earth.							
Crystalline Stalagmite.	Ursine.	Palæolithic Nodules.				Insular.	
Breccia.						Continental.	Pre-Glacial.

The foregoing Table will serve to show at one view the co-ordinations and theoretical conclusions to which the facts of Kent's Cavern have led me, as stated briefly in the foregoing remarks. The Table, it will be seen, consists of two Divisions, separated with double vertical lines. The first, or left hand, Division contains three columns, and relates exclusively to Kent's Cavern, as is indicated by the words heading it. The second, or right hand, Division is of a more general character, and shows the recognized classification of well-known facts throughout Western Europe. The horizontal lines are intended to convey the idea of more or less well-defined chronological horizons; and their occasional continuity through two or more columns denotes contemporaneity. Thus, to take an example from the two columns headed "Archæological" and "Danish-Bog," in the second Division: the horizontal line passing continuously through both, under the words "Iron" and "Beech," is intended to suggest that the "Iron Age" of Western Europe and the "Beech" zone of the Danish Bogs take us back about equally far into antiquity; whilst the position of the line under the word "Bronze," indicates that the "Bronze Age" (still of Western Europe) takes us back from the ancient margin of the Beech era, through the whole of that of the Pedunculated Oak, and about halfway through the era of the Sessile Oak; and so on in all other cases.

On the Succession of the Palæozoic Deposits of South Devon. *By* ARTHUR CHAMPERNOWNE, *M.A., F.G.S.*

Opinion is still much divided on the vexed question of the older rocks of Devon and Cornwall. General information on the history of the controversy may be gained from Prof. Geikie's 'Memoir of Sir Roderick Murchison.'

The writer (with others) holds that Jukes was right in his main thesis, viz. that the Devonian rocks are the general equivalents of the Lower Carboniferous, and not the Marine equivalents of the Old Red Sandstone; but that in his great fault theory of North Devon he was mistaken, as Mr. Etheridge has apparently demonstrated.

The South-Devonian area is perhaps more disturbed than any other equal area in the United Kingdom. Inversions are very numerous; but it is not always easy to say what beds are inverted, and what are in their normal position. To give purely palæontological reasons appears to be reasoning in a circle, and some sort of rules are necessary.

If, for example, we are studying a band of rocks inclined in one direction, but which we suspect is not intercalated between the beds on either side, and we observe that the outer or bounding planes show a tendency to converge downwards, the presumption would be that the mass is an inclined trough—if upwards, an inclined anticlinal fold. The simpler the fold the less liable we shall be to error.

In applying these principles the author selects three areas for comparison, viz., the Torquay Promontory, the tract south of Brixham and east of the Dart, and the Plymouth district.

In the Torquay district a series of Red Sandstones is undeniably subjacent to the Great Devon limestone. It is believed that the Red Sandstones of the other areas fall into the same horizon, and that together they represent the Old Red Sandstone, the base of which is scarcely seen south of the Bristol Channel.

Professor Phillips's section at Plymouth shows that the southern boundary of the Plymouth limestone is steeper by 25° than the northern (the former being 70° and the latter 45°).

Blue and grey fossiliferous slates &c. separate the limestone from the violently contorted Red Sandstones of Staddon Point.

The convergent dips of the limestone, together with the contortions of the Staddon beds, points to the conclusion that the limestone occupies a trough, and the Staddon beds are an inclined anticlinal, as Jukes also believed.

Phillips held at that time that the superposition of beds on each side of the Sound on the Plymouth limestone, "except by some improbable conjecture, could not be shaken" ('Geology of Oxford and the Valley of the Thames,' p. 79), but he subsequently modified this opinion.

The bright claret-coloured slates at Mutley, north of Plymouth, show a transitional character to Old Red Sandstone, but no sandstones are seen, and the further we cross the beds to the north the less are the axes upraised, and the slates may have overlapped the Old Red and rested on the granite before it was upheaved; but when this took place the beds which skirt it were compressed into far less space than they had previously occupied.

If the Staddon beds are above the Plymouth limestone they must be overlapped with a wide unconformity by the Culm Measures of Tavistock and Launceston; but the Culm Measures of North Devon are, on the contrary, perfectly conformable to the underlying series.

The Fossiliferous beds of Whitesand Bay, in the strike of the Plymouth limestone, are also probably older than that limestone.

In the Brixham area the limestone of Higher Brixham, extending from a little west of that town to Sharkham Point, is doubled under beds to the south older than itself. This is seen to be the case near the Point, the base of a sharply doubled inclined trough being well exposed above the sea-level, the contorted Red Sandstones of Southdown Cliff corresponding with an anticlinal.

The beds are not cut out by a fault along the strike, and it is a mistake to represent the iron-ore of Sharkham Point as a lode.

In the Torquay district, provided that the Cockington Red Sandstones, like those of the Lincombe and Warberry Hills, can be shown to be older than the limestones, these last must be the newest Palæozoic beds of the Promontory; but they are not seen in their natural relations, the intervening space being marked by New Red Rocks.

The Great Devon limestones, then, are, as Mr. H. B. Woodward has said, the highest rocks of South Devon, and the belief in a series of slates and Red Sandstones overlying them is a fallacy.

The beds which do succeed the limestones are the Culm Measures (Upper Carboniferous), and, from the field work of Messrs. Woodward and Reid, there is reason to believe them perfectly conformable.

In this case the difference between the Devonian and Carboniferons Limestones would be one of life distribution—a geographical and not a chronological difference.

This would probably have been long ago recognized had the characteristic Ichthyolites of the Old Red occurred in the Staddon beds.

If any doubt remains as to the position of the Great Devon Limestone, it might be brought to a practical test by boring through supposed Upper slates.

In America we are told that Old Red Sandstone overlies Devonian rocks and fossils. But can the Great Devon Limestone with certainty be equated with any of the formations beneath the Catskill beds? It is very doubtful, and their Lamellibranchiate Fauna is said to present somewhat of an Upper Silurian facies.

If this be so, those geologists may be quite right who look for marine equivalents of the Old Red, in some parts of the world, bridging over the Siluro-Carboniferous interval. At the same time, in not admitting that the Great Devon Limestone is such an equivalent, future observers would be unfettered in working out the structure of Devonshire.

On the Origin and Antiquity of the Mounds of Arkansas, U.S. *By* Prof. J. W. Clarke.

These mounds form a prominent feature of the State. They are present on all soils capable of cultivation, alike on the small prairies, in the densest forest, and the tablelands of the Ozark Mountains, but excepting the bottom-lands of Arkansas and Mississippi rivers. They vary from 3 to 5 feet in altitude, and are from 50 to 140 feet in diameter.

The author suggests that they were evolved from the simple corn-hillock by a race who followed the retreating glaciers.

Note on the Serpentine of Duporth, in St. Austell Bay, Cornwall. *By* J. H. Collins, *F.G.S.*

In this paper the author shows that an intrusive Greenstone rock, extensively worked for road-stone at St. Mewan, near St. Austell, is, within 3 miles of that place, converted into a Porphyritic Serpentine, and believes that this change has been effected by the agency of mineral solutions acting through fissures from below.

On the Drift of Plymouth Hoe. *By* J. H. Collins, *F.G.S.*

The author stated that excavations were nearly always going on in the neighbourhood of Plymouth Hoe, and that fresh sections of the so-called *Raised beaches* and *Glacial deposits* were continually being exposed.

He had lately visited the Hoe, Mount Batten, and Deadman's Bay, in company with Mr. Whitley, of Truro, and had found gravels, sands, and clays lying in the hollows of the limestone and filling fissures and caverns. The gravels were sometimes cemented by stalagmite into a conglomerate. The pebbles were composed of quartz, limestone, tourmaline and schist, greenstone, blue and red grit, hard clay-slate, schorl rock, granite, elvan, flint, chert, stalagmite, and one pebble of granite, all of which the author considered had been derived from the rocks of the neighbourhood within a few miles. None of the pebbles were in the least degree ice-scratched, and there were very few angular fragments of any kind.

The gravels had yielded bones of Rhinoceros, Elephants, and other animals of the so-called Mammoth period.

The author discussed the evidence of local denudation, and arrived at the following conclusions:—

1. The deposits are not raised beaches.
2. They are not glacial.
3. They were formed rapidly.
4. Gravels, fissure deposits, and cave deposits are of the same age.
5. That they belong to the Mammoth period.
6. There is no evidence in the immediate neighbourhood to carry back their formation more than a few thousand years.

Note on the Correlation of certain Post-Glacial Deposits in West Lancashire. *By* C. E. De Rance, *F.G.S., of H.M. Geological Survey.*

The valley of the Ribble, at Preston, is entirely excavated in Glacial drift, consisting of Boulder-clay, with an included bed of sand and shingle, together reaching a thickness of between 150 and 200 feet. At the bottom of the valley is a broad alluvial plain through which the river swings in a series of S-like curves, denuding away the sides of the valley, and forming them into steep cliffs where the convex curves of the S touch the margin of the valley, on the slopes of which are left fragments of old river-terraces, marking the former position of the Ribble before it had vertically denuded as low as at present.

The terraces, as well as the lowest alluvial plain, generally exhibit the following sequence of deposits:—

1. Fine alluvial silt and loam.
2. Peaty beds and trunks of trees.
3. Large gravel and stones washed out of the drift.

Marking:—1. Alluvial deposit from floods.
2. Obstruction of drainage.
3. Denudation.

Throughout Western Lancashire an extensive plain occurs often below the sea-level, covered with peat often 30 feet in thickness, and descending to a depth of some 60 feet beneath high-water mark—a depth sufficient, if the district was elevated to that amount, to connect Cumberland with the Isle of Man, in which, as in

England, *Cervus megaceros* occurs in the grey clays underlying the peat, which, in the main inland districts of Lancashire, is replaced by marine sands and shingle with recent shells resting on the Boulder-clay. A submerged forest invariably occurs on the base of the peat, and is well seen on the coast or the mouth of the River Alt, near Liverpool, on the coast of Wirval, in Cheshire, and at Rossall, near Fleetwood: at the latter place a horizon of Scotch Fir is found beneath one of Oak; occasionally Beech most occurs both at the base and at higher horizons in the peat, overlying which at Rossall occurs Tidal Alluvium, in which were discovered a large number of Roman coins, which gives a pre-Roman date to the growth of the thick peat of Lancashire. In Cheshire there is a very similar sequence, and Neolithic flint implements have been found in the Peat Series, and are preserved in the Liverpool Museum.

When the Lancashire Peat is followed into the valley of the Ribble it is found to be continuous with the peat horizon found in the alluvium of the lowest alluvial flat of that river. In other words, the valley of the Ribble at Preston had been excavated as low as it is at present before the obstruction of drainage, which led to the destruction of the forests in the plains and the consequent growth of thick peat, the whole of which denudation took place after the deposition of the newest of the Lancashire Glacial Deposits, the Upper Boulder-clay. The old river-terraces, therefore, that fringe the sides of this valley are distinctly of post-Glacial age, though of far greater antiquity than the lowest plain, which is the partial equivalent to the peat of the plains.

To sum up the total information obtainable in West Lancashire, it would appear that after the deposition of the Upper Boulder-clay the Ribble gradually cut a broad valley, a mile in width and 180 feet in depth, out of the Glacial Drift; at the same time the sea was denuding the western edge of the drift and wearing back a lowland plain, on which afterwards grew a forest surrounding the whole of the N.W. of England, the land standing higher than at present; after which the outfall of the streams became obstructed and the growth of the peat ensued, which was followed by a subsidence of some 70 feet or more, followed by the denudation of coast-lines (still going on), the sequence being, commencing at the newest:—

	In the Plains.	*In the Ribble Valley.*
Denudation	Modern waste	Waste of alluvial plain.
Subsidence	Tidal Alluvium	Alluvial silt.
Obstruction of drainage	Peat	Peat-bed.
Pause	Forest	
Denudation	Shirdley Sand Presall Shingle	Gravel.
Older Denudations, &c.	Nil	Old Terraces.

In the valley of the Irwell the work of excavation is also post-Glacial, and series of old river-terraces occur; and though no Palæolithic implements have ever been found in them, or in any stream north of the Mersey and the Humber, the author cannot resist the conclusion, looking to the work of excavation done, that these terraces are of the same geological age as those further south.

On the Devonian System in England and in Belgium. *By* G. Dewalque, *For. Corr. G.S.*

Having surveyed, last year, the Devonian system of this country, I avail myself of the Meeting of the British Association to offer a few remarks on the results of my survey. As my visit was short I cannot lay claim to a minute aquaintance with this great formation in England; but as I am well acquainted with it in Belgium and the Rhenish provinces, I hope the following remarks may prove of some interest to geologists.

A. I had not the time to visit South Devon. As regards North Devon my conclusions are as follows:—

1. The metamorphic character is more prevalent there than in Belgium, especially in the Middle and the Upper Devonian.

2. All this series is perfectly continuous from Barnstaple to Lynton. Nowhere is there a reappearance of such identical rocks as to prove by repetition of the series the existence of a fault.

3. The Sandstones of Baggy Point and Marwood (*Cucullæa* zone) perfectly agree, both lithologically and palæontologically, with certain portions of our "*Psammites du Condroz.*" The Red Sandstones of Pickwell Down correspond to the lower part of these *Psammites.*

4. The limestone of Ilfracombe represents, as already stated on palæontological evidence, the *Stringocephalus limestone* (Calcaire de Givet) of Belgium and Germany, while the lithological appearance of the rock is very distinct.

Hence it is easy to compare this part of the Devonian series with that of the Continent. In this respect I differ but little from Mr. Etheridge.

5. The Devonian limestones are much more abundant on the Continent than on this side of the Channel. I think, moreover, that the same is to be said of the Carboniferous formation—that is to say, that the *Mountain limestone* is replaced in North Devon (at least in part) by the beds of Barnstaple and Pilton. I found in the slates of Pilton, beds and nodules of siliceous concretions (*phthanites*), which represent, I think, the *chert* of the *Carboniferous limestone,* or the so-called *phthanites* of our "Calcaire carbonifère."

B. As to the *Old Red Sandstone,* I spent a week in Hereford, but saw very little of it. I could only examine conveniently the *cornstones,* of which I had from the descriptions a very imperfect notion. Such limestones occur identically in Belgium, with red shales, sandstones, and conglomerates, in the northern trough, or "Bassin de Namur"*.

This fact seems to me of the highest value, for it leads me to this paradoxical conclusion, viz. the *Old Red Sandstone* of the United Kingdom is a marine formation, probably formed in the same ocean as the Devonian. The *Old Red* of Belgium, with the cornstones exhibited, lies regularly between limestones with *Stringocephalus Burtini* and others with *Spirifer disjunctus.* That is certainly a marine formation; the same must be the case with the English *Old Red Sandstone.*

On some of the Stockworks of Cornwall. *By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

The author divided the Tin Stockworks into three classes, according as they occur in killas, granite, or elvan, and then described the mode of occurrence of Tin-ore at some of the most important of them.

The following is a list of the Stockworks referred to:—*Killas Stockworks,* Wheal Prosper, Mulberry, Minear Downs, Park of Mines, Polperro, Trevaunance, Wheal Coates, Great Wheal Fortune.

Granite Stockworks, Carclaze, Carrigan Rock, Belowda Hill, Rock Hill, Cligga, Balmynheer, St. Michael's Mount.

Elvan Stockworks, Hobb's Hill, Castle-an-Dinas, Terras, Gover, Budnick, Rosewarne, Wheal Jennings, Poldory, Wherry. (See Quart. Journ. Geol. Soc. vol. xxxiv. 1878, Aug.)

On some Tin-Mines in the Parish of Wendron, Cornwall. *By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

The author described the Tin-deposits of the following mines:—Balmynheer, The Lovell, and South Wendron.

At Balmynheer there is a mass of stanniferous rock 36 fathoms long, and 30 or 40 feet thick, dipping N. It is mainly a mixture of quartz, chlorite, gilbertite, iron-pyrites, and tinstone.

* Specimens from England, and others from Belgium, were exhibited. They were all recognized as cornstones.

The Lovell mine is worked upon two so-called lodes, which are irregular masses of tin-bearing rock, adjoining certain joints running about N.E. and S.W. The rock is made up of quartz, gilbertite, mica, zinc-blende, chlorite, iron-pyrites, and tinstone.

South Wendron is remarkable for a pipe of somewhat similar rock.

The author supposed that the tin-bearing rock is an altered granite, and brought forward in support of his argument the facts—1st, that pseudomorphs of quartz and of gilbertite after orthoclase are found at the Lovell mine; and 2ndly, that there is always a gradual passage from the tin-bearing rock into the granite. (See Quart. Journ. Geol. Soc. vol. xxxiv. 1878, Aug.)

On the Great Flat Lode south of Redruth and Camborne.
By C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

In this paper the author described an important tin-lode which is wrought in various places for a distance of $3\frac{1}{2}$ miles, at Wheal Uny, West Basset, &c.

In some places it occurs (for instance, at Wheal Uny) at the junction of the clay-slate (*killas*) and granite, but in other mines it lies entirely in granite.

Its characteristics are—

1. A *leader* or true fissure vein, generally only a few inches wide, and filled with clay, fragments of the enclosing rocks, and tin- or copper-ores, dipping 30° to 50° S., and striking from 20° to 45° N. of E. (true).

2. The *lode*, from 4 to 15 feet wide, on one or both sides of the leader, consisting mainly of schorl-rock, containing grains and veins of tin-ore. It yields from 1 to 3 per cent. tin-ore.

3. A *capel*, or non-stanniferous or slightly stanniferous schorl-rock, separating the lode from the killas or granite.

4. Absence of any *wall* or plane of separation between the *lode* and *capel*, or between the *capel* and granite.

The author said that all the appearances pointed to the fact that the lode and capel are merely altered granite. In confirmation of this view, he explained that he had found cavities in the lode resembling felspar crystals in shape, and probably left by its removal; furthermore the microscopic examination of the *capel* shows apparent pseudomorphs of quartz after felspar.

If it is admitted that the mass of the "Great Flat Lode" and its *capels* are altered rocks once containing felspar, we are driven to conclude that that rock must once have been granite, because of the gradual passage of the *capel* into granite. Supposing this view to be correct, we must adopt a similar explanation in the case of many of the important tin-lodes in Cornwall.

The great mines north of Carn-Brea Hill, such as Dolcoath, Cook's Kitchen, some of the Carn-Brea lodes, South Crofty, and East Pool, all furnish "*tinstuff*" more or less similar to the stanniferous rock described above; and the author ventured the opinion that half of the tin-ore obtained in Cornwall is now derived from altered granite. He contended that the typical tin-lode of Cornwall should no longer be represented as the mere contents of what was once an open fissure, and asserted that though fissures were necessary, their principal function was, not to serve as receptacles for minerals, but to convey the fluids which changed the granite and deposited the tin-ore in little minor cracks and pores of the altered rock. The large tin-lodes, in the author's opinion are merely long tabular *stockworks* rather than ordinary mineral veins.

In the year 1876, 83,452 tons of tinstuff were produced from the Great Flat Lode, yielding 1846 tons of clean tin-ore (*black tin*), or more than $\frac{1}{8}$ of the total quantity of tin-ore obtained from Cornwall. (See Quart. Journ. G. S. vol. xxxiv. 1878, Aug.)

On the Geological Significance of the Boring at Messrs. Meux's Brewery, London.
By R. A. C. Godwin-Austen, *F.R.S.*

A Short Sketch on the Finding of Silurian Rocks in Teesdale.
By W. Gunn, *F.G.S.*

Note on the Fossil Flora of the Arctic Regions. *By* Professor HEER.

The Post-Tertiary Fossils procured in the late Arctic Expedition; with Notes on some of the Recent or Living Mollusca from the same Expedition. *By* J. GWYN JEFFREYS, *LL.D., F.R.S.*

The fossils were collected by Captain Feilden and Mr. Hart, the Naturalists of the Expedition, and by Lieut. Egerton and Dr. Moss, two of the officers of H.M.S. 'Alert,' in very high latitudes, viz. between 82° and 83° N. long. The furthest point reached by the Expedition was 83° 20′ 26″. These fossils were found in mud-banks or raised sea-beds, at heights ranging from the level of the sea to 400 feet above it. They consisted of 18 species of Mollusca, 1 of Hydrozoa, 1 of Foraminifera, and 1 of marine plants, being altogether 21 species, all of which now live in the Arctic Seas. The author gave a list of the species, and showed their distribution in a recent or living as well as fossil state; and he added some remarks as to the recent Mollusca procured in the Expedition, and as to the apparent abundance of marine animals in the "Palæocrystic Sea" of Sir George Nares.

On the Occurrence of Pebbles in Carboniferous Shale in Westmoreland. *By* G. A. LEBOUR, *F.G.S.*

This paper was a note of the occurrence of rounded and subangular pebbles of quartz or quartzite (which were exhibited) in a bed of Carboniferous shale in Angill, Westmoreland. The pebbles were all of the same character, and were probably derived from some of the Lake-District rocks and not from veins. The author brought the present note forward chiefly to elicit the opinions of members of the Section as to the probable origin of the stones. The rocks associated with the shale in question were briefly described.

Notes on the Age of the Cheviot Rocks. *By* G. A. LEBOUR, *F.G.S.*

The great mass of the Cheviots consists essentially of porphyrites passing into granite and syenite, of ashes, and of doleritic rocks of varied character. Wherever Silurian rocks are seen in contact with this mass they are tilted up and disturbed by it. Wherever, on the other hand, unfaulted junctions of Carboniferous beds (including the so-called Upper Old Red, or Basement beds) with Cheviot Traps are seen, the former rest undisturbed upon the latter. Moreover, the basement beds are largely composed of fragments of Cheviot porphyrite, &c., and these extend upwards into the Tuedian or Calciferous Sandstone Series. The Cheviot rocks as a whole, then, are post-Silurian and pre-Carboniferous, probably of Devonian age. This is well attested if not a very generally known fact. Two sets of rocks, however, of minor importance in the mass appear to bear witness to at least one, and probably two, later dates in the history of the range. These are, first, certain vesicular dolerites which occur chiefly in the southern portion of the English side of the Cheviots, and which form bosses among the porphyrites, and appear to be quite distinct from the more compact dolerites which seem to pass gradually into the latter. The vesicular dolerites are, in fact, intrusive in the porphyrite and in the compact dolerites. This fact alone would give no clue to their age. This clue is afforded by bosses of this vesicular dolerite piercing through the older Carboniferous rocks immediately to the south of the Cheviot mass near the head of the Redewater, in Northumberland, a mile or two from the Scottish border. Rock of this character is seen nowhere else in the district. It seems fair, therefore, to assume that the vesicular dolerites are at least of Tuedian age. In this they probably agree with a mass of intrusive porphyry which crosses the valley of the Tweed near Corham, but which the author has not studied.

The second set of rocks claiming attention are some doleritic breccias which occur in somewhat obscure and confused patches in Punchestown, Burn, and perhaps elsewhere. These breccias consist of fragments of porphyritic and *Lower Carboniferous rocks* embedded in a matrix of dolerite. They are therefore at least post-Tuedian, probably of Bernician or Carboniferous-Limestone age. We thus have in the Cheviot mass rocks of probably Devonian, Tuedian, and Bernician age belonging to the same eruptive centre.

On the Occurrence of Aviculopecten *and other Marine Shells in Deposits associated with Seams of Coal containing Salt Water in the Ashby Coal-field. By* WILLIAM MOLYNEUX, *F.G.S.*

The author described the strata passed through in sinkings for coal at the Colliery belonging to the Coton Park and Linton Colliery Company (Limited), on the Leicester branch of the Midland Railway, near Burton-on-Trent, as consisting of Keuper Sandstones, Bunter Conglomerates, and Permian Marls and Breccias, about 300 feet in thickness, lying horizontal and unconformable to the succeeding Coal-measures. The situation of the pit was west of the supposed boundary fault of the Coal-field, and about half a mile north of Gresley Station. In the shale immediately overlying the *Main* Coal were found specimens of *Aviculopecten papyraceus, Goniatites Listeri, Posidonia*, sp., *Orthoceras*, sp., and *Lingula mytiloides*. The coal in question has long been known to contain large quantities of water, yielding, according to an analysis by the late Dr. Ure, 3700 grains of chloride of sodium to an imperial gallon. It is also possessed of bromine and other constituents of sea-water; and the Saline Baths at Ashby and Moira are supplied with it, the water being pumped from the coal in the Moira pits adjoining. The Main Coal had been worked at its base or outcrop many hundreds of years; but the occurrence of salt water in it did not appear to have been noticed till the deep pit of Moira was sunk in 1832, by the late Mr. Ed. Mammatt, the author of 'Geological Facts,' in which work Dr. Ure's analysis is contained; the discovery and manner in which the water is found is fully described. With the above exception, and a brief notice of it by Professors Hull and Green, in the 'Memoirs of the Geological Survey' (Ashby Coal-field), the author was unaware of any published reference to the water. Salt water had also been discovered about two years ago in sinkings for coal through New Red Sandstone and Permian rocks, at the village of Snarestone, near Measham, by the Appleby Magna Colliery Company (Limited); and in this case it was found in a bed of shale immediately overlying a seam of coal which, there was every reason to conclude, occupied the horizon of the *Main* Coal of the Ashby field, but which from local causes had here become attenuated and impoverished. In the shale the author found *Lingula mytiloides*, but none of the other shells of which the Coton Park series is composed. The upper part of the seam found here consisted of brown cannel, the lower portion of bright bituminous coal, in every respect corresponding with the character of the *Main* Coal; and the division of the seam, about three inches in thickness, was made up in part of compressed plants and a stony brown cannel containing several specimens of *Palæocarabus Russellianus, Anthracosia*, sp., *Beyrichia*, sp., and spores of *Lepidodendron*. The original discovery of the salt water was in coal uncovered by any newer rocks than Drifts of the Boulder-clay series; but the two sinkings in question, together with an earlier sinking through similar strata at Netherseal, placed on record the existence of the salt water in coal where covered over by the naturally on-coming groups of rocks.

It did not appear to the author that any explanation had been advanced to account for the presence of the saline water in this isolated position. Most of the other coal-seams of the field, both above and below the Main Coal, contained water, but in no other instance was it in the least charged with saline matter. The author showed that it could not have been derived from the saliferous marls, because where the Bunter and Permian intervened, the water (of which they contained enormous quantities) was perfectly fresh; and had the Red Marls spread over the upturned edges of the coal-seams been the source of the saline matter the water of other coal-seams must have been similarly affected. Immediately above the *Main* Coal, between it and the shale containing the marine shells, is a bed of impervious clay called "Tow," and directly below it an equally compact bed of fire-clay; and it was the author's opinion that the saline water of the coal was in fact the fossil or pent-up water of the sea in which those animals lived whose fossil remains had been found in the shales above, and that it had been preserved to the present day from evaporation and admixture by the impervious beds of clay, the position and character of which he had described above. He adduced evidence he had met with of the total submersion of every seam of coal found in the Ashby coal-field, and in the other coal-fields of the Midlands, immediately after the completion of the formation or deposition of each seam; and from the fossils and other data therewith associated, the submerging agent was, with few exceptions, fresh water; but although there were several instances of the alternation of fresh- with salt-water deposits in the Coal-measures generally, he knew of no other in which there was so direct and clear an association of salt water with the fossil remains of marine animals. The history of the Coal-formation of this county was as yet but imperfectly understood.

The Carboniferous Limestone and Millstone Grit in the Country around Llangollen, N. Wales. By George H. Morton, *F.G.S.*

The author described the Carboniferous Limestone exposed in the Eglwyseg ridge near Llangollen, N. Wales. He stated that the finest section is exposed at the Ty-nant ravine on the west of Cefn-y-Fedw, and that the country around must be considered as the typical area of the Lower Carboniferous series of North Wales. The Millstone Grit, or Cefn-y-Fedw Sandstone, which reposes on the limestone in the same district, was also described. The following tabulation explains the succession and thickness of the entire series:—

Tabular view of the Carboniferous Limestone and Cefn-y-Fedw Sandstone in the country around Llangollen.

		ft.	
Cefn-y-Fedw Sandstone.	Aqueduct Grit, or Upper Sandstone and Conglomerate	70	Upper Cefn-y-Fedw, Dee-Bridge, or Millstone-Grit series.
	Upper Shale	30	
	Dee-Bridge Sandstone	30	
	Lower Shale with Fire-clay and bands of limestone	18	Middle and Lower Cefn-y-Fedw or Yoredale series.
	Middle Sandstone	200	
	Cherty Shale	50	
	Lower Sandstones and Conglomerate	250	
	Sandy Limestone	75	
Carboniferous Limestone.	Upper Grey Limestone	300	Upper Carboniferous Limestone.
	„ White „	300	
	Lower „ „	120	Lower ditto.
	„ Brown „	480	
		1923	
	Upper Old Red Sandstone	300	

Each of the subdivisions was separately described, and a section from the Ty-nant ravine to Tyfyn-uchaf was exhibited, showing the regular succession of the whole of the strata from the Old Red Sandstone to the Coal Measures. The following Table shows the gradual attenuation of the Carboniferous Limestone towards the south-east:—

Attenuation of the Carboniferous Limestone.

Subdivision.	Ty-nant.	Tan-y-Castell.	Trevor Rocks.	Bronheulog.	Fron.
Upper Grey Limestone	300	300	250	66*	88*
„ White „	300	250	140	99	27†
Lower „ „	120	115	117	104	27
„ Brown „	480	360	100‡	26‡	27
	1200	1025	607	295	169

This section shows how the limestone diminishes in thickness with the rise of the Wenlock shale towards the south-east. Between the Ty-nant ravine and Tan-y-Castell it has thinned out 200 feet, and at Fron-y-Cysyllt, four miles from the former place, the attenuation is not less than 900 feet.

The list of fossils collected by the author contained 77 species. Of these, 58 occur in the Upper Grey Limestone, and only 18 in the Lower Brown Limestone. If the Carboniferous Limestone is simply divided into Upper and Lower Limestone, 38 species are peculiar to the two upper subdivisions and 19 to the two lower subdivisions, 20 species being common to both. However, the species are by no means confined to the subdivisions in which they are found near Llangollen, for they occur at different horizons in other districts.

On the Source and Function of Carbon in the Crust of the Earth.
By A. S. Mott.

Note on the Carboniferous Coast-line of North Cornwall.
By S. R. Pattison, *F.G.S.*

The portion of coast described extends from near Bude to Boscastle, and belongs to the formation first identified by Professor Sedgwick, in connexion with the diagnosis made at Bideford by him and Sir Roderick Murchison, as Culm, or Lower Coal-measures. Bude lies in or near the centre of this formation. The strata have a general northerly dip, and proceeding southwards down the coast of course lower beds become exposed. The Bude beds contain a thin film of Culm, with associated plant remains in a very fragmentary condition. Professor Morris many years ago, in a note published in the 'Proceedings of the Geological Society of Cornwall,' identified some of these remains as *Calamites*, *Sigillaria*, and *Asterophyllites*. Professor Hull states the number of species in the North Devon beds, of which these are the continuation, at 23, and Mr. Townsend Hall at 26. The Bude beds are continued by foldings and succession downwards; but on arriving at St. Gennes a system of deep blue schistose sandstones appears, from the base line of the cliff along the remarkable coast landslip which extends for two miles. From these dark blue beds fragments or nodules containing Goniatites appear on the beach. These Goniatite beds extend from Carn Beak to the Buny Cliff, in the parish of St. Juliott. They are most abundant at the St.-Gennes end of the landslip. Here, at a sandpath descending to the shore, on the beach, are huge fragments of fallen rock, containing very fine large impressions of plants, especially *Sigillaria*. Proceeding towards Boscastle, at the gloomy gorge of Pentargin, the soft black shales so characteristic of Boscastle form the bulk of the cliff; but below them rises a slaty rock, once quarried, and in this are found the usual fragmentary plants of the Bude rocks. This, with the associated soft black beds, is the farewell rock of the Carboniferous series; for at the Summer-house Cliff, on the south side of Boscastle, slates arise under the black shales, which at the summit contain traces of Crinoids, and are the commencement of the Devonian slates which are continued to Tintagel and well known as Devonian.

* Upper portions have been denuded. † Reposes on the Wenlock Shale.
‡ Base not ascertained with certainty.

These few facts serve to verify the general conclusions arrived at by former observers, and, when more fully investigated and the fossils identified, will help to correlate the Carboniferous of North Cornwall with the divisions now established elsewhere. They serve, at least, to show that there are provinces in our local geology still holding out temptations of further conquest to the geological explorer.

Sketch of the Geology of the Coast from the Rame Head to the Bobb Tail. *By* W. PENGELLY, *F.R.S.*

On some Peculiar Stalactitic Formations from the Island of Antiparos. *By* J. S. PHENÉ.

On the Exploration of some Caves in the Limestone Hills in Fermanagh. *By* T. PLUNKETT.

In the caves were found a large quantity of human and animal remains, together with rude flint inplements, bone and iron pins, and coarse pottery. Some of these caves are found at an elevation of over 300 feet above the adjoining valleys, showing the extraordinary waste of the surface of the country by the denuding forces of ice and water. Before being explored they were almost filled to the roof with cave-earth.

After removing the upper stratum of dark earth in a cave which occurs in the Knockninny hill in the south side of Fermanagh, a large cinerary urn was found placed in a niche in the side of the cave, inverted on a flag and containing burnt human bones. It stood $14\frac{1}{2}$ inches high and 15 inches in diameter, and was devoid of any ornamentation save a few scratches made across the line when the clay was soft. On digging deeper down some angular blocks of stone were turned up which had evidently fallen from the roof of the cave during its earlier history. Underneath these blocks charcoal, human remains, bones of the wild boar, red deer, fox, and short-horned Celtic cow were found. The cave-earth having been removed five vertical feet below where the urn was found, a floor of stalagmite, highly crystalline, was met with, underneath which an ancient hearth was found, together with rude flint implements and broken pottery and portions of human skulls. The human remains found in this cave were considered to be of very great antiquity.

Cave No. 2 contained a vast quantity of cave-earth and gravel and penetrated an escarpment on the side of a limestone hill. Layer after layer of cave-earth was removed to a depth of 20 feet. Three floors of stalagmite were blasted up with dynamite, and underneath every one of the floors human relics and animal remains were found. Bone pins of various patterns were found in the lowest stratum of the cave, and broken animal bones, charcoal, and rude pottery were found interspersed through the whole of this mass of cave-earth from top to bottom.

The exploration of several other caves which occur in the same locality was described. These have yielded a quantity of flint flakes, rude pottery, and the bones of the horse, wild boar, wolf, red deer, and remains of various other animals. In one cavern a human jaw was found embedded in glacial clay and associated with scratched stones. The entrance to this cave was in a steep limestone acclivity about 250 feet above the adjoining valley. The work is still going on, and Mr. Plunkett expects to find objects of still greater interest.

On the Junction of the Limestone and Culm-measures near Chudleigh. *By* CLEMENT REID, *F.G.S., of the Geological Survey of England and Wales.*

Although there was little positive evidence of the relations between the Devonian Limestone of Chudleigh and the Culm-measures, there were indications of conformability in the general arrangement of the strata, and in one instance evidence of passage-beds between the two. Mr. Reid pointed out that the Limestone and underlying Devonian Slates were faulted against the Culm-measures on the west, as supposed by Jukes; and he had been able to trace the fault through certain points which had previously been held as evidence of unconformability.

On a new Method for Studying the Optical Characters of Minerals. By H. C. Sorby, *F.R.S. &c.*

The author first described the principles on which this method depended, and showed that the great difference between the appearance seen with the naked eye and the microscope is due to the object-glass being able to collect divergent rays. In looking with a two-magnifying power at a small circular hole seen through a section of a crystal, very different phenomena present themselves, according to its optical characters. If it has no double refraction, only one well-defined circular hole can be seen. If the mineral possess double refraction and only one optic axis, like calcite, two images of the hole are seen. If the section be cut perpendicular to the axis, two circular holes are seen directly superimposed but at two different foci. If the section be in the plane of cleavage two widely divided images are visible—the one due to the ordinary ray being circular, and the other, due to the extraordinary ray, being distorted and drawn out in two opposite planes at two different foci. When the section is cut parallel to the axis, this image due to the extraordinary ray is still more elongated, but the images are directly superimposed. We thus at once learn that the mineral has double refraction, has an optic axis, and also what is the direction in which the section is cut. In the case of crystals like aragonite, which have two optic axes, there is no ordinary ray; and at two focal points we see the circular hole drawn out in opposite planes into crosses. The character of these crosses depends upon the direction of the section; but the fact of the crosses being seen at once proves that the mineral has two optic axes. Some facts are better observed if, instead of a circular hole, we examine through the crystalline plate a grating with two systems of lines at right angles to one another. We then obtain what the author calls unifocal or bifocal images, according to the systems of crystallization. Crystals without double refraction have only one unifocal image; crystals having one optic axis have one unifocal and one bifocal image; whereas crystals having two optic axes give two bifocal images. The definition of unifocal images is independent of the position of the lines; whereas in the case of bifocal images the lines are distinctly visible only when they are parallel or perpendicular to a particular axis of the crystal, and spread out and become obscure and disappear when rotated to a different azimuth. The above-named general characters differ so much in different minerals that they furnish a most valuable means for their identification.

Influence of the Position of Land and Sea upon a Shifting of the Axis of the Earth. By Arthur Wm. Waters, *F.G.S., F.L.S.*

The author pointed out how the unequal distribution of land and sea may be an agent in preventing the movements of elevation and depression of the land, in one part of the globe, balancing those in another, and further showed how similar movements in various localities would differently affect the pole.

Any movement, such as a submarine elevation, which displaced water would spread it over the oceanic area; and the effect of this would, with the present configuration, be the same as if about $\frac{1}{12}$ of the weight had been added in the southern hemisphere along 45° 44′ long. E., viz. in a line passing by the entrance of the White Sea over the Caucasus through the middle of Madagascar.

As every submarine movement would create a force acting in this direction, there seems reasonable grounds for thinking the tendency would be for the shifting of the axis to take place near this line. Dr. Jules Caret considers that the pole must have moved approximately in a line passing through 52° long. E., and what is cause, what effect, and how far they react on one another is fully worthy of examination by any physical geologist.

The shifting caused by any elevation of land near the equator or poles is very slight, so that the effect of the water displaced is, up to about the 5th degree of latitude, as great or greater than that caused directly by the movement of the land. From this it is apparent that near the equator a submarine movement may act on the pole in a contrary direction to that exercised by a similar movement nearer 45° lat. As about $\frac{1}{11}$ of the globe is included between the latitudes 5° N. and 5° S., the effects of movements here are specially worthy of consideration.

The effects of the drying up of an ancient Caspian sea was taken as an illustration of the points brought forward. The loss of water of double the area of the Caspian, evaporating to a depth of about 200 feet, would, by the loss of weight of water, shift the pole about 166 feet towards the White Sea; but as this water would be so distributed as to cause additional weight along 45° 44′ long. E. in the southern hemisphere, it would shift the pole still further in the same direction, making a total of about 176 feet. If there were a Caspian Sea in the south along this line, then similar phenomena would cause a movement of 156 feet as against 176 feet in the north.

On the Occurrence of Branchipus *or* Chirocephalus *in a Fossil State in the upper part of the Fluvio-marine Series (Middle Eocene) at Gurnet and Thorness Bays, near Cowes, Isle of Wight. By* HENRY WOODWARD, *F.R.S., of the British Museum.*

The author referred to the great interest surrounding the geology of the Isle of Wight, from the labours of Ibbetson, Forbes, Mantell, Prestwich, Bristow, and many others, and the rich Fauna contained in its strata, much of which remains to be described, although its stratigraphical geology has been well worked out by the officers of the Geological Survey.

Mr. Woodward called attention to a thin band of freshwater limestone occurring at the base of the cliff belonging to the Bembridge series, from 2 to 12 inches thick, which at places is full of remains of plants and insects, *Dytiscus, Curculio, Formica,* &c., and, what is most remarkable, the diaphanous bodies of a small Phyllopod Crustacean without a hard shelly covering. This little Crustacean is closely related to the "Brine-shrimp" (*Artemia salina*), so abundant in the brine-pans at Lymington at the present day. *Branchipus* or *Chirocephalus* is a freshwater Crustacean found living in ponds in Devonshire and Kent. Its preservation is due to the admirable nature of the fine argillaceo-calcareous rock in which it has been entombed in such numbers, the delicate outline of its gill-feet being stained with iron so as to be as well shown as in a photograph.

Notes on the Devonian Rocks near Newton Abbot and Torquay; with Remarks on the Subject of their Classification. By HORACE B. WOODWARD, *F.G.S., of the Geological Survey of England and Wales.*

After having alluded to the imperfect state of the information respecting the Devonian rocks, especially in regard to local details of structure, the writer pointed out that the succession of strata near Newton Abbot and Torquay was (in descending order) as follows:—3, Limestone; 2, Slates; and 1, Red Sandstones. He noted the resemblances in lithological characters between these beds and the Lower Carboniferous rocks and Old Red Sandstone, with which they were classed fifty years ago by De la Beche. He likewise drew attention to their relations with the Culm-measures, observing that while there were indications of conformability to them, no positive proof to the contrary had been established; and the supposed instances of unconformability were all of them, as Jukes had considered, capable of explanation by faults and other disturbances. Attention was drawn to some striking cases of such phenomena. The impossibility of accepting fossil evidence alone was insisted upon, inasmuch as its value in classification could only be gained after the stratigraphical relations of the beds had been made out, and at present the exact horizons from which many of the species had been collected was not determined.

Further, the theory that the Devonian rocks were the equivalents in time to the Old Red Sandstone, required the existence at this period of a great barrier between the marine deposits of the former group and the freshwater accumulations of the latter, and there was no physical evidence in support of this. Taking all the facts into consideration, the author argued that they were in favour of the classification proposed by Jukes, which regarded the lowermost Devonian rocks as Old Red Sandstone, and the slates and limestones as Lower Carboniferous, formed in an area which constituted a zoological province differing to some extent from that in which these rocks were deposited further north in the British area.

Notes on the Palæontology of Plymouth. *By* R. N. Worth.

BIOLOGY.

Address by J. Gwyn Jeffreys, *LL.D., F.R.S., Treas.G.&L.SS., President of the Section.*

Being merely an amateur naturalist, and not having had any strictly scientific education, I consider it a great honour to be invited to preside over this important Section of the Association. I cannot pretend to give such an Address as may be expected from the President; but I will offer some remarks on a subject in which I take considerable interest and have done some work, viz. the deep-sea Mollusca.

The historical part of the subject has been fully treated by Dr. G. C. Wallich in his 'North-Atlantic Sea-bed,' 1862; by Professor Prestwich in his Presidential Address to the Geological Society of London in 1871; and by Professor Sir Wyville Thomson in his 'Depths of the Sea,' 1873.

By the term "deep-sea" I do not mean the zone which the late Professor Edward Forbes called the eighth, and which he supposed to be the lowest and the limit of habitability, in his elaborate and excellent Report on the Ægean Invertebrata, published by the Association in 1844. That zone comprised the depths lying between 105 and 230 fathoms. Nor would I refer to it the "deep-sea" zone which I defined in the Introduction to my work on 'British Conchology,' 1862; this applied to the British seas only, and extended to the "line of soundings," being about 100 fathoms. Since that time the exploring expeditions in H.M.SS. 'Lightning,' 'Porcupine,' 'Challenger,' and 'Valorous,' as well as in the Norwegian frigate 'Vöringen,' have shown that Mollusca inhabit the greatest depths that have been examined, and that life is not less abundant and varied in the abysses of the ocean than it is in the shallowest water. Instead of 300 fathoms or 1800 feet, which Forbes assumed to be the extreme boundary of submarine life, we must now take 3000 fathoms or 18,000 feet, and even much lower depths. It may be well to distinguish two zones of depth exceeding that which I have termed "the line of soundings;" and I would propose the name "abyssal" for depths between 100 and 1000 fathoms, and "benthal" (from the Homeric word *βένθος*, signifying the depths of the sea) for depths of 1000 fathoms and more.

The first knowledge that I had of the Mollusca from the lowest or "benthal" zone I owe to Dr. Wallich, who kindly gave me a few small shells which he got in a sounding of 1622 fathoms in N. Lat. 55° 36′, W. Long. 54° 33′, off the coast of Labrador, during his cruise in H.M.S. 'Bulldog' in 1860. These consisted of undescribed species of *Aclis*, *Homalogyra*, and *Pleurotoma*, *Pleurotoma tenuicostata* of M. Sars, and fragments of *Saxicava rugosa,* Linné, and of other shells which are unknown to me. Among these was a dead but perfect specimen of *Crenella faba,* Fabricius, which is a common inhabitant of the laminarian zone in Arctic seas, and may have been voided by a fish or sea-bird. This would account for the occasional occurrence at great depths of other shallow-water shells and fragments.

I had the good fortune to take part in the two 'Porcupine' expeditions of 1869 and 1870 and in the 'Valorous' cruise of 1875; and the Mollusca of the 'Lightning' (1868), 'Challenger' (1873–76), and 'Vöringen' (1876) expeditions have been submitted to my inspection. I am consequently enabled to form some idea of the bathymetrical distribution of the Mollusca thus obtained, with the aid of my dredging experience for upwards of forty years.

Perhaps the best way of communicating this idea to others will be by giving the subjoined list of the species of deep-sea Mollusca dredged by me in the 'Valorous,' all of which are found at depths exceeding 1000 fathoms. The range of depth there and elsewhere in the North Atlantic and Mediterranean will be noted, as well as some geological and other observations. Four only of such deep dredgings were made during the cruise, viz. in 1100, 1750, 1450, and 1785 fathoms. The first two were in Davis Strait, and the other two between Cape Farewell and W. Long. 26° on the return voyage.

Names of species.	Range of depth in fathoms.	Observations.
BRACHIOPODA.		
Terebratula tenera, *Jeffreys*	1450	
Atretia gnomon, *J.*	1100–1750	
Discina Atlantica, *King*	690–2400	Coralline-Crag fossil.
CONCHIFERA.		
Pecten fragilis, *J.*	1000–1785	
Amussium lucidum, *J.*	156–1450	
Lima ovata, *S. V. Wood*	1450	Coralline-Crag and Monte-Mario fossil.
L. subovata, *J.*	49–1450	
L. gibba, *J.*	1450–1785	
Idas argenteus, *J.*	994–1450	
Dacrydium vitreum, *Möller*	30–2435	Sicilian fossil.
Nucula reticulata, *J.*	420–1470	
Leda acuminata, *J.*	20–1750	Sicilian fossil, as *L. Messanensis,* Seguenza.
L. pusio, *Philippi,* var.	257–1750	Sicilian fossil.
L. pustulosa, *J.*	202–1470	Sicilian fossil.
L. expansa, *J.*	690–1750	
L. lata, *J.*	165–1785	
L. sericea, *J.*	740–1450	
Glomus nitens, *J.*	557–1750	
Limopsis tenella, *J.*	1450	
L. cristata, *J.*	292–1095	
Arca pectunculoïdes, *Scacchi*	20–1100	Coralline-Crag and Sicilian fossil.
Malletia excisa, *Ph.*	1443–1750	Sicilian fossil.
M. cuneata, *J.*	718–1800	
Montacuta Dawsoni, *J.*	3–1750	Fragments only at greatest depth.
Kellia symmetros, *J.*	488–1750	
Axinus cycladius, *S. V. Wood*	30–1750	Coralline-Crag fossil.
A. eumyarius, *M. Sars*	114–1456	

Names of species.	Range of depth in fathoms.	Observations.
Axinus Croulinensis, *J.*	20–1785	
A. incrassatus, *J.*	40–1750	
Diplodonta Torelli, *J.*	30–1450	Fragment only at greatest depth.
Isocardia cor, *L.*	40–1785	Fry only at greatest depth.
Tellina calcaria, *Chemnitz*	1–1750	Sicilian fossil. Fragments only at greatest depth.
Poromya rotundata, *J.*	1450	
Pecchiolia abyssicola, *M. Sars*	110–1450	Fragments only at greatest depth.
P. gibbosa, *J.*	1450	Fragment only.
P. tornata, *J.*	1785	Fragment only.
Neæra striata, *J.*	435–1450	
N. exigua, *J.*	1450	
N. notabilis, *J.*	1450	
N. circinnata, *J.*	994–1450	
N. papyria, *J.*	1450	
N. angularis, *J.*	290–1785	Fragment only at greatest depth.
Solenoconchia.		
Dentalium candidum, *J.*	410–2435	
D. capillosum, *J.*	220–1785	
D. ensiculus, *J.*	740–1785	
D. subterfissum, *J.*	1000–1476	Fragment only from 'Valorous.'
D. vagina, *J.*	1450–1785	
Siphodentalium vitreum, *M. Sars*	150–1750	
S. affine, *M. Sars*	100–1450	
S. Lofotense, *M. Sars*	20–1750	
Cadulus tumidosus, *J.*	110–1450	
C. Olivi, *Sc.*	539–1450	Sicilian fossil.
C. cylindratus, *J.*	1215–1476	
Gastropoda.		
Propilidium ancyloïdes, *Forbes*	60–1450	Sicilian fossil, as *Rostrisepta parva*, Seg.
Puncturella profundi, *J.*	740–1750	
Scissurella crispata, *Fleming*	7–1095	Sicilian fossil.
S. tenuis, *J.*	1450	
Cyclostrema basistriatum, *J.*	50–1095	Sicilian fossil.
Acirsa prælonga, *J.*	994–1450	
Eulima stenostoma, *J.*	50–1456	
Natica affinis, *Gmelin*	5–1100	Fragments only at greatest depth.
N. sphæroides, *J.*	1750	A young shell.
Seguenzia formosa, *J.*	325–1785	Sicilian fossil, as *S. monocingulata*, Seg.
S. carinata, *J.*	690–1095	
Cerithium procerum	400–1450	*C. Danielseni*, Friele.
Trophon Fabricii, *Beck*	35–1450	Fragment only at greatest depth.
Fusus attenuatus, *J.*	690–1215	
F. Sabini, *Gray*	100–1450	Fragments only at greatest depth.

Names of species.	Range of depth in fathoms.	Observations.
Pleurotoma tenuicostata, *M. Sars* ..	40–1622	
P. exarata, *Möll*.	5–1230	
Cylichna alba, *Brown*	7–1400	Sicilian fossil.
Utriculus lacteus, *J*.	1443–1450	Fragment only at greatest depth.
U. substriatus, *J*.	1750	
Actæon exilis, *J*.	49–1450	Sicilian fossil.
Scaphander puncto-striatus, *Mighels and Adams*.	26–1450	Sicilian fossil. Fragment only at greatest depth.

Besides undeterminable fragments of other and probably new species.

The species named in the above list are 75 in number. Of these no less than 46 have been described by me for the first time in the 'Annals and Magazine of Natural History' for 1876 and 1877. Several of them were also procured in the 'Porcupine,' 'Challenger,' and 'Vöringen' expeditions. A great many more deep-sea species remain to be worked out and described by me from the 'Porcupine' expeditions of 1869 and 1870.

I have not included the Pteropods in the list, although their shells occur at the greatest depths—because they are oceanic, and inhabit only the surface or superficial zone, their shells falling to the bottom after death and when evacuated by predaceous animals.

The Mollusca of very deep water or the benthal zone are certainly peculiar, and constitute part of a distinct fauna, notwithstanding that some of them frequent shallower water. It is very difficult to say how far they may be affected by bathymetrical conditions. An important contribution to this part of the subject was made by Mr. Buchanan at a recent meeting of the Royal Society of Edinburgh, in which he stated, as the preliminary result of his analysis of the sea-water collected in the 'Challenger' expedition, that as regards the percentage of oxygen present at different depths, it diminishes from the surface to a depth of 300 fathoms, and increases from this point to lower depths*. See also my account of the behaviour of *Trochus occidentalis*, when dredged from the deep-sea zone on our northern coasts, which is explained by Mr. Buchanan's statement†.

They are not always of a small size. In the 'Porcupine' expedition of 1869 the dredge brought up, at the depth of 1207 fathoms, in the Bay of Biscay, a living specimen of *Fusus attenuatus*, which measures two inches and a quarter in length; and another dredging at the depth of 2435 fathoms (nearly three miles), in the same part of the Bay, yielded a living specimen of *Dentalium candidum* about an inch and a half long. In the 'Challenger' expedition was trawled, at the depth of 1600 fathoms, in the South Atlantic (S. Lat. 46° 16′, E. Long. 48° 27′), a living specimen of a magnificent shell belonging to *Cymbium* or an allied genus, which has a length of six inches and three quarters and a breadth of four inches! And during my cruise in the 'Valorous,' I dredged, at the depth of 1100 fathoms, in Davis Strait, a living specimen of *Dentalium candidum* an inch and three quarters long. These treasures of the deep are so apt to entrance the imagination of a naturalist, that I have often dreamt of walking on the sea-bed and picking up unknown and wonderful shells; and in my waking hours I have envied the faculty of the Argonaut in Morris's 'Life and Death of Jason,'

"Euphemus, who had power to go
Dryshod across the plain no man doth sow."

I hope it is pardonable to avail one's self of a little poetical licence to make the quotation applicable to the bottom as well as to the surface of the sea.

The distribution of the deep-sea Mollusca is unquestionably caused by submarine currents, with the direction and extent of which, however, we are unacquainted.

* 'Nature,' June 14, 1877.
† 'British Conchology,' vol. iii. pp. 335, 336.

As far as I have had an opportunity of judging from the Mollusca of the North and South Atlantic, I am inclined to think that the Arctic and Antarctic currents do not extend beyond the Equator. The South-Atlantic species procured by the 'Challenger' party in deep water appear to be different from those of the North Atlantic in similar depths, according to our present notion of species. It is unnecessary for me to renew my objection to the phrase "representative species," as Sir Wyville Thomson has satisfactorily disposed of the matter in page 14 of his 'Depths of the Sea.'

It will be seen, on referring to the list of deep-water Mollusca procured in the 'Valorous' cruise, that several of the species are also Sicilian fossils. They occur in the Pliocene formation of the south of Italy. Professor Seguenza has just published a very complete and valuable catalogue entitled 'Elenco dei Cirripedi e dei Molluschi della zona superiore dell' antico plioceno,' which are arranged in two divisions, "Depositi littorali" and "Depositi submarini." But some further distinction would seem to be necessary in order to separate the strata, inasmuch as certain species which are assuredly littoral are included in the submarine division. For instance, *Actæon pusillus*, Forb. (which lives at depths varying from 40 to 1456 fathoms), and *Cylichna ovata*, J. (66–862 fathoms), are entered in both divisions; while peculiarly shallow-water species, such as *Patella vulgata, Tectura virginea*, and six now also living species of *Chiton*, appear only in the submarine or deep-water division. Many of the species in Seguenza's Catalogue (besides those noticed in the 'Valorous' list of deep-water Mollusca), which had been previously considered extinct, were discovered by me in the 'Porcupine' expeditions to be still living; and I have no doubt that the rest of the so-called extinct species, from the upper zone of the older Pliocene in Sicily, will sooner or later be detected in future deep-sea explorations. In fact our examination of the abyssal fauna has been hitherto extremely slight and cursory, taking into account the enormous extent of area, the difficulties caused by unfavourable weather, and the inadequacy of the instruments used in the investigation. Our good neighbours, the Norwegians, have not relaxed in their work; and while this Address is being delivered their second year's expedition to the Arctic seas will almost have been completed. May every success attend them!

There has been lately a good deal of controversy as to the supposed "continuity of the Chalk;" and the affirmative of the proposition has been most ably argued by my colleague and friend, Sir Wyville Thomson, in his 'Depths of the Sea.'

Prof. E. Forbes, in his Report on Ægean Invertebrata (1844), was, I believe, the first to state the proposition. He says, at p. 178, that the strata in his lowest region, or 230 fathoms, would, if filled up, "present throughout an uniform mineral character closely resembling that of chalk, and will be found charged with characteristic organic remains and abounding in Foraminifera. We shall, in fact, have an antitype of the chalk."

Sir Wyville Thomson supports his view by the weighty authority of Dr. Carpenter, Prof. Huxley, and Prof. Prestwich; and although the late Sir Charles Lyell entered a vigorous protest against the hypothesis, and went so far as to designate it a "popular error," I will refrain from expressing any opinion of my own, but will content myself with stating a few facts in elucidation of the question.

The comparison of the deep-sea ooze with the geological formation known as chalk depends on two points, viz. the mineral composition and the organisms belonging to each.

1. *Mineral composition.*—The late Prof. David Forbes, whose knowledge as a mineralogist and chemist was universally recognized, furnished me, on my return from the 'Porcupine' expedition of 1869, with a complete analysis of a sample of Atlantic mud procured at a depth of 1443 fathoms. He proved that it differed from ordinary chalk in containing scarcely more than 50 per cent. of carbonate of lime, whereas chalk consisted all but entirely of carbonate of lime. Indeed Sir Wyville Thomson admits that "a more careful investigation shows that there are very important differences between them."

2. *Organisms.*—I must here confine myself chiefly to the Mollusca, which Sir C. Lyell regarded as "the highest or most specialized organization" on which geological reasoning and classification are founded.

Misle1 by the apparent resemblance of Mediterranean and Atlantic ooze to the ancient chalk, geologists have been accustomed to consider the chalk fauna as having lived in deep water. Let us see how this is with respect to the Mollusca. I have lately, with the assistance of Mr. Henry Woodward and Mr. Etheridge, examined the Cretaceous Mollusca in the British Museum and the Museum of Economic Geology; and Mr. Etheridge has most obligingly prepared and furnished me with a tabular list of the genera and number of species in each genus in the Upper Cretaceous group (exclusive of the Gault and Greensand), which list I will, with his permission, here insert:—

Genera.	No. of species in Chalk-marl.	No. of species in Lower Chalk.	No. of species in Upper Chalk.
BRACHIOPODA.			
Argiope	1	1	..
Crania	1	2	2
Kingena	1	1	1
Magas	2	1	1
Rhynchonella	13	7	3
Terebratella	2	1	2
Terebratula	11	10	4
Terebratulina	2	2	2
Terebrirostra	1	..	..
Thecidea	..	1	1
Trigonosemus	1	1	1
Total	35	27	17
LAMELLIBRANCHIATA. (Conchifera.)			
Avicula	1	1	..
Exogyra	3	2	3
Gervillia	?	..	..
Inoceramus	6	8	9
Lima	3	9	7
Ostrea	3	5	11
Pecten	5	10	12
Pinna	..	..	2
Plicatula	2	1	1
Spondylus	4	2	4
Arca	2	2	1
Astarte	..	1	1
Chama	..	..	1
Cypricardia	..	..	1
Diceras	..	..	1
Isocardia	..	..	1
Leda	..	1	..
Modiola	..	1	1
Opis	1	1	..
Pholadomya	1	1	3
Teredo	1	1	2
Trigonia	3	..	..
Unicardium	..	1	1
Venus	1	1	..
	36	48	62

Genera.	No. of species in Chalk-marl.	No. of species in Lower Chalk.	No. of species in Upper Chalk.
Radiolites	..	?	1
(Solenoconchia.)			
Dentalium	1	1	..
Gastropoda.			
Actæon	1	1	..
Aporrhais	2	3	..
Avellana	1	1	..
Calyptræa	..	..	1
Cerithium	1	1	..
Columbellina	2	..	..
Dimorphosoma	2	..	..
Dolium	..	1	..
Emarginula	1	2	..
Fusus	..	1	2
Gibbula	1	..	..
Hipponyx	..	..	1
Natica	..	1	..
Patella	..	..	1
Pleurotomaria	3	2	3
Pterocera	1	..	..
Rostellaria	1	..	..
Scalaria	..	1	1
Solarium	1	3	1
Trochus	1	1	2
Turbo	..	3	..
Turritella	..	1	1
	18	22	13
Cephalopoda.			
Ammonites	29	31	9
Ancyloceras	1	..	..
Aptychus	..	..	6
Baculites	1	2	1
Belemnitella	1	2	3
Belemnites	3	2	..
Crioceras	..	..	1
Hamites	..	3	1
Helicoceras	..	..	1
Nautilus	10	10	2
Scaphites	1	2	1
Turrilites	11	11	..
Anisoceras	1	..	..
	58	63	25

A glance at the above list, and, much more, an inspection of the Chalk Mollusca in a good collection, ought to convince any conchologist that all these genera were comparatively shallow-water forms. I should infer that the depth might have been from low-water mark to 40 or 50 fathoms. None of the genera are deep-water. *Chama, Ostrea, Pinna, Calyptræa, Hipponyx*, and, most assuredly, *Patella* cannot be placed in the latter category; and the old proverb, "noscitur ex sociis," will apply to mollusks as well as to men. *Teredo* may have been littoral or have come from floating wood. Not a single species of *Leda, Pecchiolia* (or *Verticordia*), *Neæra*, not one of the Solenoconchia nor of the *Bulla* family occurs in the upper or white Chalk, although they now inhabit the deep-sea ooze and especially characterize the modern deposit.

But *Nautilus* and *Spirula* are believed by some to be deep-water forms. This must be a mistake. Although the animal of that common species *Nautilus pompilius* has rarely been met with, the shells are often found on beaches in the Indian Ocean and South Pacific; and I am not aware of any instance of a deep-water mollusk being cast ashore. It is not likely. Rumphius (the "Plinius Indicus"), in his 'Amboinsche Rariteitkamer,' or Cabinet of the Curiosities of Amboyna, 1705, has given an interesting account of the habits of the Pearly Nautilus, a translation of which I will copy from the admirable monograph of Professor Owen:—"When the Nautilus floats on the water, he puts out his head and all his tentacles, and spreads them upon the water, with the poop of the shell above water; but at the bottom he creeps in the reverse position, with his boat above him, and with his head and tentacles upon the ground, making a tolerably quick progress. He keeps himself chiefly upon the ground, creeping also sometimes into the nets of the fishermen; but after a storm, as the weather becomes calm, they are seen in troops, floating on the water, being driven up by the agitation of the waves. This sailing, however, is not of long continuance, for having taken in all their tentacles, they upset their boat, and so return to the bottom."

As to the *Spirula*, the old Dutch naturalist remarked that it attaches itself to the rocks, and is thrown up on the beach when the north wind blows. Péron found the first living specimen in Australia; Mr. Percy Earl obtained one on the coast of New Zealand; the late Sir Edward Belcher another in the Indian Archipelago; Mr. Bennett got one off Timor; and an imperfect specimen was procured in the 'Challenger' Expedition. I was favoured, in January 1875, by Mr. J. Tyerman, of Tregony, sending for my inspection a perfect specimen of *Spirula australis*, and one of *Argonauta gondola* in spirit of wine, with a memorandum that "the *Spirula* and *Argonauta* were taken by a friend while dredging or, rather, skimming for Pteropods in the Persian Gulf." Mr. Tyerman added that other live specimens of the *Spirula* were captured at the same time. Sir Lewis Pelly informs me that the Persian Gulf is nowhere deeper than between 40 and 50 fathoms. *Spirula* has apparently the same habit as species of *Loligo* and allied genera, in occasionally frequenting the surface of the sea. The shells of *S. australis* are thrown up in considerable numbers on every beach in the North Atlantic, having been wafted northwards by winds and the equatorial current or so-called "Gulf Stream."

Assuming, therefore, that the usual habitat of Mollusca in past epochs did not differ from that of recent Mollusca of the same kind, I think we may safely conclude that the shells of the Cretaceous system, or, more strictly, the Upper Chalk, belonged to shallow and not deep-water Mollusca.

Mr. Woodward tells me that the Chalk Crustacea are also shallow-water forms.

The white chalk is in many places principally composed of *Globigerinæ, Orbulinæ*, and coccoliths or coccospheres, all of which inhabit at present the surface of the sea. According to Dr. Wallich, *Globigerina* is found in all latitudes and at all depths, ranging from 50 to 3000 fathoms *. Mr. Parker and Prof. Rupert Jones (first-rate authorities on the Foraminifera) admit that *Orbulina* and *Globigerina* are "occasionally found in shallow water"†.

I cannot identify a single species of the Cretaceous Mollusca as now living or recent. All of them are evidently tropical forms. One of the Cretaceous species, indeed, *Terebratula striata*, Wahlenberg, has been supposed by some palæontologists to be identical with *T. caput-serpentis*, the latter of which has a range of bathymetrical distribution from low-water mark to 808 fathoms; its geographical extension is equally great, and it has also not a slight amount of variation in

* North-Atlantic Sea-bed, p. 137.
† Quart. Journ. Geol. Soc. vol. xvi. p. 279.

shape and sculpture. But I am not disposed to unite the two species. In *T. striata* the ribs are much narrower than in the typical *T. caput-serpentis* and are finely beaded or tuberous, especially towards the beaks, and they are not so close together as in the variety *septentrionalis*. This question of identity depends, however, on the capability of hereditary persistence which some species possess; and although a certain degree of modification may be caused by an alteration of conditions in the course of incalculable ages, our knowledge is not sufficient to enable us to do more than vaguely speculate, and surely not to take for granted the transmutation of species. We have no proof of any thing of the kind. Devolution, or succession, appears to be the law of nature; evolution (in its modern interpretation) may be regarded as the product of human imagination. I am not a believer in the fixity of species, nor in their periodical extinction and replacement by other species. The notorious imperfection of the geological record ought to warn us against such hasty theorization. We cannot conceive the extent of this imperfection. Not merely are our means of geological information restricted to those outer layers of the earth which are within our sight, but nearly three fourths of its surface are inaccessible to us, so long as they are covered by the sea. Were this not the case, we might have some chance of discovering a few of the missing links which would connect the former with the existing fauna and flora. It is impossible even to guess what strata underlie the bottom of the ocean, or when the latter attained its present position relatively to that of the land. The materials of the sea-bed have been used over and over again in the formation of the earth's crust; "Omnia mutantur, nihil interit;" * and the future history of our globe will, to the end of time, repeat the past. What does Shakespeare say, as a geologist, to such cosmical changes?

"O heaven! that one might read the book of fate,
To see the revolution of the times
Make mountains level, and the continent
(Weary of solid firmness) melt itself
Into the sea! and, other times, to see
The beachy girdle of the ocean
Too wide for Neptune's hips."

There is also the difficult problem of submarine light, evidenced by the facts of deep-sea animals having conspicuous and well-formed eyes, and of the shells of deep-sea Mollusca being sometimes coloured, which is yet unsolved.

Much more remains to be done; and probably many generations, nay, centuries, must elapse before the very interesting subject which I have now ventured to submit to your consideration will be mastered or thoroughly understood in all its varied aspects. Let us then confess our ignorance, and conclude in the sublime words of the Psalmist:—"Thy way is in the sea, and thy path in the great waters, and thy footsteps are not known" †.

Anatomy and Physiology.

Address by Professor A. Macalister, *M.D., M.R.I.A.*

During the thirty-six years which have elapsed since the former meeting of the British Association at Plymouth, in the year 1841, the whole aspect and position of the system of sciences now grouped under the name of Biology have undergone a complete change. Then they were little more than crude and disconnected clusters of facts, whereas now they have become sciences so organic in their unity and so philosophic in their basis that they have risen wholly above the reproach which the cultivators of the mathematical sciences were once wont to cast upon the biologist.

* Ovid, Met. xv. 165. † Ps. lxxvii. 19.

More especially is this true of that corner of the scientific vineyard which it is the business of this department to cultivate, the two sciences of Anatomy and Physiology, of which it is not enough to say that they have made enormous advances, for they have become remodelled in almost every respect. Then the business of this department was supposed to be purely medical, as can be seen from the record of the sectional proceedings at that meeting, when the subjects considered were such as scald head, opium, squinting, and dropsy. From these narrow limits we are now emancipated; Anatomy, in its true scientific sense of Animal Morphology, and a truly scientific Physiology have now become no mere adjuncts to a professional education, but have won for themselves a very prominent place among independent sciences.

This year the department of Anatomy and Physiology meets under singularly favourable auspices. Our sciences have had the honour of supplying a President, one peculiarly our own, to the entire collective body of the British Association; and as in the animal body the special characters of the head impress themselves throughout the whole extent of the organism, so in our own body corporate we are naturally to expect that an Anatomical President will give to the Department of Anatomy and Physiology the stimulus of an increased and vigorous vitality.

Owing to the rapidly increasing general interest in Biological Science and to the increased facilities for research, every year adds largely to our stock of facts, so largely, indeed, in point of detail, that a single year's advances in knowledge suffice to fill more than one portly volume. In two directions especially has our knowledge progressed—in pure Physiology, where it trenches on the domain of Physical Science, and in Embryology.

As in the science of Sociology, for the right understanding of any institution, our most philosophical method of study consists in an examination of the conditions which led to its origin and of the influences under which such an institution has grown up, so in our efforts after the comprehension of the organology of the living body, we can only hope for an adequate understanding of the nature of its component parts by a parallel course of study, an examination of the first appearance of the organ and of its primitive nature, together with a view of the external conditions which acted on it, inducing internal reactions and consequent alterations without. It is along the lines of this method of research that the largest amount of progress has been made in Morphology during the past few years; and in this direction the most rapid future advances may be expected. Each animal attains unto its adult condition by a devious course of growth, which here and there exhibits strange complications, shadows, apparently the precursors of coming events settling down and then vanishing, transitory conditions appearing and disappearing.

In this field of research the number of labourers has been increasing from year to year; and by the improvements which are rapidly being made in methods of work, an abundant harvest of important results is being gathered in, which is widening and strengthening the basis of the science of Morphology. In the list of those whose labours have conduced to place the science of Embryology in its present position, no name stands higher than that of Allen Thomson.

The records of Embryological research for the past few years contain many important additions to our knowledge concerning fundamental parts of this science; some relate to the early formation and primary developmental changes in the egg, and others elucidate later and more specialized conditions of embryonic structures.

In dealing with this part of my subject I am in considerable difficulties, as I find myself forestalled in some respects by the President, and hesitate to intrude into the domain which his master-hand has so clearly elucidated.

Among the researches of the first group I would briefly refer to the elaborate observations made by E. van Beneden, Bütschli, Jhering, and Oscar Hertwig, on the primary changes in the ova at the first beginning of development. It had long ago been noticed that (as our President reminded us) the disappearance of the germinal vesicle is one of the most universal of the early conditions of incipient growth in the fertilized egg, and the ultimate fate of this nucleus of the egg has been sought for carefully and with varying, but unsatisfactory, results. In 1845 Frey described that at certain early stages one or more singular bodies were found external to the yolk, but within the egg; and other observers, especially Robin, noticed that these masses are extruded at one pole of the vitelline mass. To these the name polar bodies, or *Richtungsbläschen*, direction-vesicles, has been given; and it has been conjectured that the appearance of these corpuscles is in some way related to the vanishing of the germinal vesicle. The three problems which this primary stage of development presents for solution are:—1st, What is the method whereby the stimulus to development directly operates on the egg? 2nd, What becomes of the germinal vesicle? and 3rd, In what manner and from what source the direction-corpuscles arise, and what function do they serve in the animal economy?

In relation to the first inquiry, the researches of E. van Beneden * and of many others show that on the surface of the ovum, in the mammal, spermatic nuclei are observable before development; and the careful researches of Oscar Hertwig †, and, after him, of Fol show that in the purple Sea-urchin (*Strongylocentrotus lividus*) the nucleus or head of one of these traverses the vitelline membrane of each egg, enters the yolk, and therein travels until it reaches the nucleus of the egg; whereupon the two, by fusion, form the segmentation-nucleus, which then begins to cleave and to set up the conditions which we formerly looked upon as primary in the developing egg. In certain Leeches also, Hertwig ‡ has shown that the entrance of the spermatozoa takes place in the same way; and in the egg of the Frog the track of the entering nucleus has been even more easily observed, being indicated by a streak of clear protoplasm in the midst of the dark pigment of the egg. We may correlate with this Auerbach's § observation, that in certain Nematodes nuclei become approximated in the egg, and thereby originate the segmentation-nucleus; and while the exact nature of the burrowing nucleus has been questioned by Bütschli, yet Hertwig's discovery of a tailed spermatic nucleus burrowing into the egg in *Strongylocentrotus*, and a similar instance quoted by him from Hensen, together with the absence of any probability or reason to the contrary, seem to render it certain that the ingoing nucleus is either an unaltered spermatozoon, or (though this is less probable) a compound nucleus of vitelline and spermatozoal elements, as E. van Beneden has surmised.

In the second place, as to the fate of the germinal vesicle, the results of observations have been various, although reconcilable. Thus, Oellacher ‖ describes that in the eggs of the Trout the germinal vesicle is emitted, having first reached the surface; Goette ¶ finds that in the bombardier frog (*Bombinator*) the germinal vesicle seems to vanish without visibly approaching the periphery; while Bütschli finds that in Nematodes the vesicle is extruded as a direction-corpuscle, and Van Beneden states that at least some of the materials of the vesicle are extruded; Hertwig, who has studied these transformations in Leeches with great care, describes that at the beginning of development the nucleolus or germinal spot first appears amœboid, then divides, while simultaneously the wall of the germinal vesicle thins and vanishes, its place being marked by a clear non-granular space, within which a spindle-like body forms, consisting of a central plate of granules, formed from the broken-up nucleus, and rays of protoplasm disposed in two tapering cones fore and aft from this central "nuclear plate," as Strasburger has called it, the whole being a somewhat closterium-like or caraway-seed-like figure, at each of whose extremities there is a clear space surrounded by an aureole of star-like rays in the protoplasm of the egg. The material of this spindle, or carylolytic figure, as it is called, is derived from the germinal spot and from some of the original protoplasmic contents of the now indistinguishable germinal vesicle. Approaching the surface, one of the points of the spindle makes a hillock or projection on the periphery of the egg, then the nuclear plate divides transversely, one layer being displaced outwards into the papilla, while the other remains within the circumference of the egg-sphere.

The papilla then becomes constricted off from the surface of the egg, and forms

* Bulletin de l'Acad. royale de Belgique, 2e série, t. xl. (1875).
† Morphologische Jahrbuch, Bd. ii. iii.
‡ Morphologische Jahrbuch.
§ Organologische Studien, Heft ii., 1874.
‖ Archiv für mikrosk. Anat. Band viii.
¶ Entwickelungsgeschichte der Unke.

a nearly isolated sphere, the first of the direction-corpuscles, while a second radiating system arises in an unknown manner within the egg, and, approaching the still included half of the first spindle, forms with it a second spindle, which, by a similar process, gives rise to the second direction-corpuscle.

A third radiating system then appears, similar in most respects to the preceding one, but having in its centre a small nucleus, which, becoming vacuolated, ultimately combines with the nucleus of the included end of the last spindle, derived from the nuclear plate, and forms with it the segmentation-nucleus. This third radiating centre Hertwig believes, from its close similarity to the second or *Samenkern* of the Sea-urchin egg, to be the spermatic nucleus.

From these and other confirmatory observations, which time forbids me to refer to, we are warranted in drawing the conclusion that the germinal vesicle is not entirely expelled, but that it undergoes a transformation, mixing in part with the neighbouring yolk, and, having usually parted with a portion of its substance in the form of the *Richtungsbläschen*, it supplies one essential element to the formation of the segmentation-nucleus for further development.

On the third line of inquiry, namely, as to the nature and origin of the direction-corpuscles, there has been hitherto no accurate concordance among observers. Robin* describes these as derived from the homogeneous yolk-substance; Bütschli†, Oellacher‡, and others consider them to be formed from the extruded germinal vesicle, or at least to contain a part of that structure. Oscar Hertwig §, in this connexion, has attempted to distinguish two kinds of bodies emitted from ova; to the first he limits the name *Richtungsbläschen*, and these he characterizes as always arising by a process of budding, to which the division of the nucleus is a necessary preliminary. Such true direction-corpuscles he considers as representing a kind of suppressed parthenogenesis, a theory which is borne out by the observations made by Richard Hertwig || on the infusorium *Spirochora gemmipara*, wherein he shows that similar spindles are formed before fission takes place in that form. Strasburger¶, on the other hand, who has discovered similar bodies in the ovules of conifers, supposes that by these corpuscles certain elements are got rid of, which, by their presence, prevent development in the egg.

From the true *Richtungsbläschen* Hertwig distinguishes the simple protoplasmic matter produced from some eggs, not by any process of budding, and apparently with no precedent spindle-stage. These he calls, after Fol, "excretion-spheres."

On this subject we require much additional information before we can feel warranted in drawing any inferences or conclusions as to the true nature of these remarkable bodies.

Among the observations on special parts of later stages of embryonic growth, I shall ask your attention specially to two sets of recent researches:—1st, those on the primitive groove of the fertilized egg; and 2nd, those on the embryology of limbs.

As most of my hearers are aware, Prof. Dursy ** first described, several years ago, that in one of the earliest stages of the developing embryo there is formed a primitive groove, which, having appeared and lasted for a short time, finally vanishes, being pushed out of existence by the medullary groove, the first trace of origin of the spinal cord. This arrangement, singular from its transitoriness, has naturally attracted much attention, and various hypotheses have been advanced to account for its existence; some, like the veteran embryologist Kölliker, have expressed their belief that this groove is but a continuation of the medullary groove, with which, prior to Dursy's discrimination, it had always been confounded, and that its margins, the primitive folds, are simple extensions of the medullary folds; but such a view fails to account for its obvious distinctness, for its frequent want of symmetry††, for the evident fusion beneath it of the embryonic layers, epi- and mesoblast, and probably also, at its hinder end, of the hypoblast (though Kölliker

* Journal de la Physiologie, 1862.
† *Op. cit.*
‡ Journal de la Physiologie, 1862.
§ Morph. Jahrb. Bd. iii. p. 70.
|| Jenaische Zeitschrift, 1877, p. 149.
¶ Zellbildung, p. 294.
** Der primitive Streif des Hühnchens.
†† Goette, Archiv für mikrosk. Anat. vol. x. p. 145.

denies this*); in fact, for a single peculiarity among them any which characterize this primitive groove.

Mr. Schäfer, of University College, conceives this groove to be an infolding of the epiblast or outer layer of the embryo, which then expanding laterally, forms the *mesoblast* by a process of lateral cell-growth; and his sections of the embryonic Guinea-pig show clearly that from the fusion of layers which constitute the axis-cord of His at the bottom of the primitive groove, the laterally outgrowing mass of mesoblast can be seen to spring. Those who adopt the view of Kölliker and Hensen, that the mesoblast is derived from the epiblast, will probably regard this hypothesis, or some modification of it, with favour; but if (as I am from my own observations personally inclined) we regard the mesoblast as a derivative from the inner embryonic layer, then we are forced to look elsewhere for an explanation of the appearance.

Our own English embryologist, Mr. Balfour, whom as a fellow member of the British Association we delight to honour, has made this groove the subject of examination, and has correlated it with the change in position of the embryo on the surface of the germinal disk. He has shown that in the egg of the bird or mammal the embryo from the first appears in the centre of the blastoderm, while in more generalized forms, such as the Shark, the first trace of the embryo is marginal; and from this position it gradually recedes, as in the growth of the blastoderm, over the surface of the yolk the former extends more rapidly at each side of the embryo than it does opposite the embryo itself, and in the course of development the two headlands which border the bay at whose fundus the embryonic shark appears, approximate and unite mesially, forming a sutural line leading from the margin of the embryo to the edge of the blastoderm. He considers that in the highly specialized form of the bird or mammal the primitive groove is the heirloom of this ancestral change in condition; and if we correlate with this historic evidence such appearances as the marginal notch in the germinal disk, described by Professor Rauber † of Leipzig, and considered by him as the ideal hinder edge of the primitive groove, we can, I believe, make out an almost overwhelming case in favour of this theory, more especially as we cannot but believe that the change which Balfour postulates has taken place, and that this, in accordance with morphological analogy, should leave some trace of its having existed behind it.

Prof. Rauber ‡, who has also written several papers on this subject, has considered this groove to be a trace of the opening of invagination of the hypoblast, a groove continuous with the extremity of the blastopore, or primitive mouth, of which, indeed, he supposes it to form a part. This view is based principally on the dorsal extension of the blastopore in *Amphioxus* and in Ascidians §, and on the general evidence of the origin of the hypoblast by invagination, as well as on the observed fusion of the hypo- and mesoblast at the hinder end of the groove and their separateness anteriorly. As the blastopore is placed at the hinder end of the embryo, at the bottom of the bay of blastoderm, and as the neural and hypoblastic canals are here confluent, as are the primitive and medullary grooves, this may be one factor in the formation of the groove, at least of its anterior extremity. Into the larger question of the origin of the mesoblast time forbids our entering.

I shall now very briefly direct your attention to a second series of embryological researches, viz. those on the earliest formation and ontogeny of limbs.

In his remarkable and suggestive series of papers on the development of Elasmobranchs, Mr. Balfour ‖ describes the first appearance of the limb to be a thickened ridge of epiblast, more prominent in front and behind than mesially, and forming a continuous lateral fin. In later stages of development the mesoblast beneath this ridge thickens, projects, and, being substituted for the epiblast, forms the chief substance of the limb as it afterwards exists. In the rabbit-embryo Kölliker ¶ like-

* Entwickelungsgeschichte, p. 125.
† Morpholog. Jahrbuch, Bd. ii. p. 571, Taf. 37. fig. 11.
‡ Gegenbaur's Morpholog. Jahrb. Bd. ii. p. 550.
§ Kowalewsky, "Embryologische Studien," Mém. Acad. St. Pétersb. 1871, p. 30.
‖ Journal of Anatomy and Physiology, vol. xi. p. 132.
¶ Entwickelungsgeschichte, 1876, p. 211.

wise describes the same condition, a primarily epiblastic superficial process, replaced, as development progresses, by a mesoblastic outgrowth; and in the bird-embryo Foster and Balfour, Kölliker, and others describe similar stages. Here we have two very remarkable conditions—first, an indication that the primitive vertebrate form possessed an epiblastic system of appendages; and, secondly, that the limbs are the remnants of a continuous lateral fin. To the first hypothesis, that the primary appendicular system was epiblastic, there are no ontological objections; for in such generalized forms among Vermes as *Sagitta* we have lateral epiblastic fin-processes, which, like the hooks of *Peripatus* or the bristles of *Polychæta*, may well indicate allied epiblastic forms of archaic protovertebral limbs. As the surviving forms of protovertebrates, such as the Tunicates and *Amphioxus*, as well as the lowest craniotes, like the Lampreys, are limbless, they give us no information as to the primary condition, as this deficiency may in them be due to obsolescence*. Thus, as from the now classic researches of Kleinenberg†, we have learned that, in the primitive Metazoa there was a primary muscular system derived from the epiblast, which has vanished in higher forms of animals, being replaced by a secondary musculature of mesoblastic origin, and with the mesoblast derived, at least in Invertebrates and Ichthyopsids, from the hypoblast, so we have now learned that there was probably in the protovertebrates an epiblastic appendage system, which, having no inherent muscular apparatus, and being incapable of sufficient specialization, vanished or became rudimental, and was replaced by the more permanent and more plastic mesoblastic limbs.

The second point is of still greater interest, namely, that Embryology supplies us with demonstrative evidence that the limbs are the remains of a continuous lateral fin. This Mr. Balfour has found to be the case in Elasmobranchs, and there are traces of similar though shadowy thickenings along the Wolffian ridge in frogs and in birds. But while the epiblastic ridges are thus continuous, the mesoblastic enlargements are much more indistinctly so, even from the first, exhibiting the two-fold arrangement of fore and hinder limbs.

I cannot forbear in this connexion referring to a closely related point in the general subject of the morphology of limbs.

The vertebrate animal is primarily composed of a chain of similar segments, and there is no *à priori* reason in morphology why any one metamere should not bear limbs as well as any other. Nay, from the analogy of Chætopod worms, we might expect that, as in these, each zonite usually bears two pairs of parapodia or stumpy foot-processes, so in similarly derived and similarly segmented forms there might be at least traces of a similar multiplication of appendages.

In effect, we really do find a somewhat parallel series in the metameres of fishes; for, as Mr. Balfour has shown, the mediodorsal fin comes into existence precisely in the same manner as the lateral fin-ridge; and being a double structure, as we learn both in its specialized form and even in the structure of the cartilaginous precursor of the interspinous bones, it may reasonably be supposed to represent structures homologous with the system of notopodia in a laterally compressed worm, fused together, while the paired fins may be regarded as the neuropodia, separated by the visceral cavity, and which in the degraded and compressed metameres behind the visceral cavity also coalesce, forming another primary ridge, that of the anal and caudal fin.

In relation to the primary source of origin and method of derivation of limbs, we have to account for two separate factors, the limb-girdle and the limb-rays; with regard to the former, I can now only refer to the hypothesis of Gegenbaur and Dohrn, that the limb-girdles represent modifications of the visceral arches, and I pass this by with two comments:—1st, that the visceral arches are themselves, to a certain extent, specialized, and, consequently, it would be better to state the hypothesis thus—that the limb-girdles and visceral arches are specializations of corresponding paraxial structures in different metameres; 2nd, in the light of the evident fundamental complexity of the limb-girdles, it seems a simpler explanation of phenomena to regard each girdle as made up of the arches of several (probably three or more metameres fused) rather than as subdivisions of a single arch.

* *Cf.* Dohrn, Ursprung d. Wirbelthiere u. Functionsmech.

† Hydra.

As to the primary nature of the limb-ray, Professors Huxley and Gegenbaur have taught us, in their recent reconstruction of the theory of the archipterygium, that the primitive limb was constructed somewhat like the limb-ray of *Ceratodus*, having a central jointed axis from which diverge, fore and aft, lateral processes, or, to use the elegant nomenclature of Professor Huxley, "the primitive vertebrate limb consisted of a column of mesomeres, to each of which a lateral pre- and post-axial paramere was articulated."

But even this form, though doubtless the stock from which the limbs of all vertebrates above the Dipnoi have sprung, is regarded, and with reason, by Gegenbaur as a derivative one, formed by the coalescence of a still more archaic arrangement of rays appended to the paraxial arches referred to above. It is possible that the primary fusion may have taken such a form as that which Gegenbaur represented in his original *archipterygium*, with more than one cartilage appended to the girdle, a form of which the arrangement in the Dog-fish and Angel-shark may be representative; and these, by a still further concentration, attended with an exaltation of the mesopterygium and a displacement of the propterygium as in *Hexanchus*, or of the pro- and metapterygium, as in *Cestracion*, may thus reach the elongated form of the limb in Dipnoi. It seems obvious that this fish, *Ceratodus*, though singularly generalized, has arisen from a point in the vertebrate stem above the starting-point of the Elasmobranchs.

Whether this has been the case or no, whether the Elasmobranch has been derived from an earlier condition than the Dipnoan progenitor or no, the researches of Professor Huxley have made it plain that it is from the meso- and not from the metapterygium that the single basal ray-bone of the higher vertebrates has arisen.

A curious question will naturally occur to any one considering the genesis of limbs—What is the reason that, in vertebrate animals, the number of limbs is limited, and apparently has been always limited, to four? And as we have seen that there is an ontological possibility that each of these contains elements from several metameres, there is no morphological reason, and therefore must be some mechanical cause, for this limitation. Were the primitive vertebrates terrestrial, we could understand that the tetrapod has a mechanical advantage over the tripod or any condition with an inferior number of limbs, both statically, from the indeterminateness of the strain on each support in the four-legged form, and in progression, from the easily understood conditions of stability of equilibrium in walking; while the tetrapod excels the hexapod or millepede, not only because, by a reduction in number, the amount of nutrition required for the use of the limbs is minimized, but it is absolutely demonstrable that the facility of rotation is increased by the reduction of the limbs to the lowest number consistent with other conditions of utility. In connexion with this point, Professor Haughton has made some curious observations, the results of which I hope we shall have laid before us in this department during our present meeting.

But the earliest vertebrates were aquatic; and yet even here we find the fourfold division of these actinal appendages. These primitive forms differed from worms in the greater amount of fusion of their metameres, which at an early period had ceased to give to these animals an externally jointed appearance, as we may learn from *Amphioxus*, which has branched from the vertebrate stem long before most of the secondary characters, which are constant throughout the rest of the vertebrates, had been foreshadowed. Being thus more consolidated than worms, and moving, as they would necessarily do, more as a unit and less as a chain, the advantages of the mode of propulsion by a tail over swimming by means of the continuous lateral fin of united parapodia would be increasingly manifest with increasing somatic rigidity. Hence, naturally, the parapodia of the hinder somites would coalesce to form a tail, as they have done in fishes, and the appendages placed further forward would undergo retrogression, unless some function could be found for them which would make their retention an advantage in the economy. In the long worm-like forms like Lampreys, such a retrogression has absolutely taken place, as in fishes of this form the use of lateral fins is reduced to a minimum; hence in the elongated form of ordinary fishes, like Eels, Band-fishes, and Blennies, the lateral fins become rudimental or vanish. But these organs are of obvious use in giving a capacity to alter the plane of motion, a power which is necessary for most fishes; and they not only act in elevation and depression, but in lateral rotation, as any one can verify for himself by watching fishes in an aquarium. In order to accommodate these united lateral appendages most conveniently to the sinuous curves into which the body of a fish is thrown in swimming, and to diminish the surface of resistance to the water, the parapodia have divided themselves into two groups, leaving the centre of the body, where the cephalic and caudal curves meet during progression, free from lateral appendages..

Time would fail to permit me to catalogue the many other recent additions to our knowledge of Ontogeny derived from Embryology, so I must draw to a conclusion by referring very briefly to the department of morphological science with which my own daily work brings me most closely into contact, viz. that of Human Anatomy.

Considering the limited field, and the care with which the human body has been scrutinized for so many years, it is easily understood that the amount of annual progress is inconsiderable, except in matters of minute detail; still every year gives to us a solid addition to our knowledge; and of the fruits of the past year's work, I would refer, in passing, to the papers of Bernays on the development of the Auriculo-ventricular Valves, of Klein on the Histology of the Omentum, and of Herbert Watney on the Distribution of the Connective Reticulum throughout the whole alimentary canal.

In matters of detail it is still surprising how much yet remains to be done even in this much wrought department. In a subject so personally interesting as that of Human Anatomy, it is surely of practical utility, if not of scientific interest, that we should have correct and broadly based statements regarding averages of conditions in the case of the variable structures of the human body (and what part is not variable?). In the dissecting-rooms of Great Britain and Ireland there are at least six hundred human bodies examined annually, and yet there are few variable structures concerning which we have observations made on any thing like such a numerical basis.

It has been the fashion on the part of certain anatomists to disparage the work of those who observe and collate such cases of variety; but surely such a method of regarding any group of constantly recurring morphological facts is unphilosophical, even though the bearing of the facts be not at first sight obvious; and until we know the laws of whose operations these so-called anomalies are special cases, on general principles it becomes the business of the anatomist to collect, collate, and record these cases. Thanks to the researches of the laborious and indefatigable Prof. Wenzel Gruber, of St. Petersburg, that prince of descriptive anatomists, and to those of others too numerous to mention, the anatomical text-books of to-day are much more definite than they were thirty years ago. Yet much still requires to be done; and in even our most recent hand-books we often seek in vain for information on points of descriptive anatomy. Surely it is to be hoped, and not too much to expect, that in a few years some of the many small lacunæ in our knowledge will be filled up, and the study of human anatomy will become, not a mere matter of words and names, as it has in too many respects been heretofore, but a really scientific study, a practical application of sound morphological principle.

Anthropology.

Address to the Department of Anthropology. By Francis Galton, *F.R.S.*

Permit me to say a few words of personal explanation to account for the form of the Address I am about to offer. It has been the custom of my predecessors to give an account of recent proceedings in Anthropology, and to touch on many branches of that wide subject. But I am at this moment unprepared to follow their example with the completeness I should desire and you have a right to expect, owing to the suddenness with which I have been called upon to occupy this chair. I had, indeed, the honour of being nominated to the post last spring; but circumstances arising which made it highly probable that I should be prevented from attending this meeting, I was compelled to ask to be superseded. New arrangements were then made by the Council, and I thought no more about the matter. However, at the last moment, the accomplished ethnologist who otherwise would have presided over you was himself debarred by illness from attending, and the original plan had to be reverted to.

Under these circumstances I thought it best to depart somewhat from the usual form of Addresses, and to confine myself to certain topics with which I happen to have been recently engaged, even at the risk of incurring the charge of submitting to you a memoir rather than an address.

I propose to speak of the study of those groups of men who are sufficiently similar in their mental characters or in their physiognomy, or in both, to admit of classification; and I especially desire to show that many methods exist of pursuing the inquiry in a strictly scientific manner, although it has hitherto been too often conducted with extreme laxity.

The types of character of which I speak are such as those described by Theophrastus, La Bruyère, and others, or such as may be read of in ordinary literature and are universally recognized as being exceedingly true to nature. There are no worthier professors of this branch of Anthropology than the writers of the higher works of fiction, who are ever on the watch to discriminate varieties of character, and who have the art of describing them. It would, I think, be a valuable service to Anthropology if some person well versed in literature were to compile a volume of extracts from novels and plays that should illustrate the prevalent types of human character and temperament. What, however, I especially wish to point out is, that it has of late years become possible to pursue an inquiry into certain fundamental qualities of the mind by the aid of exact measurements. Most of you are aware of the recent progress of what has been termed Psycho-physics, or the science of subjecting mental processes to physical measurements and to physical laws. I do not now propose to speak of the laws that have been deduced, such as that which is known by the name of Fechner, and its numerous offshoots, including the law of fatigue; but I will briefly allude to a few instances of measurement of mental processes, merely to recall them to your memory. They will show, what I desire to lay stress upon, that the very foundations of the differences between the mental qualities of man and man admit of being gauged by a scale of inches and a clock.

Take, for example, the rate at which a sensation or a volition travels along the nerves, which has been the subject of numerous beautiful experiments. We now know that it is far from instantaneous, having, indeed, no higher velocity than that of a railway express train. This slowness of pace, speaking relatively to the requirements that the nerves have to fulfil, is quite sufficient to account for the fact that very small animals are quicker than very large ones in evading rapid blows, and for the other fact that the eye and the ear are situated in almost all animals in the head, in order that as little time as possible should be lost on the road in transmitting their impressions to the brain. Now the velocity of the complete process of to and fro nerve-transmission in persons of different temperaments has not been yet ascertained with the desired precision. Such difference, as there may be, is obviously a fundamental characteristic, and one that well deserves careful examination. I may take this opportunity of suggesting a simple inquiry that would throw much light on the degree in which its velocity varies in different persons, and how far it is correlated with temperament and external physical characteristics. Before I describe the inquiry I suggest, and towards which I have already collected a few data, it is necessary that I should explain the meaning of a term in common use among astronomers, namely "personal equation." It is a well-known fact that different observers make different estimates of the exact moment of the occurrence of any event. There is a common astronomical observation, in which the moment has to be recorded at which a star that is travelling across the field of view of a fixed telescope crosses the fine vertical wire by which that field of view is intersected. In making this observation it is found that some observers are over-sanguine and anticipate the event, while others are sluggish and allow the event to pass by before they succeed in noting it. This is by no means the effect of inexperience or maladroitness, but it is a persistent characteristic of each individual, however practised in the art of making observations, or however attentive he may be. The difference between the time of a man's noting the event and that of its actual occurrence is called his personal equation. It remains curiously constant in every case for successive years, it is carefully ascertained for every assistant in every observatory, it is published along with his observations, and is applied to them just as a correction would be applied to measurements made by a foot-rule that was known to be too long or too short by some definite amount. Therefore the magnitude of a man's personal equation indicates a very fundamental peculiarity of his constitution; and the inquiry I would suggest is to make a comparison of the age, height, weight, colour of hair and eyes, and temperament (so far as it may admit of definition) in each observer in the various observatories at home and abroad, with the amount of his personal equation. We should thus learn how far the more obvious physical characteristics may be correlated with certain mental ones, and we should perhaps obtain a more precise scale of temperaments than we have at present.

Another subject of exact measurement is the time occupied in forming an elementary judgment. If a simple signal be suddenly shown, and if the observer presses a stop as quickly as he can when he sees it, some little time will certainly be lost, owing to delay in nerve-transmission and to the sluggishness of the mechanical apparatus. In making experiments on the rate of judgment, the amount of this interval is first ascertained. Then the observer prepares himself for the exhibition of a signal that may be either black or white, but he is left ignorant which of the two it will be. He is to press a stop with his right hand in the first event, and another stop with his left hand in the second one. The trial is then made, and a much longer interval is found to have elapsed between the exhibition of the alternative signal and the record of it than had elapsed when a simple signal was used. There has been hesitation and delay: in short, the simplest act of judgment is found to consume a definite time. It is obvious that here, again, we have means of ascertaining differences in the rapidity of forming elementary judgments and of classifying individuals accordingly.

It would be easy to pursue the subject of the measurement of mental qualities to considerable length, by describing other kinds of experiment, for they are numerous and varied. Among these is the plan of Professor Jevons, of suddenly exhibiting an unknown number of beans in a box, and requiring an estimate of their number to be immediately called out. A comparison of the estimate with the fact, in a large number of trials, brought out a very interesting scale of the accuracy of such estimates, which would of course vary in different individuals, and might be used as a means of classification. I can imagine few greater services to Anthropology than the collection of the various experiments that have been imagined to reduce the faculties of the mind to exact measurement. They have engaged the attention of the highest philosophers, but have never, so far as I am aware, been brought compendiously together, and have certainly not been introduced, as they deserve, to general notice.

Wherever we are able to perceive differences by intercomparison, we may reasonably hope that we may at some future time succeed in submitting those differences to measurement. The history of science is the history of such triumphs. I will ask your attention to a very notable instance of this, namely, that of the establishment of the scale of the thermometer. You are aware that the possibility of making a standard thermometric scale wholly depends upon that of determining two fixed points of temperature, the interval between them being graduated into a scale of equal parts. These points are, I need hardly say, the temperatures of freezing and of boiling water respectively. On this basis we are able to record temperature with minute accuracy, and the power of doing so has been one of the most important aids to Physics and Chemistry as well as to other branches of investigation. We have been so accustomed from our childhood to hear of degrees of temperature, and our scientific knowledge is so largely based upon exact thermometric measurement, that we cannot easily realize the state of science when the thermometer, as we now use it, was unknown. Yet such was the condition of affairs so recently as two hundred years ago, or thereabouts. The invention of the thermometer, in its present complete form, was largely due to Boyle; and I find in his Memoirs (London, 1772, vol. vi. p. 403) a letter that cannot fail to interest us, since it well expresses the need of exact measurement that was then felt in a particular case, where it was soon eminently well supplied, and therefore encourages hope that our present needs as Anthropologists may hereafter, in some way or other, be equally well satisfied. The letter is from Dr. John Beale, a great friend and correspondent of Boyle, and is dated February, 1663. He says in it:—

"I see by several of my own thermometers, that the glass-men are by you so well instructed to make the stems in equal proportions, that if we could name some degrees, . . . we might by the proportions of the glass make our discourses intelligible in mentioning what degrees of cold our greatest frosts do produce. . . . If we can discourse of heat and cold in their several degrees, so as we may signify the same intelligibly, . . . it is more than our forefathers have taught us to do hitherto."

The principal experiments by which the mental faculties may be measured require, unfortunately for us, rather costly and delicate apparatus; and until physiological laboratories are more numerous than at present, we can hardly expect that they will be pursued by many persons.

Let us now suppose that, by one or more of the methods I have described or alluded to, we have succeeded in obtaining a group of persons resembling one another in some mental quality, and that we desire to determine the external physical characteristics and features most commonly associated with it. I have nothing new to say as regards the usual anthropometric measurements; but I wish to speak of the great convenience of photographs in conveying those subtle but clearly visible peculiarities of outline which almost elude measurement. It is strange that no use is made of photography to obtain careful studies of the head and features. No single view can possibly exhibit the whole of a solid, but we require for that purpose views to be taken from three points at right angles to one another. Just as the architect requires to know the elevation, side view, and plan of a house, so the Anthropologist ought to have the full face, profile, and view of the head from above of the individual whose features he is studying.

It might be a great convenience, when numerous portraits have to be rapidly and inexpensively taken for the purpose of anthropological studies, to arrange a solid framework supporting three mirrors, that shall afford the views of which I have been speaking, by reflexion, at the same moment that the direct picture of the sitter is taken. He would present a three-quarter face to the camera for the direct picture, one adjacent mirror would reflect his profile towards it, another on the opposite side would reflect his full face, and a third sloping over him would reflect the head as seen from above. All the reflected images would lie at the same optical distance from the camera, and would therefore be on the same scale, but they would be on a somewhat smaller scale than the picture taken directly. The result would be an ordinary photographic picture of the sitter, surrounded by three different views of his head. Scales of inches attached to the framework would appear in the picture and give the means of exact measurement.

Having obtained drawings or photographs of several persons alike in most respects, but differing in minor details, what sure method is there of extracting the typical characteristics from them? I may mention a plan which had occurred both to Mr. Herbert Spencer and myself, the principle of which is to superimpose optically the various drawings and to accept the aggregate result. Mr. Spencer suggested to me in conversation that the drawings reduced to the same scale might be traced on separate pieces of transparent paper and secured one upon another, and then held between the eye and the light. I have attempted this with some success. My own idea was to throw faint images of the several portraits, in succession, upon the same sensitized photographic plate. I may add that it is perfectly easy to superimpose optically two portraits by means of a stereoscope, and that a person who is used to handle instruments will find a common double eyeglass fitted with stereoscopic lenses to be almost as effectual and far handier than the boxes sold in shops.

In illustration of what I have said about photographic portraits, I will allude to some recent experiences of my own in a subject that I have still under consideration. In previous publications I have treated of men who have been the glory of mankind; I would now call your attention to those who are its disgrace. The particular group of men I have in view are the criminals of England, who have been condemned to long terms of penal servitude for various heinous offences.

It is needless to enlarge on the obvious fact that many persons have become convicts who, if they had been afforded the average chances of doing well, would have lived up to a fair standard of virtue. Neither need I enlarge on the other equally obvious fact, that a very large number of men escape criminal punishment who in reality deserve it quite as much as an average convict. Making every allowance for these two elements of uncertainty, no reasonable man can entertain a doubt that the convict class includes a large proportion of consummate scoundrels, and that we are entitled to expect to find in any large body of convicts a prevalence of the truly criminal characteristics, whatever these may be.

Criminality, though not very various in its development, is extremely complex in its origin; nevertheless certain general conclusions are arrived at by the best writers on the subject, among whom I would certainly rank Prosper Despine. The ideal criminal has three peculiarities of character: his conscience is almost deficient, his instincts are vicious, and his power of self-control is very weak. As a consequence of all this he usually detests continuous labour. This statement applies to the criminal classes generally—the special conditions that determine the description of crime being the character of the instincts, and the fact of the absence of self-control being due to ungovernable temper, or to passion, or to mere imbecility.

The deficiency of conscience in criminals, as shown by the absence of genuine remorse for their guilt, appears to astonish all who first become familiar with the details of prison life. Scenes of heartrending despair are hardly ever witnessed among prisoners; their sleep is broken by no uneasy dreams—on the contrary, it is easy and sound; they have also excellent appetites. But hypocrisy is a very common vice; and all my information agrees in one particular, as to the utter untruthfulness of criminals, however plausible their statements may appear to be.

The subject of vicious instincts is a very large one: we must guard ourselves against looking upon them as perversions, inasmuch as they may be strictly in accordance with the healthy nature of the man, and, being transmissible by inheritance, may become the normal characteristics of a healthy race, just as the sheep-dog, the retriever, the pointer, and the bull-dog have their several instincts. There can be no greater popular error than the supposition that natural instinct is a perfectly trustworthy guide, for there are striking contradictions to such an opinion in individuals of every description of animal. All that we are entitled to say is, that the prevalent instincts of each race are trustworthy, not those of every individual. A man who is counted as an atrocious criminal by society, and is punished as such by the law, may nevertheless have acted in strict accordance with his instincts. The ideal criminal is deficient in qualities that oppose his vicious instincts; he has neither the natural regard for others which lies at the base of conscience, nor has he sufficient self-control to enable him to consider his own selfish interests in the long run. He cannot be preserved from criminal misadventure, either by altruistic or by intelligently egoistic sentiments.

It becomes an interesting question to know how far these peculiarities may be correlated with physical characteristics and features. Through the cordial and ready assistance of Sir Edmund Du Cane, the Surveyor-General of Prisons, who has himself contributed a valuable memoir to the Social Science Congress on the subject, I was enabled to examine the many thousand photographs of criminals that are preserved for purposes of identification at the Home Office, to visit prisons and confer with the authorities, and lastly to procure for my own private statistical inquiries a large number of copies of photographs of heinous criminals. I may as well say that I begged that the photographs should be furnished me without any names attached to them, but simply classified in three groups, according to the nature of the crime. The first group included murder, manslaughter, and burglary; the second group included felony and forgery; and the third group referred to sexual crimes. The photographs were of criminals who had been sentenced to long terms of penal servitude.

By familiarizing myself with the collection, and continually sorting the photographs in tentative ways, certain natural classes began to appear, some of which are exceedingly well marked. It was also very evident that the three groups of criminals contributed in very different proportions to the different physiognomic classes.

This is not the place to go further into details: indeed my inquiry is far from complete. I merely quote my experiences in order to show the way in which questions of character, physiognomy, and temperament admit of being scientifically approached, and to give an instance of the helpfulness of photography. If I had had the profiles and the shape of the head as seen from above, my results would have been much more instructive. Thus, to take a single instance, I have seen many pencil studies in outline of selected criminal faces drawn by Dr. Clarke, the accomplished and zealous medical officer of Pentonville Prison; and in these sketches a certain very characteristic profile seemed to me conspicuously prevalent. I should have been very glad of photographs to corroborate this. So, again, if I had had photographic views of the head taken from above, I could have tested, among other matters, the truth of Professor Benedict's assertion about the abnormally small size of the back of the head in criminals.

I have thus far spoken of the characters and physiognomy of well-marked varieties of men: the Anthropologist has next to consider the life-history of those varieties, and especially their tendency to perpetuate themselves, whether to displace other varieties and to spread, or else to die out. In illustration of this, I will proceed with what appears to be the history of the criminal class. Its perpetuation by heredity is a question that deserves more careful investigation than it has received; but it is on many accounts more difficult to grapple with than it may at first sight appear to be. The vagrant habits of the criminal classes, their illegitimate unions and extreme untruthfulness are among the difficulties. It is, however, easy to show that the criminal nature tends to be inherited; while, on the other hand, it is impossible that women who spend a large portion of the best years of their life in prison can contribute many children to the population. The true state of the case appears to be that the criminal population receives steady accessions from classes who, without having strongly marked criminal natures, do nevertheless belong to a type of humanity that is exceedingly ill-suited to play a respectable part in our modern civilization, though they are well suited to flourish under half-savage conditions, being naturally both healthy and prolific. These persons are apt to go to the bad; their daughters consort with criminals and become the parents of criminals. An extraordinary example of this is given by the history of the infamous Jukes family in America, whose pedigree has been made out, with extraordinary care, during no less than seven generations, and is the subject of an elaborate memoir printed in the thirty-first annual report of the Prison Association of New York, 1876. It includes no less than 540 individuals of Jukes blood; among whom the number of persons who degraded into criminality, pauperism, or disease is frightful to contemplate.

It is difficult to summarize the results in a few plain figures, but I will state those respecting the fifth generation, through the eldest of the five prolific daughters of the man who is the common ancestor of the race. The total number of these was 123, of whom 38 came through an illegitimate granddaughter, and 85 through legitimate grandchildren. Out of the 38, 16 have been in jail, 6 of them for heinous offences, one of these having been committed no less than nine times; 11 others were paupers, or led openly disreputable lives; 4 were notoriously intemperate; the history of 3 had not been traced, and only 4 were known to have done well. The great majority of the women consorted with criminals. As to the 85 legitimate descendants, they were less flagrantly bad, for only 5 of them had been in jail, and only 13 others had been paupers. Now the ancestor of all this mischief, who was born about the year 1730, is described as having been a hunter and a fisher, a jolly companionable man, averse to steady labour, working hard and idling by turns, and who had numerous illegitimate children, whose issue has not been traced. He was, in fact, a somewhat good specimen of a half-savage, without any seriously criminal instincts. The girls were apparently attractive, marrying early and sometimes not badly; but the gipsy-like character of the race was unsuited to success in a civilized country. So the descendants went to the bad, and the hereditary moral weaknesses they may have had rose to the surface and worked their mischief without a check. Cohabiting with criminals, and being extremely prolific, the result was the production of a stock exceeding 500 in number, of a prevalent criminal type. Through disease and intemperance the breed is now rapidly diminishing; the infant mortality has of late been horrible among them; but fortunately the women of the present generation bear usually but few children and many of them are altogether childless.

This is not the place to go further into details. I have alluded to the Jukes family in order to show what extremely important topics lie open to inquiry in a single branch of anthropological research, and to stimulate others to follow it out. There can be no more interesting subject to us than the quality of the stock of our countrymen and of the human race generally, and there can be no more worthy inquiry than that which leads to an explanation of the conditions under which it deteriorates or improves.

Zoology and Botany.

[For Dr. J. Gwyn Jeffreys's Address, see page 79.]

On the Colour of Animals. By Wm. Ackroyd.

The tendency to change which we see in all departments of nature is perhaps nowhere more strikingly shown than in the phenomena of colour in the animal kingdom. The apparent seasonal change of garb by the arctic fauna, the assumption of brigher colours by males than by females in the gradual change from cubhood to the adult state, and the fading of the tints upon the nearing of old age, are sufficient evidences of this. The author proceeds to deal with these phenomena from a physical standpoint.

Respecting colour in the inorganic world, two propositions are enunciated, in which the coloured substance is referred to as the absorbing body.

Prop. I. *Alteration of atomic position in the absorbing body is accompanied by change of colour.*

Prop. II. is the converse of I.

Change of colour in the absorbing body is an evidence of its loss or gain of potential energy.

The latter proposition the writer attempts to apply to the study of the colour of animals, and works with the following scale, which he terms *the biological metachromatic scale*:—

Increase of Animal Potential Energy. ↑		↓ Decrease of Animal Potential Energy.
	Black	
	Brown	
	Red	
	Orange	
	Yellow	
	Green	
	Blue	
	White or Colourless	

Thus, placing a mechanical interpretation upon colour, he considers the evidences of (i) gain and (ii) loss of energy in the animal kingdom, and finally deals with (iii) adaptation to environment and (iv) colour-distribution.

I. *Evidences of Gain of Energy.*—Under this head the author includes those changes of tint in hair &c. which take place from youth to adult age. The change is not only seen in man, but in the Primates and other orders of animals. Sexual differences are tabulated, and it is shown that the fact of the male being most absorptive-coloured is indicative of its having more energy than the female. The order is reversed among the fishes.

II. *Evidences of Loss of Energy.*—Greyness accompanying old age in the animal kingdom is taken as a proof of this; greyness produced by disease and the change one sees in certain fishes previous to putrefaction.

III. *Adaptation to Environment.*—There is reason for thinking that the winter change in the arctic fauna is induced by rigour of climate, and is protective against that rigour. In dealing with adaptation as manifested in the lower orders of life, he first proceeds to show that certain well-known cases of colour-change among chemical salts produced by light and by heat are cases of adaptation to environment. It is shown that the cases of adaptation in the lower orders of animals are probably analogous, if not identical, to those among inorganic bodies.

IV. *Distribution of Colour.*—In the lighter tint generally found on the abdominal parts of animals, we have a colour localized which, in the arctic regions, is distributed all over. It may be similarly induced and have to serve the same end. Those parts are most absorptive-coloured, and presumably are the best radiators of heat, where warmth andeconomy of heat is not very necessary, as, *e. g.*, the primaries and tails of birds, and the leg-flanks, manes, and tails of quadrupeds. *Brown* horses have *black* manes and tails.

On the Habits of the Pearly Nautilus (Nautilus pompilius). *By* Dr. G. Bennett, *F.L.S.*

The author said that the idea that *Nautilus* and *Spirula* are deep-water forms is fallacious; for though the *Nautilus pompilius* has rarely been met with, the shells are often found on beaches in the Indian Ocean and South Pacific, where, he said, he was not aware of any deep-water mollusk ever having been cast. On the 24th of July, 1874, however, the 'Challenger' exploring party netted a *Nautilus* in about 320 fathoms of water off Matuka Island, and for some time kept it alive in a tub to observe it habits. It propelled itself, after the manner of Cephalopoda, "backwards," and each pair of its tentacles was found to have a definite and divergent direction. The great depth at which the 'Challenger's' specimen was captured was so opposed to experience that Dr. Bennett felt inclined to believe it was netted by the trawl as it passed near the reef, or as it was floating at a slight depth. It was noticed that the 'Challenger' *Nautilus* attained locomotion by ejecting water after the manner of the Cuttlefish. The paper described the air-chambers, by means of which the fish descends or rises at will in the water; the muscular funnel, by the use of which it propels itself in any direction, regardless of currents; and concluded with a comprehensive and clear description of its peculiarities.

On Biological Results of the North-German Exploring Expedition. *By* Dr. Otto Finsch.

In this paper Dr. Finsch pointed out the principal biological results of the North-German expedition to Western Siberia. He divided the regions traversed into the steppes, the mountains, the wooded region of the Obi, and the treeless "tundras" north of 67° north latitude, and enumerated the most characteristic animals of each region. Among the most important points were the occurrence of Himalayan and Indian forms in the mountains near the Altai range, where such truly Arctic types as the Reindeer were met with.

Remarks on the Colorado Beetle, and on the Panic existing as to the possibility of its becoming obnoxious in this Country. *By* R. M'LACHLAN, *F.R.S.*

The author dealt categorically with the history of the insect, its habits, its migratory movements, and the reason the inhabitants of Europe have had to dread its infliction upon them. The beetle, he said, has existed from time immemorial in the west of Colorado, on the eastern slopes of the Rocky Mountains. Until eighteen or twenty years ago it was little known except in its native haunts or the cabinets of entomologists. In its home its larvæ fed upon one or more species of *Solanum*; but when the white man migrated to Colorado he took with him the inevitable potato (another species of *Solanum*), which proved acceptable to the beetle, and which afforded it the means of prospering and increasing prodigiously. Growing in numbers, the beetles spread over a wider area, and continued their migrations, until, in about fifteen years from the time of the introduction of the potato to them, they had travelled from their native home to the coast of the Atlantic. But even here the insects' journeyings did not cease; and there is reason to believe that it has bred in Germany, and has been present in its larval state in England. It belongs to the class of Coleopterous insects known as Phytophaga (vegetable-feeders), which in the larval state live upon the leaves of vegetables. The life-history of the insect is stated thus:—The female lays her eggs on the leaves or other part of the plant above ground. These hatch very soon, and the larvæ proceeding from them, after eating voraciously, descend into the earth and form small cavities, in which they turn into pupæ. They then remain quiescent till the final change into the perfect beetle takes place. The insect breeds four or five times a year in America; but it is in its larval state that it does nearly all the injury chargeable to it. The perfect beetle is not known to interfere much with the plants, though some say it has attacked tubers during the hibernating period. In Europe attention was not much directed to this formidable farmer's enemy until four or five years ago, when the danger of importation forced people to weigh the disadvantages of a possible scourge, and impelled entomologists to study. Laws were passed in consequence of the agitation which then took place, the effect of which was virtually to put in quarantine vessels from America which there was reason to apprehend might bring any of the beetles. In England fear of the insect culminated in the Destructive Insect Bill, passed by Parliament a week or two since. But unless potatoes be imported in the future in far greater quantities and with less care than heretofore, the author believes the danger of their coming concealed among tubers to be very small. It is certain that the beetle swarms on the Atlantic seaboard of the United States, so that there is every chance that it has over and over again been conveyed on steamers and other vessels leaving for Europe. It therefore seems not improbable that a few should have arrived here promiscuously. The opinion expressed in the paper was that the pest is more likely to be introduced in a general manner than from any association with potatoes.

New Points in the Zoology of New Guinea. *By* Prof. ROLLESTON, *F.R.S.*

The author commenced by saying that the zoology of New Guinea has had a great deal of research bestowed upon it, and will yet have a great deal more, as a consequence of the profit which has already resulted. A point which recent zoological discoveries in New Guinea throw light upon is, that there was a dry land passage at one time between Australia and New Guinea, recent discoveries in the latter country having revealed the presence there of animals similar to, or identical with, some found in Australia. This is held as proof that where Torres Strait now is there was once dry land. But against this hypothesis is urged the difference between the vegetation of the two islands. This, however, is accounted for by what Herbert Spencer calls the circumambient medium. Though people are inclined to think vegetables considerably less sensitive than animals, sometimes they are more sensitive to heat and dryness; and the author believes that it is the greater tenderness of the vegetation in those countries which accounts for the disparity observable between the vegetable growths of New Guinea and those of Australia. In the centre of New Guinea there is a high range of mountains, which attract and impart moisture to the surrounding country; while the interior of Australia consists of great barren plains, which harbour no moisture. The plants, as they have not had the means to protect themselves available to animals, have gradually altered their form to accommodate themselves to circumstances. A curious creature, covered with prickles, living on ants and other insects, and unprovided with means of militant operations, is found on both sides of the Straits. Two kinds of *Echidna* have also been discovered in New Guinea, and corresponding with them is one in Tasmania and another in Australia. These creatures could not travel over water, and so there must have been land communication at the period of their original distribution. Quite lately an *Echidna* has been found in the south-west corner of New Guinea, and sent to Professor Rolleston by the Rev. Mr. Lawes, the discoverer, accompanied by a letter, in which the statement is made that this is the first ever found. For this species the name *Echidna lawesi* is proposed. The Cassowary has also been found on both sides of Torres Straits. Proof of the existence of the Tree-Kangaroo, both in Australia and New Guinea, Professor Rolleston also considered reliable. At its conclusion the paper treated of the Admiralty-Island pig, in the fore part of which Professor Rolleston pointed out the peculiarity of a glabella.

Specimens of Philongria rosea *exhibited. By* J. B. Rowe, *F.L.S.*

Much of the interest attaching to this minute Crustacean was due to the fact that hitherto it has been captured in one locality only in England, and in an area of only a few yards. It was first found by Mr. Spence Bate in Plymouth; but specimens were soon after discovered by Mr. Rowe in a garden at the back of his house, and four of these organisms were captured on a fern by him on the previous Sunday, three of which he exhibited. His observations confirm the remarks of Messrs. Bate and Westwood about the insect.

On the Roses of the Neighbourhood of Plymouth. By T. R. Archer-Briggs, *F.L.S.*

The author illustrated his paper by means of a map of the district of which he treated, and specimens of many of the plants referred to. The author had endeavoured to identify the roses flourishing within a radius of twelve miles of Plymouth with those species and varieties classified by Mr. Baker. This involved extensive research, both on the Continent and at home; and, among others, M. Déséglise, of Geneva, one of the first authorities on the genus, had rendered him valuable assistance. From his inquiries, he found it advisable to divide the area over which he extended his observations into six districts, four in South Devon and two in Cornwall, viz. the Erme, Yealm, Plym, Tavy and S.E. Tamar, S.W. Tamar, and Notter, Tiddy, and Seaton districts. The result of the investigations was the discovery of the following varieties of indigenous Roses:—*spinosissima; tomentosa* (Sm.), *tomentosa* (type form), *tomentosa subglobosa, tomentosa scabriuscula, tomentosa sylvestris; rubiginosa; micrantha, micrantha pedunculo nuda; canina lutetiana, canina sphærica, canina senticosa, canina dumalis, canina biserrata, canina urbica, canina frondosa, canina arvatica, canina dumetorum, canina obtusifolia, canina tomentella, canina andevagensis, canina verticillacantha* (*latebrosa* and *aspernata*), *canina collina, canina concinna, canina coriifolia; stylosa systyla, stylosa leucochroa; arvensis*, and *arvensis bibracteata.*

Notes on Anticipatory Inheritance in Plants, especially with reference to the Embryology of Parasites. *By* G. S. Boulger, *F.L.S.*

The paper was designed to call attention to three groups of facts: first, facts relating to the embryology of parasites, epiphytes, saprophytes, and carnivorous plants. These were shown to agree in having fleshy perisperm, and mostly to have reduced cotyledons. The cotyledons are absent in some, but not all, leafless parasites and saprophytes; and the latter class of plants, on the whole, have the most reduced type of embryo. Secondly, facts relating to the form of the young and mature leaves in *Tropæolum* and *Aucuba japonica*, and in seedlings of the latter species, which suggest that immature and seedling leaves indicate an ancestral type now abandoned by the plants in favour of more recently acquired forms. Thirdly, facts as resemblances of detail between the floral organs of certain plants and their leaves, under which head especial reference was made to *Sarracenia*, *Hypericum*, and *Dionæa*. These three groups of facts are considered by the author to exemplify the accumulated effect of a tendency, described by Mr. Darwin as sometimes seen, viz. that at whatever period of life a peculiarity first appears, it tends to reappear in the offspring at a somewhat earlier age (Origin of Species, chap. i. p. 10, in 6th edition). For this accumulated effect the name "anticipatory inheritance" is used.

On the Structure of the Pitcher of Cephalotus. *By* Prof. Dickson, *M.D.*

Prof. Dickson exhibited a specimen of *Pogonatum alpinum*, with two capsules included under one calyptra.

On the Classification of the Vegetable Kingdom. *By* Prof. M'Nab.

The proposed classification is a modification of that of Sachs and Prantl, and most closely follows that recently published by Luerssen. The vegetable kingdom is divided into 4 subkingdoms, Thallophyta, Bryophyta, Pteridophyta, and Phanerogamia, each including certain classes, in all 12 in number. These 12 classes are subdivided into orders, numbered from 1 to 82 in ascending series, the orders being still further subdivided into families, corresponding to the natural orders of British botanists. In each order a selected series of families was given, the attention of the student being thus directed most prominently to the larger groups instead of to the more specialized families. In the flowering plants the group of the Apetalæ was abolished, as suggested by Luerssen, and the families distributed among the Polypetalous orders.

The Classification of Flowering Plants considered Phytogenetically. *By* Prof. M'Nab.

Haeckel's monophyletic pedigree of the vegetable kingdom, as given in his 'History of Creation,' vol. ii. (English edition), was discussed, and objections to its conclusions urged. Thus in two cases the groups are known to occur *earlier* than Haeckel's theory requires; in another case (Monochlamydeous Dicotyledons) the plants do not appear until much later (in the Cretaceous instead of in the Triassic). The geological distribution of the Dicotyledonous flowering plants, founded on Schimper's 'Paléontologie Végétale,' was then fully discussed. The general conclusion drawn was the following:—1st. That the Gamopetalæ are more recent than the Choripetalæ. 2nd. That the apetalous orders must be looked upon, not as forming a separate group, but as being the lowest members of the subordinate groups of the Choripetalæ. 3rd. That the older representatives in the Chalk of the larger group generally belong to families having variable characters, more especially in regard to the number of the parts of the flower. Thus the oldest representative of the Order 69, Umbelliflorae, is *Araliophyllum* in the Chalk. The Araliaceae have variable characters, as shown by the formula, Ca_{5-10} Co_{5-10} An_{5-10} $Gu_{(\overline{2-10})}$, a formula which will include that of the Umbelliferae, viz. Ca_5 Co_5 An_5 $Gu_{(\overline{2})}$. 4th. That while the Monocotyledons are undoubtedly monophyletic, the Dicotyledons are certainly polyphyletic; hence the great difference seen in the formulae of these flowers.

On the Movements of Water in Plants. *By* Prof. M'Nab.

In some experiments published some time ago by the Royal Irish Academy, a rapidity of ascent of water in the xylum of the stem of the Cherry Laurel, equal to 40 inches per hour, was observed. Since the publication of these experiments, numerous other experiments have been performed by Professor Pfitzer of Heidelberg, with the view of ascertaining the velocity of ascent of fluid in plants. Pfitzer first experimented by observing how soon leaves that had become flaccid from want of water reassumed their normal position. He also tried the lithium-citrate method, and in a third series combined the two, using the one method as a check on the other. In his experiments with lithium citrate, Pfitzer has observed the greatest rapidity of ascent yet recorded, the *Helianthus annuus* being found to give a velocity equal to 22 metres per hour, or 15 inches per minute. Professor Pfitzer also describes a new method to supersede lithium and the spectroscope, and suggested to him by Professor Köhne, namely, a solution of soluble indigo-carmine (4 parts to 1000 of water). Experiments made with this solution have been perfectly successful.

Hoehnel, in his recently published dissertation, 'Ueber den negativen Druck der Gefässluft,' has shown that the air in the vessels of the xylum of rapidly transpiring shoots is in a state of diminished tension; and when such a shoot is cut under mercury, the mercury will rise in the stem from 20–38 centimetres in a few seconds. From his experiments he concluded that the diminution of the tension of the air in different plants was as follows:—

Quercus pedunculata	24·5	centimetres of mercury.
Æsculus hippocastanum ..	37·0	" "
Syringa vulgaris	24·0	" "
Ulmus campestris	20·0	" "
Helianthus	46·0	" "

From this it is evident that an important source of error may be introduced into all experiments with lithium or coloured solution or cut shoots, as this abnormal current, as Pfitzer calls it, may be more rapid than the normal. Experiment, however, shows that the normal current is more rapid than the abnormal, due to the diminished tension of the air in the vessels, hence no error has been introduced into the experiments from this cause.

On an abnormal Plant of Primula veris. *By* Professor M'Nab.

A plant of *Primula veris* was picked in a field on the east side of the Hill of Howth, co. Dublin, in April 1877, having in the axil of one of the older and outer leaves a single flower of *Primula vulgaris*. The plant had the leaves of the Cowslip, as well as two umbels of flowers of *P. veris*, both arising from the axils of the younger or inner leaves. One of the umbels had the flowers expanded, the other had only small buds. The single primrose flower was in all respects normal, and both it and the cowslip flowers were macrostylous. In the field along with the abnormal plant both *P. veris* and *P. vulgaris* were common, as well as occasional plants of evident hybrid origin. The abnormal plant exhibited was probably a hybrid showing the return to the parent forms, much in the same manner as the well-known *Cytisus Adami*. Mr. Darwin, in his last book on the forms of flowers, mentions the occurrence of such a form as that here described in cultivated hybrids between the cowslip and primrose. It is therefore a matter of much interest to find that similar forms may be produced in a wild state.

On the Fossil Flora of the Arctic Regions; an Extract from a Letter from Prof. HEER *to* Sir JOSEPH HOOKER, *K.C.S.I., F.R.S. Communicated by the* Rev. W. S. SYMONDS.

This was an extract from a letter from Professor Heer to Sir Joseph Hooker, and gave data relative to the flora found in extremely high latitudes.

On the recent occurrence of Lavatera sylvestris, *Brot., in the Scilly Islands. By* HENRY TRIMEN, *M.B., F.L.S.*

This Mallow was collected first in July 1873 by Mr. Curnow of Penzance, on the Island of St. Mary, and again in 1876. During the past summer it was found in abundance in the islands of St. Agnes and Tresco.

The exotic range of the species—Portugal, Madeira, Azores, Canaries, and Mogador—shows it to belong to that small, but interesting type of distribution to which the name "Atlantic" may be fitly applied. Of this type the western counties of England already possess several examples, e. g. *Arthrolobrium ebracteatum, Erica vagans* and *E. ciliaris, Trifolium strictum, T. Bocconi,* and *T. Molinerii, Hypericum bæticum* and *H. linarifolium, Physospermum cornubiense, Rumex rupestris,* and *Lobelia urens.* The term "Atlantic" was employed by Mr. H. C. Watson to indicate those and other species also which are confined in a similar way to the west of England. Many of these latter, however, do not in their exotic distribution exhibit the same strictly Atlantic distribution, but occur also in Central, Southern, or even Eastern Europe.

Lavatera sylvestris, though thus agreeing with the true Atlantic type in its distribution, cannot, however, be considered native in Scilly (as was supposed by its discoverer there) for the following reasons:—(1) It was not seen there in 1863 by Mr. Townsend, a careful botanist, who published a list of the flora of the group. (2) In the original station in St. Mary's it grows in company with *Reseda fruticulosa,* and looks clearly an introduction, in the opinion of Mr. T. R. A. Briggs. (3) It appears to have spread very rapidly, a characteristic of several Malvaceæ, e.g. *Malva borealis,* Wallm., near Plymouth, and *Lavatera cretica,* L. (a close ally of *L. sylvestris*), in several points of the coast of Western France. (4) A few specimens have occurred near Penzance, on the mainland of Cornwall, under circumstances clearly showing it to be a mere casual introduction.

On Structural Characters in relation to Habitat in Plants. By A. S. WILSON, *M.A., B.Sc.*

ANATOMY AND PHYSIOLOGY.

[For Prof. Macalister's Address, see page 87.]

The Structure and Development of the Vertebrate Skull. By G. T. BETTANY, *M.A., B.Sc.*

This paper gives an account of conclusions to be published in an immediately forthcoming work on the 'Morphology of the Skull,' by Prof. W. K. Parker, F.R.S., and G. T. Bettany. The trabeculæ are believed to be structures of the same order as the parachordal and basilar cartilages of the skull, and to be similar to the lower parts and base of neural arches in the vertebral column. The skull becomes a more or less continuous neural tube of cartilage, with new perforations at intervals, and a series of sense-capsules embedded in it laterally. The only part of the cranium answering to the main part of the vertebral centra is a slender tube of tissue surrounding the notochord, which becomes separately ossified in some forms after the manner of vertebral centra; and there are indications of three of these all becoming either fused into the basioccipital bone or absorbed. The basilar or postpituitary region of the skull corresponds to not fewer than four body-segments, and possibly represents a considerably larger number. The osseous skull supplies no data for fixing the total number of body-segments that have gone to make up the skull. The segments discernible in the skulls of Mammalia do not enable us to lay out the composition of lower skulls on that plan. The mammalian skull is the culmination of an evolution, not the simple type to which all skulls are to be referred. Many bones of the mammalian skull are modifications of bones which primarily are scales and dermal bones in lower vertebrates, and have no original relation to deep parts, and cannot receive names expressing vertebral relations.

On the use of the terms Assimilation and Metastasis. *By* G. T. Bettany, *M.A.*, *B.Sc.*

This paper urged the bringing about of a close unity between animal and vegetable physiology by the use of terms in the same sense, and the expression of processes in the same manner and wherever possible. The term assimilation is now used in a total different manner in the two, and physiology is retarded thereby. The manufacture of protoplasm out of food by pre-existing protoplasm is the legitimate use of the term assimilation. It is much better to use other words for other processes. "Chlorophyll-function" is an expression deserving of introduction. "Metastasis," or Stoffswechsel, as used by Sachs, covers much too wide an area; it should be restricted to changes occurring in order to the transport of materials, and distinguished from assimilation.

On the Mammillary and Accessory Processes as Persistent Epiphyses in the Human Spine. *By* D. J. Cunningham, *M.D.*, *Senior Demonstrator of Anatomy, University of Edinburgh.*

The author showed a vertebral column which he had obtained in the dissecting-rooms of the Edinburgh University, and called the attention of the Department to the following peculiarities which it exhibited. (1) *Twelfth dorsal vertebra*: the mammillary processes were present as separate nodules of bone quite distinct from the vertebra. (2) *First Lumbar Vertebra*: the mammillary and accessory processes were fused and constituted on each side of the neural arch a V-shaped ossicle in opposition with but not attached by osseous union to the vertebra. (3) The tip of the spinous process of the first dorsal vertebra and the tip of the transverse process of the seventh dorsal vertebra were also present in the form of ossicles, unconnected by osseous union with the basal portion of the process.

In the recent state all these ossicles were jointed to their respective vertebræ by true diarthrodial joints.

On the Myology of the Shoulder and Upper Arm of the Thylacine, Cuscus, *and* Phascogale. *By* D. J. Cunningham, *M.D.*, *Senior Demonstrator of Anatomy, University of Edinburgh.*

Towards the close of last Winter Session I was so fortunate as to obtain, for the purpose of anatomical research, all the marsupial animals brought home by the 'Challenger Expedition.' In the present instance I purpose confining my remarks entirely to the anatomy of the shoulder and upper arm of three of the least-known of these specimens, viz. the *Thylacinus cynocephalus*, the *Phalangista maculata* or *Cuscus*, and the *Phascogale calura*.

Myology.

Trapezius.—This muscle, which springs from the occipital crest, the spines of all the cervical vertebræ, and the spines of the seven anterior dorsal vertebræ, has a somewhat complicated insertion. The posterior and greater part is inserted into the scapular spine; the anterior portion sweeps over the head of the humerus and the clavicle, and is inserted differently in each of the three animals. In the *Cuscus* a very few of the fibres—those constituting the anterior free margin of the muscle —are attached to the clavicle; the others pass down and fuse with the acromial and clavicular portions of the deltoid. In the *Phascogale* the insertion of this portion of the trapezius is precisely similar, with the exception that none of its fibres enter the acromial deltoid, all join the clavicular part of that muscle. In the *Thylacine* the humeral division of the trapezius passes over the rudimentary clavicle, and some of its fibres mixing with the muscles attached to that bone, it ends entirely in the clavicular deltoid.

Acromio-trachélien (the omo-atlantic of Professors Haughton and Macalister).—In the *Cuscus* and *Phascogale* this muscle is double; in the *Thylacine* it is single.

In the *Cuscus* and *Phascogale* the muscle consists of two distinct fleshy bands, which from their position may be called the acromio-trachélien superior and the acromio-trachélien inferior. In both cases they arise from the transverse process of the altas, but in the *Cuscus* the upper muscle derives an additional slip from the transverse process of the axis. They are inserted into the acromion process and spine of the scapula. In the *Cuscus* the two muscles fuse at their insertion, and occupy the whole length of the scapular spine. In the *Phascogale* they are separate throughout, but the upper muscle fuses near its insertion with the rhomboid muscle.

In the *Thylacine* the muscle is single. It arises from the transverse process of the altas, and is inserted into the lower half of the scapular spine and into the posterior border of the acromion process.

Cleido-occipital.—This muscle is present both in the *Cuscus* and *Phascogale*, but it is absent in the *Thylacine*.

It is a very narrow slip of muscle in the *Cuscus*, and being closely applied to the upper margin of the cleido-mastoid it is not at first apparent. Posteriorly it is unattached to the sternal end of the clavicle in close apposition with the origin of the cleido-mastoid; anteriorly it is attached to the occipital ridge at the same level, and between the sterno-mastoid and trapezius.

In the *Phascogale* it is a well-marked muscle, distinct and separate from the cleido-mastoid throughout its whole extent. Its attachments are the same as in the *Cuscus*, but as it approaches the occiput it fuses with the anterior margin of the trapezius.

Subclavius.—In the *Cuscus* and *Phascogale* this muscle presents nothing worthy of special notice. In both it is very strongly developed, and in both it arises from the cartilage of the first rib, and expanding is inserted into the outer half of the clavicle by fleshy fibres. In neither does it extend beyond the outer end of the clavicle towards the acromion process or supraspinatus fascia.

In the *Thylacine* it has the same origin but a very different insertion. We trace it to the supraspinatus fascia, and through the medium of this it is inserted into the spine of the scapula.

Deltoid.—In the *Cuscus* the scapular and the clavicular portions of this muscle are separate above, but they are united at their insertion into the humerus. The former is much the larger of the two. It arises from the acromion process, from the entire length of the scapular spine, and from the fascia covering the infraspinatus muscle. As the acromial fibres pass downwards they are reinforced by those fibres of the trapezius which in man are inserted into the acromion process. The clavicular portion of the muscle arises from the middle third of the clavicle, and it receives those fibres of the trapezius which in man are attached to the clavicle. The two portions of the deltoid, thus reinforced, converge as they proceed downwards, and fusing with each other, and to a certain extent also with the lower part of the pectoralis major at its insertion, they are inserted into a well-marked deltoid impression on the upper and outer aspect of the shaft of the humerus.

In the *Phascogale* the deltoid is broken up into three distinct factors, quite separate from each other except at their insertion. This triple constitution of the muscle is due to the acromial fibres passing down as a narrow band, apart from the fibres which take origin from the spine of the scapula. The humeral portion of the trapezius joins the clavicular part, and the muscle has the same insertion as in the *Cuscus*.

In the *Thylacine* the deltoid is in two parts, a scapular and a clavicular, and these are separate from each other, both at their origin and insertion. The scapular deltoid is much the more extensive of the two. Its origin is the same as in the *Cuscus*. It is inserted into the outer aspect of the humerus, distinct from, and at a higher level than, the clavicular deltoid. The clavicular deltoid derives fibres from three distinct sources. The chief proportion is derived from the trapezius and cleido-mastoid muscle, but it also receives some which spring directly from the rudimentary clavicle. This portion of the deltoid is inserted into the outer aspect of the shaft of the humerus at a lower level than the preceding.

We are now in a position to understand the constitution of the compound muscle known in comparative anatomy as the cephalo-humeral muscle. We have already studied its component parts.

In the *Cuscus* it consists of that portion of the trapezius which in man is inserted into the acromion and clavicle, joined with the acromial and clavicular parts of the deltoid. In the *Thylacine* and *Phascogale*, on the other hand, the acromial deltoid is not a constituent. In the former it is composed of the cleido-mastoid, the anterior fibres of the trapezius, and the clavicular deltoid; in the latter by the anterior fibres of the trapezius and the clavicular deltoid.

Teres minor.—This muscle is very short, but present in them all, and quite distinct from the infraspinatus.

Triceps.—In the *Thylacine* the origin of the long head is remarkable for its great extent. This portion of the muscle arises from nearly the whole length of the axillary border of the scapula. But all the fibres springing from this do not reach down to the olecranon. They consist of two sets:—(1) A set arising from the scapula, close to the glenoid cavity, and running down in the form of a thick round fleshy muscle, which, as it approaches the elbow, blends with the other two heads of the triceps. (2) A set springing from the axillary border of the scapula, posterior to this, which constitutes a thin fleshy mass composed of short fibres. These short fibres curve forward, and are lost amongst those which spring from the scapula close to the glenoid cavity.

Coraco-brachialis.—Professor Wood, of King's College, London, in his very able paper upon "Muscular Variation" (Journ. of Anat. and Phys. vol. i.), has taught us to look upon the typical coraco-brachialis as being a muscle with a triple constitution. The animals in question afford a beautiful example of this.

In all three the coraco-brachialis superior is found, whilst in addition the median variety is present in the *Phascogale*, and the long variety in the *Cuscus*.

Latissimus dorsi.—In the *Cuscus* and *Phascogale* the insertion of this muscle is the same; in the *Thylacine* it is somewhat different. In all it is more or less connected with that of the teres major.

In the *Cuscus* and *Phascogale* the latissimus, as it approaches the humerus, divides into two parts. Of these the upper and smaller slip, which corresponds to the superior margin of the muscle, passes behind the other part and, joining the lower margin of the teres major, is inserted into the inner lip of the bicipital groove. The lower and main portion of the muscle ends in a strong tendinous band, which is attached to the bottom of the bicipital groove, separated by a wide interval from the insertion of the teres major.

In the *Thylacine* the teres major and latissimus dorsi have a common insertion into the humerus, and chiefly through the medium of a strong tendinous band, which arches backwards from the bottom of the bicipital groove, where it is firmly fixed to the humerus. This band is twisted upon itself so that its lower margin has a round and cord-like appearance. Into its anterior half are inserted the greater proportion of the fibres of the teres major, only a small portion of this muscle being directly attached to the bone, and into its posterior half the latissimus dorsi is inserted.

The *dorsi epitrochlear* muscle is present in them all.

Pectoral muscles.—These muscles have a very complicated arrangement.

Cuscus.—In this animal we have four distinct factors:—(1) A large superficial muscle; (2) an anterior deep band of muscular fibres; (3) a posterior deep muscle, which, according to Professor Macalister, is the representative of the pectoralis minor; and (4) a pectoralis quartus.

Of these the first two are simply constituent parts of the great pectoral muscle. Together they represent the pectoralis major. The superficial part arises from the whole length of the sternum and ensiform cartilage, and is inserted into the outer lip of the bicipital groove, fusing slightly with the clavicular deltoid. The deep part of the pectoralis major arises from the anterior third of the sternum, and is quite separate throughout its whole extent from the preceding muscle. Stretching outwards as a thick fleshy band, it is inserted into the external tuberosity and outer bicipital ridge.

The *pectoralis minor* arises from the posterior two thirds of the sternum, excluding the ensiform cartilage, and also from one or two of the costal cartilages. From this it extends outwards and forwards under the deep portion of the pectoralis major, and it is inserted into the inner margin of the great tuberosity of the humerus, and through the medium of fascia into the tendon of the supraspinatus muscle and the coracoid process.

The *pectoralis quartus* (of Macalister) arises from the linea alba and from the fascia over the rectus behind the ensiform cartilage, and it proceeds forwards under cover of the superficial pectoral muscle to its insertion into the upper part of the pectoral ridge.

Phascogale.—The pectoral muscles are identical with those of the *Cuscus* with two exceptions, viz. (1) there is no deep muscle corresponding with the deep part of the pectoralis major; (2) the pectoralis quartus is better developed and more in the form of a fleshy band.

In the *Thylacine* the pectoral muscles are reduced to a superficial and a deep muscle and a very rudimentary pectoralis quartus.

The superficial muscle is the representative of the pectoralis major, and arises from that part of the sternum which lies anterior to the second costal cartilage.

The deep pectoral, which represents that muscle to which in the *Cuscus* we have given the name of pectoralis minor, arises from the whole length of the sternum behind the origin of the preceding muscle, and also from some of the posterior costal cartilages.

The pectoralis major is inserted into the pectoral ridge at a lower level than the pectoralis minor, which is inserted into the outer tuberosity of the humerus and into the tendon of the supraspinatus.

The pectoralis quartus is represented by the minute slips of muscle which end on the under surface of the pectoralis major.

On the Brachial Plexus of the Cuscus. *By* D. J. Cunningham, *M.D., Senior Demonstrator of Anatomy, University of Edinburgh.*

In the *Cuscus* the brachial plexus is formed by the anterior divisions of the 5th, 6th, 7th, and 8th cervical nerves, together with the anterior division of the 1st dorsal nerve. These enter the axilla as from cords, the 5th and 6th cervical nerves having previously effected a junction. Here they all unite to form a short flattened nervous band, which lies between the axillary artery and vein.

Branches.—The branches of the brachial nerves may be divided into two sets:—1, those which spring from the cords before they enter the flattened band or plexus; 2, those which arise directly from the plexus.

Under the first heading we have the suprascapular nerve, the subscapular nerves, the musculo-spiral nerve, and the circumflex nerve.

Of these the circumflex alone deserves special notice, and this on account of the large size and extensive distribution of its cutaneous branch. Under cover of the deltoid muscle it divides into two divisions of equal size; of these, one supplies the deltoid and teres minor, whilst the other becomes superficial and gives branches not only to the skin on the outer aspect of the upper arm, but also to the skin on the outer aspect of the forearm. It apparently takes the place of the cutaneous portion of the nerve which corresponds to the musculo-cutaneous in man.

The branches arising directly from the plexus are the median, musculo-cutaneous, ulnar, internal cutaneous, and muscular branches to the pectoralis major and to the panniculus.

The median nerve, accompanied by the brachial artery and vein, passes through a large supracondyloid foramen. The same arrangement is found in the *Thylacine* and *Phascogale*.

The musculo-cutaneous nerve appears to be a purely motor nerve. It is distributed to the biceps, coraco-brachialis, and brachialis anticus.

Researches on the Life-history of the Simplest Organisms. *By the* Rev. W. H. Dallinger.

The author stated that he had worked out the life-histories of six Monads, and then proceeded to give the results of numerous experiments in connexion with the same. Motion was, perhaps, nowhere so universal as in the most minute forms of life, and here it was that we often found movement of the most graceful kind. It had now been made quite certain that the degrees of ease and force of motion of these animals depended upon the number of their flagella, which, so far as investigation had yet gone, ranged from one to four. With regard to the most minute forms of life, the author considers that the study of their life-histories shows that these forms were perfectly complete and definite; there was no mutation nor any thing unnatural. The results of his experiments with certain life-germs showed that when ordinary air was charged with given germs, any nutritive fluid receiving these germs would produce monads, while when the air was kept perfectly pure the same fluid would not produce a single monad. With the air at a temperature of 310° Fahrenheit and charged with germs, the fluid produced no monads. The author stated that he is a perfect convert to the theory of the "survival of the fittest." At a temperature of 46° the six monads with which he had been experimenting were found to live and flourish, and they could bear a sudden increase of temperature up to 60° without exhibiting any signs of inconvenience; but if, upon reaching this point, the temperature was suddenly increased by five degrees, the monads showed a faintness. The temperature might, however, by a slow process be increased to 127° degrees, in which the monads would live, and multiply even more rapidly than in a temperature of 45°. The results of similar experiments also seemed to show that it took a much longer time to produce a modification in the ovum than to produce a modification in the parent.

On Transcendental Anatomy, or a Geometrical Investigation of the best possible number of Limbs for Terrestrial and Aquatic Animals. *By the* Rev. Professor Haughton, *F.R.S.*

Treating of the swimming powers of the numerous members of the Naiad family, the author explains their various abilities of exercising muscular and fibrous force in different directions. The two-limbed Naiad is, he considers, related to our present Rays and Skates, whilst the three-limbed Naiad finds close representatives in some of the fossil fishes. Odd-limbed Naiads all possess advantages over the even-limbed ones. A fish is nothing more nor less than a one-limbed Naiad; but the Medusa is, in spite of its sluggish disposition, perhaps the most beautiful of swimming animals. The system of vortex rings (the form of force which passes through water with the least resistance) produced by these creatures in swimming is the secret of their easy locomotion.

An Improvement in the Marshall-Hall and Sylvester Methods of Artificial Respiration. *By* Dr. B. Howard.

On the Physiological Action of the Substitution Compound of Chinoline and Pyridine. *By* Prof. M'Kendrick *and* Dr. W. Ramsay.

Geography of Consumption in Devonshire.—Deaths from Consumption during the ten years 1861–70.
By Dr. William H. Pearse.

No.	Geology.	Registration District.	Mean Total Population from which drawn.	Acres per Person.	Height of Rain-gauge.	Greatest Rain in Year.	Mean Death-rate per 1000.		Mean Death-rate per 1000 Persons.
							M.	F.	
					feet.	inches.			
1.	Granite	Tavistock, excluding prisons	3794	20·0	1400	74·35	...	...	0·37
2.	do.	Tavistock	4611	15·6	1400	74·35	0·96	0·71	0·86
3.	Devonian	Barnstaple, excluding Ilfracombe	10705	8·3	850	60·82	...	...	0·45
4.	do.	Barnstaple	14991	6·3	...	60·82	0·90	0·82	0·86
5.	do.	South Molton	4313	12·9	...	46·46	0·82	1·09	0·95
6.	do.	Totnes	5618	5·8	...	...	1·07	1·20	1·12
7.	do.	Plympton	4636	3·0	350	49·26	1·0	1·35	1·18
8.	Devonian and border granite	do.	6540	2·7	175	49·05	1·39	1·07	1·23
9.	Devonian and sea-board	do.	5098	2·5	116	47·92	1·43	1·12	1·27
10.	do.	Totnes	1633	3·0	...	...	1·83	0·92	1·34
11.	Carboniferous	South Molton	14631	6·0	472	41·82	1·29	1·51	1·42
12.	Granite	Plympton	1839	11·6	...	high	1·15	1·81	1·46
13.	Devonian	Totnes	7003	1·7	120	47·06	1·23	1·65	1·46
14.	Granite	Newton	3739	9·0	950	58·95	1·77	1·26	1·52
15.	Sea-board and Carboniferous	Bideford	8667	4·3	550	49·01	1·21	1·86	1·55
16.	Sandstone	St. Thomas	17697	3·3	...	33·35	1·69	1·62	1·65

17.	Chalk and Greensand	Axminster	5092	3·6	...	35·46	1·34	2·01	1·67
18.	Devonian and Sandstone	Newton	3581	4·1	...	35·70	1·25	2·13	1·69
19.	do.	Totnes	13814	1·0	...	...	1·59	1·80	1·71
20.	Sandstone and Marl	Axminster	5785	3·7	...	...	1·39	2·01	1·71
21.	Carboniferous	Bideford	9974	2·6	173	36·82	1·76	1·76	1·76
22.	Devonian and Riverine	Tavistock	21846	2·0	283	49·36	1·89	1·72	1·80
23.	Granite (part)	Totnes	6166	5·2	650	69·99	1·59	2·38	1·91
24.	Carboniferous	Tavistock	6789	5·5	445	47·71	1·60	2·32	1·96
25.	Carboniferous and Riverine	Barnstaple	8490	4·3	31	39·47	1·75	2·17	1·97
26.	Devonian	Newton	2370	4·9	...	...	1·29	2·66	1·98
27.	Lias and Greensand	Axminster	9019	2·3	...	...	1·83	2·58	2·22
28.	Carboniferous	St. Thomas	8885	2·8	...	...	2·20	2·27	2·24
29.	Carboniferous near Granite	do.	1448	5·0	...	...	2·67	1·99	2·34
30.	Sandstone and Riverine	do.	19685	1·6	33	33·30	2·33	2·49	2·42
31.	Carboniferous	Newton	7703	3·4	639	40·80	2·65	2·19	2·42
32.	Sea-board, Sandstone, and Lime (including Torquay)	do.	35527	0·43	200	37·69	3·28	2·14	2·62
33.	Riverine and Devonian	Barnstaple	13292	1·3	31	39·47	2·78	2·69	2·74
34.	Bovey Beds	Newton	10749	1·5	...	35·97	2·87	3·07	2·97
35.	England and Wales	....	......	...	...	...	2·46	2·48	2·47
36.	London	....	......	...	...	...	3·35	2·39	2·87
37.	Granite	Dartmoor Prisons	817	...	1400	74·35	2·60	...	2·60
38.	Exminster, Devon	Lunatics	668	...	...	...	22·22	20·10	20·96

Photographs of Representations of Vascular Injection by Prof. Dantscher, *of Innsbrück. By* Dr. Allen Thomson, *F.R.S.*

The author brought under the notice of the Section the approaching publication of a series of photographic representations of the minute distribution of blood-vessels in a number of the organs of the animal body, made under the superintendence of Prof. Dantscher, of the University of Innsbrück, from injected and corroded preparations made by himself. Dr. Thomson saw some of these preparations some years ago at Innsbrück, and admired them much.

The collection has since been much increased, and the photographs executed partly on paper and partly on glass; and some of them, coloured after the original preparations, are capable of being viewed with the stereoscope so as to give a most truthful and instructive view of the beautiful structures they represent.

Dr. Thomson regretted that accidental circumstances had made it impossible to show some of these photographs to the Section. They are all to be presented to the Meeting of German naturalists at Munich in September, and the work will be dedicated to the University of Tübingen on the occasion of the four-hundredth anniversary of its foundation, which was held in the past month of July.

On a Method of excluding Germs from Rooms used for Surgical Operations. By W. Thomson, *F.C.S.*

Anthropology.

[For Mr. Francis Galton's Address, see page 94.]

On Flint Flakes from Cornwall and the Scilly Isles. By Dr. Barham.

Prehistoric Remains on Dartmoor. By C. Spence Bate, *F.R.S.*

The author made some remarks on the prehistoric remains near the Plym. The remains were unique in their character. He exhibited a diagram of the remains lying within two branches of the Plym, bounded on the upperside by Aylesbury and Higher and Lower Hartor, which were, he said, typical of all the other remains on Dartmoor. They consisted of lines of stones, about a pace apart, and of different lengths, terminating with a stone circle at one end and with a "kist vaen" at the other. The kist vaen was a stone box, two feet broad, four feet long, and about two feet four inches deep. In the one investigated the cap-stone was still there, and in a most perfect condition. Near it was a cairn or stone heap, not a barrow, which was distinguished from a cairn by being an earth heap. He had opened one or two of these cairns on Hamel Down some time ago. In one he found the remains of some burnt human bones, a single stone, and near them a single flint implement, a very fine flake, which might be supposed to make a useful flint hatchet. A second barrow near differed very little from the first. There were, however, a number of stones lying flat: beneath them he found a little ornamental article composed of amber inlaid with gold; its margin was broken, and it had little gold rivets put around the sides. Close by he found a little bronze blade of a dagger, and he ultimately conceived that the two articles were originally connected—that one was, in fact, the blade and the other the handle of a complete dagger. They were evidently not of British type. Mr. Franks had confirmed him in the idea that they were of the Neolithic period, just as flint was passing into bronze, and were probably Scandinavian in their character. On the banks of these little rivers they found the remains of tin-works to an enormous amount. He did not say they all belonged to prehistoric times; for in the days of Elizabeth, when Sir Walter Raleigh was Lord Warden of the Stannaries, he held his court in this district.

With regard to the cairns and the paralelıltra, Mr. Bate stated that Mr. Ferguson's theory was that they occupied the positions of two opposing armies. The author thought there might have been battles between the Scandinavians and the Devonshire tinners. As they found several east Tors and no west Tors, he suggested that they probably marked the position of the "Eastmen," in this case Scandinavians. With respect to the paralelıltra, his theory was that the greatest man who fell in the battle was interred in the paralelıltra, and the general mass in the neighbouring cairn.

The Rev. Prof. Beal exhibited and described a soapstone image from Pekin.

The Bulgarians. *By* J. Beddoe, *M.D., F.R.S.*

The author said that the races of Turkey were separated by national antipathies and linguistic difficulties, and yet it was difficult to separate them, because the boundaries of race in Turkey were very undefined. The true Slavs had extended themselves over a pretty large area in Asia, and maintained the same characteristics. The Bulgarians, however, though they spoke Sclavonic, were a different race altogether, and, strange to say, they had little or no Turanian element in them. The original Bulgarians were a tribe from the north-east, from the Volga region, where probably they were connected with the Huns and Avars, with whom they appeared to have much in common, and who had been considered of mixed Turkish or Finnish blood. By the kindness of Dr. Barnard Davis, who placed his rich collection at his service, the author was able to see and measure a Bulgarian skull and the cast of another, and to compare them with divers Sclavish, Turkish, and other skulls. The cranium had the following characteristics, all of which were considered by Copernicki to belong to the type:—Cylindrical form, moderate breadth, frontal region sloping away rapidly above, and to some extent also laterally; absence of frontal and parietal bones, large occipital region, comparative elevation of posterior part of skull, not one of which points were Sclavonic. The narrowness of the forehead permitted the zygomata to be visible when looked at from above. The nasal notch was deep, and the nose might have been well formed. The face was evidently prognathous, and sufficiently so to distinguish it from a Russinack, Slavack-Czech, or Civat skull. The deformity of the nose, which attained portentious proportions, occurred in a less degree among nearly pure Sclavs, such as the Poles. The skull form, however, must be traced in the main either to the pre-Bulgar inhabitants of Mœsia and Thrace, or to the true original Bulgar. The author fell back upon the latter. His conjecture was that the type was Ugrian, and that the modern Bulgarians were at least as much Ugrian as any thing else. They differed from the Serbs in some points favourably, but in more, perhaps, unfavourably. They were not, however, mere embodiments of force, but were both industrious and ambitious, with a desire of knowledge and a capacity to learn, and under more favourable circumstances better things, perhaps, might be expected.

Ethnological Hints afforded by the Stimulants of the Ancient and Modern Savages. *By* Miss A. W. Buckland.

The study of primitive agriculture, which formed the subject of the memoir read by the author before the Association last year, led naturally to that of the stimulants adopted by different races, because it was found that from a very early period in the history of mankind some sort of stimulant had been used almost universally. Among the lowest races this consisted now, as in ages past, only of some root or leaf chewed for its strengthening and invigorating properties, such as the Pitberry, recently discovered in use among nations in Central Australia, and the cocoa-leaf among the Indians of South America; but no sooner did the nations advance to the agricultural stage than they began to make fermented drinks from the roots of grains cultivated for food. Hence the beer of Egypt, which probably found its way with the wheat and barley of that land to the Swiss lake-dwellings and over a great part of Europe, having been evidently known in Greece and Rome at a very early period, whilst a similar liquor still formed the chief beverage of all African nations, being now, as formerly in Egypt, fermented by means of plants. In China and Japan rice was and is used to make wine or beer instead of wheat or barley or American maize. In Bolivia this is chewed to produce fermentation, like the "kava" of the South-Sea Islands, a practice which reappears among the inhabitants of Formosa, who use rice instead of maize. The sour milk or "koumis" of the pastoral tribes of Central Asia, and the mead of the ancient Scandinavians, both reappear among the Kaffirs of South Africa. Palm wine was used wherever palms flourished; but wine of the juice of the grape, although known in very ancient times, seemed to have been confined to the civilized races of Western Asia and Egypt, extending later to Greece and Rome. The multitude of wines described by Pliny were, however, in almost all cases flavoured with herbs or garden plants for medicinal purposes. The conclusions to be drawn from the history of fermented beverages, as recorded by travellers, were that the earliest stimulants were simply leaves and roots chosen by animal instinct, chewed, and found by experience to produce exhilaration and strength. With the dawn of civilization, these roots and plants, still chewed, were mixed with water, and thus a kind of fermentation was induced, producing a mildly intoxicating drmk; and when the agricultural stage was attained the cereals took the place of the earlier roots and leaves, and were also probably at first chewed to produce fermentation, as still in Formosa and South America, to be superseded in a higher degree of civilization with the use of the grape. Yet even in this, as in the liquors made from grain, the roots and plants of an earlier age were retained for flavour and to produce fermentation; and even the form and material of the earlier drinking-cups were retained in civilized countries skilled in the manufactory, whilst the originally medicinal character of these beverages gave rise to many superstitions, to the deification of plants and their dedication to various gods, to the birth of gods of wine, as well as to the universal custom of commencing every orgie with libations to the gods and of proposing healths at feasts. The art of distillation, though probably known early in the Christian era, is comparatively modern, and was certainly unknown to savage races until "fire-water" was introduced, to their serious detriment, by Europeans.

On some Palæolithic Implements found in the Axe Valley. *By* J. Evans, *D.C.L., F.R.S.*

The author called attention to the discovery of palæolithic implements in the valley of the Axe, a considerable collection of which had been obtained for the Albert Memorial Museum of Exeter by its curator. The implements had for the most part been found upon the South-western Railway in ballast dug in a pit at Broom, between Chard Junction and Axminster. They present the usual forms of palæolithic implements, though formed of chert from the Black Down beds, and not of flint. Though no mammalian nor testaceous remains have as yet been found in the gravel, it seems to be of the same age as the other gravels in which such implements had been found. Though the number of implements collected was large, they are by no means common. The author exhibited a large, but somewhat rude specimen. The discovery of these implements proved that where chalk flints were scarce other siliceous rocks were utilized by Palæolithic men for the same purpose.

On some Saxon and British Tumuli near Guildford. *By* Col. Lane Fox.

The author considered that in one of the tumuli the central interment, whether burnt or otherwise, must have been placed on the surface of the ground, the mound raised above it; but no trace remained. Near the centre of the mound, however, three British urns were found with burnt bones in them—probably, he thought, secondary interments, but possibly the original interment for which the mound was raised. It was evident that this was a British barrow of the bronze age. A peculiarity of the mound was that it contained no flakes, showing that the custom of throwing them into barrows was not universal. In another tumulus, near this one, the author found no central grave; but a layer of black coal, probably the result of fire, was found just beneath the surface; although in the centre a small hole was clearly seen, where, no doubt, a burnt body had been deposited. There were a great number of burnt flints, but no flake or implement of any kind. The author described six tumuli (sections of which were exhibited) in the same locality. Burnt bones, an iron Saxon knife, and other remains were found, which led the author to fix the date of the erection of the tumuli at about 500 or 600 A.D.

Some Rune-like Characters on Chalk. By J. Park Harrison, *M.A.*

The author stated that the characters in question had been found in some chalk galleries at Cissbury, in Sussex. He said they had all the appearance of early characters, and had been accepted as such by several eminent palæographists, who, however, were unable at present to decipher them. They were neither Scandinavian nor Saxon. He exhibited a diagram of a Runic inscription found on a granite block at Smolensk for comparison with the chalk inscriptions.

The Ancient People and Irrigation-works of Ceylon. By Bertram F. Hartshorne, *M.A.*

The author pointed out generally the system of social polity and the high state of civilization which existed in the island in early ages. The character and destinies of the inhabitants were mainly determined by the influence of the Buddhist religion, which was introduced into the island in the 6th century before Christ. About 500 years later the practice of devil-dancing was added to the national religious observances, with the view of appeasing the malignity of the red-eyed demon, to whose displeasure was attributed a famine and plague which happened at that time. So popular was this new custom that one hundred years afterwards King Budha Daasa ordained that every division of ten villages should have an astrologer, a devil-dancer, and a preacher attached to it. At the present day devil-dancing is of very frequent and general occurrence. The early Singalese people were essentially a martial race, owing to the repeated invasions of the Solleans from the south of India; but pearl-diving is recorded to have been a regular occupation among them in the third century B.C. In later times the social condition of the people is curiously illustrated by the rock inscriptions of the date of about 1200 A.D. The King Parakrama Bahu I., we are told, thrice visited all the towns and strongholds of his kingdom, and established such security everywhere that "even a women might traverse the country with a precious jewel, and not be asked, What is it?" His Majesty also, "wearing the crown and decorated with the Royal armaments, caused himself, as well as his chief queens, his son, and his daughter, to be weighed in a balance every year," and bestowed five times their weight of goods upon needy people, and made every one happy "by causing a constant supply of rain." The great tanks remain as monuments of the enlightened despotisms of various kings, who raised the country in turn to a splendid height of prosperity. Some of them belong to periods long before the Christian era. One, called Kalawewa, was an inland sea, thirty miles in circumference, formed by damming up two rivers by means of an immense embankment twelve miles long; another, Padawya, must have occupied a million of people for ten or fifteen years in its construction. Its bund, or embankment, is eleven miles in length, 70 feet high, and 160 feet thick at the base. The bed of the tank is now overgrown with a magnificent forest, and for miles around there is not a vestige of man. Its last restoration was effected by King Parakrama Bahu I., and a stone obelisk on the spot records how he accomplished this work, "in the hope of obtaining the happiness of this as well as the next world." King Maha Son, who reigned about 275 A.D., seems to have done most in the formation of these vast tanks. It is calculated that one which he formed, named Kanthelai, could only be constructed at the present day at a cost of upwards of one million sterling. Under the vigorous and energetic government of the Right Hon. Sir William Gregory, much has been effected in the way of the restoration of many of these tanks, and with the happiest results. The neglect and apathy of successive generations, both of rulers and of the people, has been the main cause of the abandonment and desolation of large tracts of lands, whose fertility was formerly indicated by such names as "The Golden Plains," or "The Granary of the Kings." Foreign and internal warfare no doubt caused the destruction of some irrigation works, and their continued disrepair has been mainly owing to the disregard of ancient customs, and to the abolition of the system of compulsory labour. The population has simultaneously been seriously diminished by disease, resulting from bad food and habitual violations of every principle of sanitary economy. The Tank country in the North of Ceylon has also been afflicted by a terrible scourge, termed the Parangi disease, or Wanni plague, an hereditary and peculiar malady which seems to be amenable to no direct treatment. Probably good food and pure water will ultimately tend to check it more than any thing else; and this happy result would be chiefly due to the comprehensive scheme of restoration lately initiated; whilst it is to be hoped that the island, which now requires an annual import of nearly five million bushels of rice, will before long grow sufficient for its own requirements.

Notes on Socotra. *By* F. M. Hunter.

The author described the island and its inhabitants. The Bedouins of the interior are divided into families, but there are only a few principal tribes. One tribe, called Kisshim, claims to be descendants of the Portuguese. The Momi, who reside in the eastern part of the island, are said to be the result of intermarriage between the aborigines and Abyssinians; and the Camabar, who occupy Hajair and the higher ranges above Tamarida, are supposed to have resulted from mixture of the aborigines with the Mahri Arabs. The manners and customs of the inhabitants of Socotra were described in detail. It was observed that the mark of the cross was still used on the headstones of the graves.

On the proposed Exploration of certain Caves in the neighbourhood of Tenby. *By* Ed. Laws.

In a cave near Tenby, Pembrokeshire, the author found *Hyæna crocuta*, *Ursus spelæus*, *Rhinoceros tichorhinus*, *Cervus tarandus*, *Cervus elephas*, *Equus spelæus*, human bones, the remains of domestic animals, chips of flint, a remarkable hornstone, copper pennies of George III., and an old penknife. This cave Mr. Laws advocates the exploration of. The author minutely detailed the peculiarities of such of the remains as were of indubitable antiquity, and urged that in the interests of palæontology further search should be made.

The Devil's Arrows (Yorkshire). *By* A. L. Lewis, *M.A.I.*

This name has been given to certain stones standing in a line near Boroughbridge, of which three now remain out of five known to have existed formerly. Others may have existed, but the five of which we know would have formed a tolerably symmetrical monument by themselves. The author, while contending for the pre-Roman origin of most of our rude stone monuments, is disposed to think that these might commemorate some victory of Scandinavian invaders. The author also described an easy and ingenious method by which large stones are transported and erected by some hill-tribes of India.

On the District of Mycenæ and its early Occupants. *By* Dr. J. S. Phené, *F.S.A.*

It was explained in this paper that the usual custom adopted by travellers and historians of describing ancient towns, as those of Mycenæ, Argos, Nauplia, &c., by the walls and other features peculiar to each, was not sufficiently comprehensive to convey an idea of the condition of society and military power in ancient times. They were seldom or never referred to by recent historians as parts of a kingdom, but rather as separate kingdoms; and their relationship to each other, except in cases of alliance or hostility, was very seldom hinted at. This was a partial way of viewing the matter, and conveyed but a small knowledge of those ancient times to which the Greek poets, as Homer, Æschylus, and others, referred. These historians, if faithfully examined, would be found to deal with the question on a broader base, and one more faithful to facts. Thus Agamemnon was King of Argos as well as Mycenæ, and his kingdom would be found to have extended not only over those cities, but also to a great part of Corinth, while Menelaus, his brother, governed a large portion of the territory of the Peloponnesus. The object of drawing attention to these points was to account for the number of minor Cyclopean works which are to be found on a careful inspection around the Argolic district, and which can only be accounted for by supposing they were used as outworks or garrison towns by the House of Atreus and by earlier sovereigns. Too small in themselves to be independent fortresses, they prove that even the larger ones were not independent. Thus military organization and governmental rule were shown to have existed among a people often referred to as barbarous, whose works and actions could only be explained by the ancients by referring them to the mythical Cyclops. The particular features of some of these outworks are very peculiar. The pyramid was a favourite form of those most remote from the centre of government. These pyramids Dr. Phené found east and west of the Argolic plain, at the extreme boundary of the Parthenium mountain, and as far almost as Epidaurus; while between them and the great fortresses, bearing classic names, were many unnamed and unnoticed Cyclopean structures of considerably larger dimensions than the pyramids, yet bearing no comparison with the larger cities. These garrison forts evidently guarded the passes to the great Argolic plain. The discoveries made by Dr. Schliemann would be soon under their notice in his forthcoming work; he should therefore forbear to touch upon them, as it was ground that that great investigator was exclusively entitled to tread first, whoever might subsequently support his theories or enter the lists with him antagonistically. But having seen a very large portion of the articles themselves at Athens, having carefully examined the field of the operations at Mycenæ, and made a close comparison between Dr. Schliemann's labours at that place and his labours at Troy, he might, at least, add his testimony to that of others as to the great historical value and interest of the find and the enormous age of the treasure, exhibited more prominently in the conditions of the articles of silver. Dr. Phené inclines to the belief that there is a great deal yet to be learnt of the Cyclopean cities of Greece, Asia Minor, and Italy. It was remarkable that in the Trojan district the Cyclopean city of Chigri, which is of great size and high antiquity, has attracted little notice in ancient or modern times, although many points about it answer the description of the Trojan city. Visiting the island of Samothrace, he made the ascent of the mountain, and was, he believed, the only Englishman, at least of modern times, who had accomplished it. There he found a Cyclopean city larger than any he had seen on the mainland of Greece. The position of this large city, of which we had neither record nor history, in an island most difficult of access, and having no harbour or anchorage, awoke questions of thrilling interest, especially as it was on the island on which the darkest rites of mystery, those of the Cabiri, were practised. With our present limited knowledge it is difficult to identify the people who constructed these works; but that they came from the mainland westward into Greece is generally held. If this hypothesis be sound, Samothrace was probably occupied before the Peloponnesus, and must be much older than either Tiryns or Mycenæ.

On Indian Archaic Remains and their resemblance to European Types.
By H. RIVETT-CARNAC.

On the Rationale of artificial Deformations of the Head.
By Prof. ROLLESTON, *M.D., F.R.S.*

On the Rationale of Brachycephaly and Dolichocephaly.
By Prof. ROLLESTON, *M.D., F.R.S.*

On the Flora and Fauna of Prehistoric Times.
By Prof. ROLLESTON, *M.D., F.R.S.*

The author, referring to various prehistoric trees, said that the common elm in this country spreads entirely by suckers and not by seeds, whilst such trees as the spruce and larch spread with great quickness. The author then pointed out an error into which Julius Cæsar had fallen in reference to the presence in Britain of certain trees which he had found in Gaul, particularly the Coniferæ. The beech was probably a prehistoric tree, for beechmast was a very preservable thing. Buckwheat, or beechweat, and beechmast were one and the same thing in form, both being of triangular shape. The letters f, a, g, lay at the bottom of the word for beech in most of the ancient languages in which it was named. The terms "bacon" and "beech" were allied; and a bacon-fed pig was a pig that had been fed upon beechmast. "Bacon" meant "beech," the article out of which bacon was made. After going over the list of the trees which chiefly arrest the attention as forming a portion of the landscape, the author called attention to the fact that Chaucer, who was essentially a poet of nature, omitted from his detailed lists of trees the names of the willow, beech, and birch. Spencer, writing later, and probably with Chaucer's description before him, had supplied the names of these three trees. It was the opinion of Professor Rolleston that the beech was present in England in prehistoric times, and that it formed a part of the landscape. Witch-elm was used, he thought, in very early times, for the making of coffins, whilst birch had been put to the uses of tools. Remains of the ash were found in English peat, but they were not to be traced in the Scotch peat; nor were the remains of the beech to be found in Scotch peat. The spruce fir, or Norway pine, now of common importation, was not found in England at all, though it will flourish, and does now flourish, here, and spreads by seed without help. The lime tree was, in England, taken great care of, and kept for the uses of bees. There was, however, considerable doubt as to whether or not the lime tree was indigenous to England, though the author had been informed that at a short distance from Worcester there was a large wood in which the small lime is found forming the entire mass of the underwood. Passing from trees to bees and their product, the author asked the question as to when the hive was introduced. The only real fact which they were able to get hold of in answer to this was that in all cases they found the word for hive always like the Latin. The taming of the bee had been ascribed, without any real reason for so doing, to several nations. People having neither the sugar-cane nor the beet-root from which to get sugar, would be compelled to get it from milk or grain, or from similar sources; and honey must have counted for a very great deal. Passing on to prehistoric fauna, Professor Rolleston called attention to the great changes which had taken place in the Mollusca of our country since those times. Referring to what had been termed the Roman snail, he said that this was, without doubt, a very old and well-established British snail. But there was a little snail which had come all the way from the Caspian, which was now found in such numbers in some parts of England that it would sometimes stop up water-pipes &c. It had been called a mussel, and looked something like one. Not long since it was reported that this snail had been found in prehistoric deposits; but this the author could not believe. It came to us in large numbers from Russia with the timber which we got from that country, and which was floated down the rivers to be put on board ship. It was easier for these creatures to establish themselves in and along the rivers of a country than in any other part of it. The rabbit had only very lately established itself in this country; for the author had several times found flints &c. at the mouths of burrows which had been thrown up by rabbits. Now, had these rabbits been in the country for any very long time, the chances would be that the remains of all these barrows would have been destroyed. Consequently it was his opinion that the rabbit was not one of our prehistoric animals, but that it was probably brought over by the Romans, as the chestnut, the sheep, and the fallow-deer had been brought by them. The white-breasted marten, which had once been very prevalent, was a great enemy to the rabbit, and had, doubtless, kept the latter animal in check. In the Greek islands the rabbit was now very prevalent; but the Greek name for the rabbit he did not know; for though the Greeks mentioned the hare again and again, they said nothing of the rabbit. The fallow-deer must have lived in the time of Chaucer, who spoke of "The dreadful roe, the deer, the hart, the hind." The Norway rat, or grey rat, was not known in prehistoric times, nor was the black rat. The rat came to us from the other side of the Volga; but in one of the prehistoric tumuli the author had found several handfuls of jawbones of the common water-rat. This at first puzzled him very much; but he subsequently found amongst the remains a large carnivorous tooth, a canine of the polecat, one of which animals had evidently made its nest in the tumuli and fed its young upon water-rats.

Professor Rolleston exhibited and explained the uses of a flint hammer from the Western coast of New Guinea.

Notes on the Zaparos. *By* Alfred Simson.

The Zaparos are a people in Ecuador, inhabiting chiefly the Curarai and its tributaries, the Nushinu, the Nuganu, Supinu, &c., the main river Napo, in the neighbourhood of Sinchichicta, and the Yasuni. They are expert woodsmen and hunters, with very keen eyes and ears. When unprovoked they are shy and retiring, but are quite fearless, and will not suffer any one to force them by physical means. They exhibit marked pleasure in the destruction of human life. The Zaparos are very disunited, and wander about in separate hordes. Their superstitions were described by the author, who had passed some time with these Indians.

On the Colouring-matters in Human Hair. *By* H. C. Sorby, *F.R.S. &c.*

This was only a provisional account of the author's experiments. He has been able to separate several well-marked different-coloured substances. The chief of these are the black pigment and a red-brown substance, which, when oxidized, passes into a yellow colouring-matter. Though very red human hair contains a small quantity of a pink-red substance, yet by far the greater number of the different tints of human hair may be explained by supposing that it contains a varying amount of a variable mixture of the above-named three substances.

On Ethnology of West Cornwall. *By the* Rev. W. S. Lach-Szyrma.

The variations of races that go together to make the present population of West Cornwall are to be divided into two classes:—

1. Those Britons who came here from pressure of the Saxon invasion, and the aboriginal or *quasi*-aboriginal Damounii.
2. Those who came as immigrants to settle on the coast districts.

1. The Cornu-Britons are the backbone of the population. Their language was

the ancient Cornish, a distinct tongue from the other languages of the Celtic family, but nearest to the Breton or Armorican.

Remains of the Cornish language briefly considered. Evidence of Zeuss and Pritchard to Aryan character of Cornish. Untenability of theory of Semitic or Hebrew mixture.

Eminent men of Cornu-British race.

2. Other races of foreign settlers.

(1) Anglo-Saxons not so numerous probably as might be expected in an English county.

(2) The Danish or Norse element.

(3) The tradition of a Spanish element in parts of the Lizard and Lands End district. No historical evidence, but great probability. If it really exist, most likely the immigration was in modern times.

(4) The Irish element. Direct evidence of Carew. Difficulty of distinguishing Irish race from Cornu-Britons. Probably now quite intermixed.

(5) The Jews in Cornwall. Professor Max Müller's remarks against the theory. Possibility of confusion in the tradition between Jews and other Semitic nations, *e.g.* Phœnicians.

On some Characteristics of the Malayo-Polynesians.
By the Rev. S. J. Whitmee.

GEOGRAPHY.

Address by Admiral Sir Erasmus Ommanney, *Knt., C.B., F.R.S., F.R.A.S., F.R.G.S., President of the Section.*

In opening the proceedings of this Section, it occurs to me that it will be interesting to take a general review of the magnitude of Geographical research, and the advance in Geographical science which has been effected during the lapse of time since this great National Association assembled in this renowned town and naval port of the West.

The British Association for the Advancement of Science has met in Plymouth but once before, in 1841. During that thirty-six years of time our globe, whilst gyrating in its orbit through nearly twenty-three thousand millions of miles in its progress round the sun, has turned on its own axis 13,000 times: it can scarcely fail to be a question of some interest to mark at the end of this period what Geographers have been about on the surface of this globe whilst it has thus been bodily propelled through this stupendous space.

Before entering, however, upon this consideration of the advances that have been made on the then unknown regions of the globe, I would draw pointed attention to the change which has been effected by the recognition of Geography in the proceedings of this Association since the last meeting here in 1841. Geography was then ranked only as a subordinate branch of one of the Sections; it now forms a Section of its own, and we may say that it always commands a considerable and increasing share of public interest. This growing interest is due, in a great degree, to the exciting and important revelations made by great discoveries, and the presence of many renowned travellers at our meetings. This independent position must mainly be ascribed to the labours of those distinguished and learned men who took a lead in the organization of the Royal Geographical Society of London: foremost amongst them should be placed the names of Hamilton, Greenough, Murchison, Smyth, Beaufort, Barrow, and Rawlinson.

The enlarged views now held by geographers in a more scientific direction is certainly a satisfactory feature in the progress alluded to; for in 1841 Physical

Geography was not studied: the teaching of geography was then little more than a dry catalogue of places and countries, sketched on plane surfaces. The geography that is now taught in schools is a description of the physical condition of all the surface of the earth. In way of illustration of this progress, draw a comparison of an old school map of 1841 with one of the best forms of school maps recently produced by Stanford. Physical Geography is now looked upon as an essential work in the routine of ordinary education. The geographers of the present day, whilst appreciating the marvellous achievements of our great travellers, commonly deplore the deficiency of scientific training which blinded the observation from perception as to the value of many treasures in nature for scientific purposes.

Geographical science has of late years received considerable impulse from the establishment of new societies on the Continent, and most especially from the inauguration of International Congresses, which are destined to renew in a wide field of action all that has been so auspiciously established within the British Islands by our own Association. The movement was inaugurated in the renowned city of Antwerp in 1871, the native place of Mercator, and was marked by a great success. A second International Congress of geographers was held in Paris in 1875, which was equally satisfactory in its results. The first fruits that have been already gathered from the effect of international cooperation have been the discussion of unsettled problems, the establishment between nations of a common interest in the great expeditions of discovery, the improvements of instruments adapted to the particular needs of travellers and navigators, and of the methods of delineation adopted for maps and charts. Amongst the distinguished foreigners who have taken a leading position in the diffusion of geographical knowledge, there is no one who deserves a more grateful recognition at our hands than Dr. Augustus Petermann, of Gotha, the now somewhat venerable editor of the 'Geographische Mittheilungen,' which has for so long a period poured its streams of valuable information over the world.

It will be fresh in the memory of many assembled here, how excellent an opportunity of comparing the position and methods of the past with those of the present day, in all that relates to geographical investigation, was afforded by the Loan Exhibition of scientific instruments and appliances which was established at South Kensington last year. The visitor to that Exhibition was able to compare the astrolabe of Sir Francis Drake and of the mariners who steered the Spanish Armada to the coast of England, the back-staff of John Davis, the quadrant of Hadley and of Captain Cook, with the finished specimens of the sextant of this day; the compass of Galileo with the standard compass of the Admiralty, corrected by the Astronomer Royal, for use on board iron ships, and with the light multiple-needle of Sir William Thomson. The collection of maps, charts, and models which were exhibited effectually demonstrated all that has been said concerning the advance of geographical science. Here was to be seen a copy of the chart of the coast of America discovered by Columbus on his second voyage, made by the pilot who accompanied him; a chronometer which belonged to Captain Cook, and was taken by him to the Pacific in 1776, and was again taken to the Pacific by Captain Bligh in the 'Bounty,' 1787 (it was taken possession of by the mutineers at Pitcairn's Island, and was sold in 1808 by Adams to a citizen of the United States at Chili, where it was purchased by Captain Sir Thomas Herbert, R.N.). The manuscript maps of Livingstone, together with the instruments used by that great African traveller on his last journey, were exhibited; and what was of personal interest to me was "the first traces ever found of the Franklin Expedition," discovered by Captain E. Ommanney, H.M.S. 'Assistance,' on 23rd August, 1850, at Franklin's first winter quarters near Beechey Island. But of all the inventions of interest to the navigator was "the bathometer," produced by the genius of Dr. Siemens, for measuring the depth of the sea without sounding-lines. By means of this instrument, which can be placed in the cabin, the mariner can record with the same ease as reading off the barometric pressure the depth of the sea beneath him at a moment's glance.

In the year 1841 the triangulation of the British Islands was in progress; the great base-line on Salisbury Plain, which was to be made the test of the accuracy of the work, remained to be surveyed; this base was laid down in 1849; the primary base-line, on the margin of Lough Foyle, was measured in 1827. The base on Salisbury Plain was 360 miles away, and its length in the first instance was computed by a connected series of triangles projected on from Lough Foyle. When this base was measured by the standard compensation base, it was found that the actual measurement agreed within five inches of the length computed by the triangulation and trigonometry: this fairly expresses the accuracy which had now been introduced into this branch of surveying.

The English triangulation was connected with the systems of France and Belgium in 1862, and in 1865 a remarkable International Congress was held at Southampton, in which town the standards of linear measure of England, India, Russia, Belgium, Prussia, Austria, Spain, Italy, and the United States were compared with each other as a preliminary to a measurement of a great arc of a parallel of latitude. In the very year in which the British Association last met at Plymouth, the arc of India, which extends from Cape Comorin to the Himalaya, was completed. In 1867 a base-line was measured at Bangalore, which was found to be within a quarter of an inch of the length that had been assigned to it by a series of triangles from Vizagapatam. The detailed plan of the survey of London was completed on 326 sheets in 1871. General Dufour brought out his celebrated map of Switzerland in 25 sheets: this is one of the finest specimens of mapping the physical features of a country ever accomplished.

In the work of hydrographical progress we have ample reason to be proud of all that has been accomplished by this country, under the direction of those eminent hydrographers of the Admiralty—Beaufort, Richards, and Evans. To enumerate all the work that has been carried out by the several scientific naval officers employed in the surveying service all over the world, and give them a full consideration of their merits, is beyond the limits of this brief space; the accuracy of our surveys is so thoroughly credited, that our Admiralty charts and sailing directions afford to the mariners of this great maritime nation every confidence in the pursuit of their calling. The delineation of our charts has attained such a high degree of boldness in style and clearness as to give them a reputation of excellence among all nations. Although our maritime surveyors have accomplished mighty work in the examination and the correctly laying down a very extensive proportion of the coasts on our globe, there remains a large amount of interesting work for our attention; for the "unsurveyed world" is of considerable extent—new routes are opened up to the commercial world in unfrequented seas, which demand the careful examination of the skilled marine surveyor.

During the period now before us, our kindred across the Atlantic have taken up a very high position in this branch of hydrography: the admirable manner in which the United-States Coast Survey has been conducted is exemplary to all nations as regards its liberal provision, as well as for the comprehensive and systematic method of execution in carrying out this great work. I would point to the reports made to Congress for the last quarter of a century as containing matter of surprising interest both to the mariner as well as to the scientist; every new object is recorded with minute precision, an enormous amount of information is collected on meteorology, magnetism, tides and currents, as well as on hydrography and geography; also discussions on the causes as to the increase and decrease of coral-reefs, besides important additions to natural history; above all, the complete investigation and information regarding the great Gulf-Stream. It is a work nobly organized and executed, truly worthy of a great maritime nation. Here I deem it as opportune for this Section to accord a tribute of praise to the works of Captain Maury, of the United States. He has honoured us with his presence at the meetings of this Association, and favoured us with the benefit of his information—his elaborate charts of the trade-winds of the Atlantic Ocean and his laborious work on 'Winds and Currents' being a combination of science and experience which have contributed to abridge our long ocean voyages; the production of his marvellous work, the 'Physical Geography of the Sea,' in which the "wonders of the deep" led the way to a general interest on the subject of oceanic physics, and its style and language are so engrossing that it is attractive to the general reader, and takes its place as a work of literary excellence.

It is no less our duty to recognize the services of Admiral Sir Edward Belcher, who was a constant attendant at this Section, and was a great contributor to the proceedings of several branches of this Association. As a marine surveyor, he leaves behind him a large amount of work in all quarters of the globe, which is celebrated for accuracy. He published a very able work on 'Marine Surveying.' The greatest portion of his life was devoted to the surveying service in all parts of the world. He first came into notice as lieutenant of the 'Blossom,' in the expedition to meet Franklin in 1826–27, on the latter's journey along the coast to ascertain the practicability of a North-west Passage; and his last service was in command of an Arctic expedition in search of Franklin's ships, when a large extent of new discovery was added to our charts of the Arctic seas; and the rescue of McClure from his perilous position was accomplished by the expedition under his orders; so that he took a large share in the completion of the so-called North-west Passage.

At the very time that the British Association was holding its last meeting at Plymouth, Captain James C. Ross was engaged on his memorable expedition into the Antarctic Sea, a region replete with interest for discovery and scientific investigation. The 'Erebus' and 'Terror,' old bomb-ships, were selected for this service, names for ever famed to posterity. James Ross and his second, Captain F. R. M. Crozier, afterwards second to Franklin, and survivor, in command, were officers of tried experience and scientific attainments, who served many a year in all the voyages under the renowned Parry. Men endowed with less courage and practical knowledge would never have faced the perils and hazards in pushing through streams of floating ice and icebergs for hundreds of miles, until arrested by the formidable impenetrable precipice of eternal glacier which caps the south pole axis of our globe.

This expedition was sent forth by a representation from the British Association, in 1838, on behalf of those eminent *savants* of the day in this country and in Europe, chiefly in the cause of terrestrial magnetism in the southern hemisphere, in connexion with a system of simultaneous observations which were being conducted at fixed stations at various points on the earth's surface; and to no better hands could this great undertaking have been entrusted than to James Ross, who fixed the position of and planted the British flag on the north magnetic pole.

The expedition set out in August 1839, and returned in safety in September 1843, bringing results of the highest importance in the history of maritime discovery, the crowning feature being the discovery of Victoria Land, lying between the parallels of 70° and 78° S., with two high mountains, named Erebus and Terror, respectively 12,400 and 10,900 feet elevation above the level of the sea, Erebus being a volcano in full action, emitting flame and smoke in awful majesty amidst its glacial and silvery solitudes. The southern progress was arrested by a coast presenting a vertical cliff of ice from two to three hundred feet high, which being higher than the ships' mastheads precluded any observation into the interior of this supposed continent. This imposing icy barrier was examined for some hundred miles; it is the nursery of icebergs, and was found inaccessible everywhere.

The position of the South magnetic pole was laid within the icy barrier, and approximately determined from lat. 76° 12′ S., and long. 164° E.; the magnetic dip there observed was 88° 40′; the pole was assigned to be 160 miles from the ship on the 17th February, 1841.

In the following year a further examination of the icy barrier was attempted, and the highest southern latitude ever attained by man was on the 23rd February, 1842, when the mean latitude of the two ships was 78° 10′ S. Throughout the voyage a series of magnetic observations were recorded without intermission, with the utmost regularity, thus accomplishing the main object in view: the mass of work brought home has taken some years to discuss, under the direction of Sir Ed. Sabine.

In this expedition oceanic physics was a prominent work; deep-sea soundings and dredgings were frequently obtained; serial observations for temperature, the conditions of sea-water at the surface and at great depths, have supplied data for theorizing on oceanic circulation. As many as 161 deep-sea temperature soundings were obtained, chiefly in the southern and Antarctic oceans, varying from 12 to 7200 feet; in lat. 15° 33′, long. 23° 14′ W., soundings were tried for with 4600 fathoms of line, the greatest depths of the ocean that had ever been satisfactorily ascertained up to that time. Meteorological observations of great value were made, and the fact established that a lower barometric pressure exists in the Southern hemisphere than in the Northern. It is impossible to do more than refer to the above leading results of this voyage, reflecting so much honour on the skill and courage of all concerned in it.

Those regions on our terrestrial surface which have attracted the enterprising traveller are naturally those where civilized men have not penetrated—the ice-bound seas of the Arctic regions; also the interior of Africa, which in 1841 was a blank on our map, where the equator alone extends through a stretch of something like 2000 miles, and the northern tropic through more than 4000 miles of land. Little was known of Australia within the fringe of settlers located on certain parts of the coast. I will therefore, in the first instance, speak of Arctic exploration, which has so recently culminated in the Expedition under Nares to the Polar Sea.

When the British Association met here in 1841, Franklin had not started on his memorable attempt to force the North-west Passage from the Atlantic to the Pacific Oceans: at that time the coast-line of Arctic America had not been completely explored. It was not known whether the projecting mass of Boothia was connected with the American continent, or whether the neighbouring King William's Land was an island or a peninsula. Parry, in 1819, had discovered the group of islands extending to the west from Wellington Channel, still bearing his name; and twelve years after, James Ross fixed the site of the magnetic pole on West Boothia.

The 'Erebus' and 'Terror,' under the command of Sir John Franklin and Captain F. R. M. Crozier, entered Barrow Straits in the summer of 1845, and from that time were lost to sight.

It was not until 1848 that the Government yielded to the public demand for succour being sent after the missing ships; and an expedition, consisting of the 'Investigator' and 'Enterprise,' under the command of that distinguished Arctic and Antarctic voyager, Sir James Ross, was sent out. The extent of his efforts was limited to a small range of search. His ships wintered at Port Leopold, at the entrance of Regent's Inlet. In the spring of 1849 he made a sledge journey along the shores of North Somerset and to the east side of Peel Sound to lat. 72° 38′, long. 95° 40′ W. On the return of the navigation season, finding he could not advance, owing to Barrow Straits being blocked with ice, Ross returned home with his ships, but without a vestige of Franklin's people. Universal disappointment was manifested at this result. The veteran traveller, Sir John Richardson, with the noble spirit of sacrifice to duty for which he was distinguished, had returned from his examination of the Arctic shores of America, between the Mackenzie and the Coppermine rivers, without finding any clue to the missing ships. This was sacred ground to him, associated as it was with the trials undergone when he was the companion of Franklin in their overland journey to the Arctic coasts, 1820–21, to discover the North-west Passage. The Admiralty, the Hudson's Bay Company, the United States and Russian Governments, together with private enterprise, all combined, in 1850, to leave nothing undone to secure an effectual pursuit after Franklin's ships, the 'Erebus' and 'Terror.' The two ships brought back by Sir James Ross were fitted out with all dispatch, to enter the Arctic seas through Behring Straits before the navigation season of 1850 closed. You all know the eventful history of those two ships, the 'Enterprise' (Captain Collinson) and 'Investigator' (Commander McClure). They parted company in the Pacific Ocean never to meet again,—thus becoming, in fact, two separate expeditions, and adding greatly to our geographical knowledge, by filling up the vacant space on our charts between the continent of America and the Parry group. The 'Investigator' was abandoned in Mercy Bay, on the north coast of Banks's Land, by McClure and his gallant crew, leaving the British ensign and pennant flying. There they probably will remain, a monument to our intrepid band of seamen who completed the North-west Passage, the relics of which, like those of Barentz in his North-east expedition, recently found at Novaia Zemblia, may be lighted on some three centuries hence. The 'Enterprise,' by hugging the Arctic shore of America from Behring Straits to Dease Straits, has proved the practicability of accomplishing the North-west Passage from Baffin's Bay to the Pacific in one season, in a vessel suitable for the service. This was the object which Sir Allen Young had in view when he generously diverted his expedition into Smith's Sound last year, to effect a communication with Nares's Polar Expedition.

Lieutenant Pullen had examined the coast between Wainwright's Inlet and the Mackenzie River in the autumn of 1849, in a boat voyage full of adventure; no traces of Franklin's ships were discovered, nor had the Esquimax seen any thing of them or the crews.

In 1850, the Behring Straits Expedition being fairly set off, the Admiralty purchased two ships, the 'Resolute' and 'Assistance,' to which were attached two steam tenders, the 'Pioneer' and 'Intrepid.' The introduction of steam, and an improved form of ship with fine lines, instead of the square-ended bomb-vessels of Parry's time, marked a new era in Arctic navigation, and facilitated the means of exploring the icy regions. This expedition was sent to follow up the search *viâ* Barrow's Straits, and entrusted to the command of Capt. H. T. Austin in the 'Resolute,' seconded by Capt. E. Ommanney in the 'Assistance,' Lieutenant Sherard Osborn commanding the 'Pioneer,' Lieutenant Cator the 'Intrepid.' Simultaneously with this expedition it was desirable to enlist the services of men experienced in the enterprising and hazardous life of the whaling trade. A *carte blanche* was confided to Captain William Penny, a seaman eminently qualified for the object he had at heart, to equip an expedition in the north. Two smart clipper brigs were fitted out with every requisite for the service, and manned by a noble set of daring seamen experienced in ice navigation. These vessels, the 'Lady Franklin' and 'Sophia,' set out from Aberdeen on April 13th, 1850, with the object of searching the Wellington Channel. A noble-spirited merchant of New York, Henry Grinnell, at his own cost equipped two vessels to enter upon the search: they were commanded by Lieutenant E. J. De Haven, United States Navy; and the veteran Sir John Ross, at three score and ten, started in a small schooner to look for his old friend Sir John Franklin.

I will now pass briefly through the proceedings of the expedition most interesting to myself, the one above-named, under Austin and Ommanney, which left Greenhithe, 4th May, 1850. In our passage through Baffin's Bay we were more or less obstructed and detained by ice, reaching Cape York, in North Greenland, early in August. Here we divided into two expeditions—the 'Resolute' and 'Pioneer' proceeded to examine Pond's Bay; I was left to search the north shores of Barrow Straits. Having embarked an Esquimaux at Cape York, we first examined Wolstenholme Sound, and found a record left there by H.M.S. 'North Star,' which had been forced to pass the winter there; then crossing the north water of Baffin's Bay, through loose ice, the coast of North Devon, from Cape Warrender to Cape Riley at the entrance of the Wellington Channel, was examined, discovering Port Dundas. On the 23rd August, 1850, whilst searching along the shore at Cape Riley, I stumbled on "the first traces ever found of Franklin's ships" since they were last seen in Baffin's Bay in 1845, consisting of fragments of stores and clothing. Cape Riley is the southern point of the Bay, which proved to be the first winter quarters of Franklin, 1845–46. We searched about in vain on Beechey Island and around the locality, but to our grievous disappointment no record could be found, though the sad evidence afforded by three graves, with the names of the deceased seamen and their ships, was a confirmation that the 'Erebus' and 'Terror' left their quarters in the summer of 1846. Seeing that the other ships were coming up in order to follow the clue so happily found, whilst the few days of navigation were available, it was incumbent on me to push across Wellington Channel with the 'Assistance' and 'Intrepid' for Cape Hotham, Cornwallis Land. In doing this we were closely beset in heavy ice, and sustained some very awkward pressures. The south coast of Cornwallis Land was explored without finding further traces. September set in, the navigation season closed, and the expedition was finally frozen in for the winter two miles eastward of Griffith Island.

With regard to the other expeditions, Penny's vessels took up their winter quarters in Assistance Bay, about forty miles to the eastward of our position, as did also Sir John Ross. The American vessels under De Haven got beset in Wellington Channel, and they drifted helplessly under the influence of that current which bears such a remarkable feature in ocean circulation, and is so eventful in the history of Arctic voyagers. De Haven's ships, beset in pack ice, were drifted through Lancaster Sound into Baffin's Bay, then southward to Davis Straits, and, after an anxious winter, were released in the Atlantic Ocean.

Throughout the winter of 1850–51 our speculations were incessant as to the course Franklin had taken from Erebus and Terror Bay, and our minds and efforts were cheerfully devoted to preparations for sledge travelling with the return of spring. Although we were not fortunate in finding a harbour for wintering in, we were in fixed ice out of the influence of currents. Our expeditions were in good position for searching the south shore of the Parry Islands, and exploring beyond Cape Walker, which was distant about 60 miles to the S.W. As regards Penny's vessels, they were well situated for searching the Wellington Channel northward. With the fine crews at our command and ample resources, we had the means of exploring all the coasts westward and southward, and ascertaining the fate of our missing countrymen. On the Behring Straits side of the North-west Passage depôt ships were in station, and Collinson's expedition from the Pacific we fondly hoped might meet us halfway in 1851.

The year 1851 opened with sanguine hopes that Franklin's track would be fallen in with. We had searched many conspicuous positions for record, the absence of which involved a mystery over his course from Beechey Island. In April our sledging parties set out, perfectly organized and trained, to carry out exploration to the utmost limit of our resources. To examine the south shores of the Parry Islands and reach Winter Harbour of Parry was an important object; but to reach Cape Walker and follow on the course south-west from that position to the American continent, as suggested to Franklin in his instructions, afforded the best hopes of success. This route of search was confided to me, and, with Lieutenant Osborn, six officers, and forty-five men, we crossed over Barrow Straits 60 miles to Cape Walker. "Again no traces found." I provided for a search along the west shore of Peel Inlet, down to lat. 72° 49′ N., long. 96° 40′ W., whilst I continued the examination of the coast, accompanied by Lieutenant Osborn, to the west and south to Ommanney Bay, and attained a position in lat. 72° 40′ N., long. 105° W., the extremity of our journey. This land I named Prince-of-Wales Land. The coast trended away to the south-east, and around the horizon bounded a sea of solid heavy ice. On the very same day of reaching our extreme west (24th May, 1851) it became known to us afterwards that a party was advancing towards us from McClure's ship, the 'Investigator,' in Prince-of-Wales Straits, to a point in lat. 72° 21′ N., long. 112° W.: thus on that very day a party from the Pacific, and one from the Atlantic Ocean, were within 140 miles of each other; except for this small gap between us the North-west Passage was completed! I retraced the shores of Prince-of-Wales Land to Cape Walker, 200 miles of coast, and reached the 'Assistance' again off Griffith Island, after an absence of sixty days from the ship, and having travelled over 500 miles.

The land explored was generally low, and covered with hard frozen snow, very destitute of animal life, a most dreary journey; the only vestige of a human being having trod this land before was the remains of a very old cache, with fragments of bones. A low shingly beach in many parts indicated shallow water off the coast, on which a frozen sea of ice rested, in many places of great thickness. The one feature of scientific interest of the journey was fixing the magnetic meridian of 180°, passing due north of the magnetic pole. Lieutenant McClintock accomplished a great achievement in reaching Melville Island of Parry, and Liddon Gulf; the search of Parry's Winter Harbour was of great interest, conspicuous records and other traces of that noble navigator were found there.

Lieutenant McClintock was absent 80 days from the ship; the parties under him had searched all the southern shores and inlets of the Parry Islands; his own party travelled 700 miles, a marvellous feat for seamen.

In the mean time Penny's expedition had explored both sides of the Wellington Channel to a high latitude, 76° 25′ N., travelling over a large extent of new ground with his energetic officers and crews, defining the north coast of Cornwallis Land and a cluster of islands in the broadest part of the channel; to the north-west of the channel he observed open water leading to the Polar Sea.

With the end of June sledge-travelling ceased, and with it came disappointment; no clue of the missing ships had been traced from Beechey Island. A large extent of new ground had been thoroughly searched, yet their fate remained shrouded in mystery. The amount of sledge-travelling was unprecedented (this mode of exploration in icy regions was here developed to perfection); our great journeys were accomplished without loss or sickness; the total distance actually travelled over by our crews amounted to 5817 miles, under the severity of Arctic cold.

The summing up of results and opinions inferred that Franklin had not gone westward, and an examination of Jones Sound, at the head of Baffin's Bay, was made, with no better success, before the expedition returned to England.

The year 1851 closed replete with matter of great Arctic interest. Extensive exploration had been carried out beyond any that had been effected before. Important additions to science and geography had been obtained. The first wintering quarters of the Franklin Expedition had been discovered; but regarding the course it had taken after it left Beechey Island every effort had failed to ascertain, and the country clamoured for another search.

The same ships were refitted: Sir Edward Belcher, in the 'Assistance,' had the command of the expedition, Captain H. Kellett was second, in the 'Resolute,' aided by McClintock and Osborn, in the steam tender, with a depôt ship to accompany them; these vessels left Woolwich, April 15th, 1852.

Search to the north-west up the Wellington Channel, and to Melville Island, was the tenor of the Admiralty instructions. From Beechey Island the Expedition divided into two divisions: Belcher was favoured with open water, and attained a wintering quarter at Northumberland Inlet, in a high northern latitude, nearly 77° N., on the north-east coast of the Wellington Channel. Kellet and McClintock reached Melville Island, and were compelled to winter near Dealy Island, about 30 miles eastward of Parry's Winter Harbour. At the sandstone bearing the inscription that Parry wintered there in 1819–20, while laying out provision depôts for spring travelling, Lieutenant Mecham, on the 14th of October, found at Winter Harbour the important record deposited by Commander McClure in April 1852, which stated that H.M.S. 'Investigator' was frozen up in Mercy Bay, Banks's Land, and had completed the North-west Passage. At that period of the year, October, it was impossible to send a party across the straits which separated the two ships 'Resolute' and 'Investigator.'

Referring back to the proceedings of the 'Investigator,'—the ship entered Behring Strait in 1850, and rounding Point Barrow continued her course eastward, searching the Arctic American coast up to Cape Bathurst, and stretching northward discovered Baring Island; McClure then proceeded eastward, made the discovery of Prince Albert's Land, and entered a strait trending to the north-east, with a prospect that it would lead him into Barrow Straits; but winter arrested his progress, in Prince-of-Wales Straits, where the winter of 1850–51 was passed. An excursion from the 'Investigator' took McClure through the straits to an open sea, and on 26th October, 1851, he pitched his tent upon the shores of Barrow Straits (now called Parry Sound), lat. 70° 31′ N., long. 114° 14′ W., the land on the north being that put down by Parry, in 1820, as Banks's Land. Thus was established the existence of a passage between the Atlantic and Pacific Oceans, denominated the North-west Passage.

McClure passed the first winter in Prince-of-Wales Straits; in his spring travelling he had explored Baring Island and the north shores of Prince Albert's Land, embracing 800 miles of coast; but not a vestige of civilized man was seen. With the return of the navigation season his attempts to push through Prince-of-Wales Straits into Barrow Straits failed, from an unbroken body of ice covering the sea beyond these straits; his greatest advance in that direction was lat. 73° 13′ N., long. 115° 32′ W. Retracing his course through Prince-of-Wales Straits, and rounding Nelson Head, he continued hugging along the coast of Baring Island, trending northward, contending with formidable ice and severe pressures, overcoming perils and hazards never surpassed. The 'Investigator' was navigated round the north of Baring

Island; then, pressing on to the eastward, at the close of the navigation season, the ship found safety on the 24th of September, 1851, in Mercy Bay, lat. 74° 6′ N., long. 118° 15′ W. That night the 'Investigator' was firmly frozen in, never to be released.

The winter passed. In April 1852 McClure crossed the straits, sledging over to Melville Island; at Winter Harbour he deposited a record of his position at the sandstone bearing the inscription of Parry's visit; he here found the record of McClintock left by him in 1851, on his journey from the 'Assistance.'

The summer of 1852 passed away, keeping the 'Investigator' in her ice-bound prison; a second winter was to be passed in Mercy Bay, on short allowance of provisions; mean temperature of January 1853 was $-44°$. Arrangements were made for abandoning the ship, when, early in April, a party from Kellett's ship at Melville Island electrified their vision; the means of succour were at hand. The sequel was, the 'Investigator' was abandoned; McClure and his gallant band were transferred to the 'Resolute,' Captain Kellett, and under his command they reached England, in 1854, *viâ* Barrow Straits.

During the spring and summer of 1853, great work was accomplished by the crews of Belcher's division and Kellett's under McClintock, Richards, Osborn, Hamilton, &c., under whose leadership the configuration of the northern shores of the Parry Islands was completed, and large geographical discoveries were added to the North Polar regions—McClintock's explorations of Prince Patrick's Islands, and Sir Edward Belcher's discovery of Belcher Straits connected with Jones Sound, leading to Baffin's Bay, accompanied by valuable scientific and hydrographical information. I will not prolong the account of the proceedings of those gallant explorers any further. By Sir Edward Belcher's orders his ships were all abandoned in 1854, the officers and crews fell back to Erebus and Terror Bay, and finally reached England with the heroes of the North-west Passage. And here ended the Government search for Franklin's ships. But where could they be? Beyond my discovery of the first traces in 1850, nothing authentic of their whereabouts had been found—their fate remained shrouded in mystery.

The services which Dr. John Rae, the eminent Arctic traveller, rendered to this cause in the search for Franklin added a considerable extent of new coast-line in connexion with the North-west Passage. In 1851 he descended the Coppermine River, and crossed the strait over to Wollaston Land, near Cape Franklin; then explored the coast in a north-west route up to Cape Baring, in 70° N. lat. and 117° 17′ W. long., and returned to Port Confidence early in June. After a few days' rest he set off again on a boat expedition, and explored a continuous coast-line along Wollaston Land to Victoria Land on to a position in lat. 70° 2′ N., long. 101° 25′ W., on the 15th August, which was the extreme limit of his journey, where his navigation was stopped by ice. Victoria Straits separated him from King William Island. Could Rae have then advanced 50 miles due east he must have struck on the site of Franklin's disaster. Rae retraced his course along the shores of Victoria and Wollaston Land, returning to Fort Confidence by 10th September. In these two ably conducted journeys he travelled along 400 miles of new-discovered coast. He met with Esquimaux who knew nothing of Franklin's ships, but picked up some pieces of wood and line bearing the Government mark. Amongst other contributions to Geography was the spirited summer voyage of Commander Inglefield in a small schooner in 1852, when he entered Smith's Sound to a higher latitude than was ever attempted before. Some extent of coast-line was added to on this route into the Polar Sea.

In October, 1854, important intelligence was received from Dr. Rae, who had been sent to the North in 1853 to complete certain surveys on the west coast of Boothia. After wintering at Repulse Bay, during his spring journey he met with Esquimaux, in whose possession he found several articles, including pieces of plate, on one of which Sir John Franklin's crest was engraved, which were identified as belonging to the officers of the 'Erebus' and 'Terror,' and was told that a party of white men had perished some four years gone by. The recovery of these precious relics, the only ones found since those discovered by me at Cape Riley and Beechey Island, together with the statements made by the Esquimaux, was conclusive as to the fact that the ships must have been abandoned near the neighbouring coast. This painful discovery, and the return of Belcher's expedition, may be said to terminate the Franklin search, which had been carried on by this Government since 1847. The exploration produced valuable results for geographers, which are seen at a glance by comparing the Arctic chart of 1845 with that of the year 1854.

The 'Enterprise,' under Captain Collinson, returned to Behring Straits in 1851, and followed closely on the discovery of Prince-of-Wales Straits by McClure in 1850, and the researches of Dr. Rae upon Wollaston and Victoria Lands, collecting much valuable geographical and hydrographical information of great interest, spending three winters in the Arctic Sea. The first winter was passed in Prince-of-Wales Straits, and he communicated with Melville Island. Frustrated, like McClure, in passing through this Strait to the north-east, Collinson made for the Dolphin and Union Strait, and coasted eastward to Cambridge Bay, where he passed the second winter. In the spring of 1853 he attained the lat. of 70° 25′ N. on Victoria Land, and thus, like Rae, was actually within a few miles of the last resting-place of Franklin's ships. With exhausted supplies, and seeing no prospect of advance to King William's Land, he had to return to Behring Straits by the same route; but, unfortunately, before he reached the Strait the ship was again beset in ice for a third winter, which was passed in Camden Bay; and in August 1854 he effected his escape by Behring Straits, and reopened communication with the civilized world after an interval of 1,126 days.

An expedition was generously provided by the United States Government for the search of Franklin through Smith Sound, under the command of Dr. Kane, in a vessel of 120 tons. A winter station was gained the first summer in lat. 78° 37′ N., long. 70° 40′ W., on the Greenland coast. Many interesting discoveries and scientific observations collected were of great value. The coast of Greenland was traced to lat. 81° 22′ N., and on the American side of Kennedy Channel to 82° 30′ N. Open water was seen in the Polar Sea. The lands discovered north of the 80th parallel were named Grinnell on the American side of the Strait leading to the Polar Sea, and Washington Land on the Greenland side. In this highest latitude ever wintered in, the sun was 120 days below the horizon. The lowest temperature observed indicated −70° F.

The geological structure of the lands was fully described by Dr. Kane, together with the natural history and botany of these regions: the stupendous Humboldt glacier and smaller glaciers were grand features, and afforded evidence as being the source of iceberg supply. Moreover, life exists in this locality in the shape of a tribe of Esquimaux isolated from the rest of the world.

The heavy floe-ice never cleared out of Smith's Sound; and, after the second winter, the vessel was abandoned; Kane with his followers escaped in boats after a perilous voyage to Upernavik.

A few years subsequently (1860–61) another Polar expedition left the United States, under Hayes, for these regions; but such was the condition of Smith's Sound then, which was choked with ice, that Hayes could not effect an entrance into it with his sailing schooner, so had to winter at Port Foulke.

After all that was done in the searching between 1847 and 1855, beyond the relics and graves found at Beechey Island by me in 1850, and the relics recovered by Rae, no authentic records of the ill-fated expedition had come to light throughout the vast extent of coast explored under so many highly gifted and zealous leaders.

There still remained a strong feeling on the part of the public and the relatives of Franklin's Expedition to clear away the mystery connected with the discovery of Rae; though it was evident that the ships had been abandoned, yet no records or documents had yet been found. The limited area for search lay south of Peel Inlet.

Lady Franklin, supported by Sir Roderick Murchison, Allen Young, and other eminent names, contributed largely towards a "final search" for the 'Erebus' and 'Terror.' The yacht 'Fox' was purchased, and the command fell into the able hands of Captain F. Leopold McClintock, already distinguished for his remarkable feats of ice sledge-travelling and explorations; Lieutenant W. R. Hobson, R.N., and Captain Allen Young came forward and served under him. Well furnished with all requisites, the 'Fox' left Aberdeen the 1st July, 1857. On her outward voyage she became beset in crossing the north water of Melville Bay, and was frozen in for the winter, which was passed drifting bodily with the pack-ice southward in the prevailing current. She was beset in lat. 75½° N., and drifted in 242 days to lat. 63½° N., long. 58° 25′ W., altogether 1194 geographical miles. On April 28th, 1858, the 'Fox' anchored in the Danish harbour of Holsteinborg in Greenland. Nothing daunted by this detention of a dreary winter imprisonment in the ice-pack, with the attendant anxieties and perils, after a refit McClintock proceeded northward again with better success, touching at Beechey Island, the first winter quarters of Franklin, and then went down Prince Regent's Inlet to Bellot Straits, where the 'Fox' was frozen in for the winter. With the return of spring (1859) travelling parties set off to explore West Boothia and King William's Land, which resulted in the great discovery of the "Record," the only one ever found, and which was picked up near the site of the magnetic pole fixed by James Ross (1831). The contents were brief, and to this effect: that the expedition ascended the Wellington Channel to lat. 77° N., that it returned by the west side of Cornwallis Island, and wintered, 1845-46, at Beechey Island. After leaving Beechey Island the ships were beset on 12th September 1846, and continued wintering in the ice until 24th May 1847, when they were in lat. 70° 5′ N., long. 98° 23′ W., on which day Lieutenant Gore and Mr. Des Vaux with six men left the ship all well. Round the margin of the record is written:—

"April 25th, 1848.—H.M. ships 'Erebus' and 'Terror' were deserted on the 22nd April, five leagues N.N.W. of this, having been beset since 12th September, 1846. The officers and crews, consisting of 105 souls, under the command of Captain F. R. M. Crozier, landed at lat. 69° 37′ 49″, long. 98° 41′. This paper was found by Lieutenant Nairn, under the cairn supposed to have been built by Sir James Ross in 1831, four miles to the northward, where it had been deposited by the late Commander Gore in June, 1847. Sir James Ross has not, however, been found, and the paper has been transferred to this position, which is that in which Sir James Ross's pillar was erected. Sir John Franklin died on the 11th June, 1847, and the total loss by death in the expedition has been to this date 9 officers and 15 men.

"JAMES FITZ-JAMES,
"*Captain H.M.S. 'Erebus.'*

"F. R. M. CROZIER,
"*Captain and Senior Officer.*

and start to-morrow, 25th, for Back's River."

The "Record" was then deposited again on the site of Sir James Ross's pillar, where it was found by Lieutenant Hobson, on 6th May 1859, detached to search in that direction by Captain McClintock. Relics of clothing, watches, plate, guns, &c. were found along the beach, also the body of a young man; the boat was found on the beach in lat. 69° 9′ N., long. 99° 27′ W.; all of which have often been described before, and need not be repeated. No journals were found nor the ships seen. The shore had not been visited by Esquimaux since the abandonment of the 'Erebus' and 'Terror.'

The whole of the coast of King William's Island was searched by McClintock, while Allen Young examined Prince-of-Wales Land, and determined its insularity by a laborious journey, filling up the intervening space between the points reached by my parties in 1851.

Thus was successfully accomplished the object of this voyage, and the mystery of the ill-fated expedition cleared up by the several searching expeditions for Franklin's ships: the heroes had perished at the point of success.

Franklin died gloriously at his post, as did the old voyager Barentz on the shores of Novaia Zemblia in 1596. The conclusions drawn from Rae's discoveries were confirmed; but the total disappearance of the ships remains unaccounted for.

After the important discoveries brought to geographical knowledge by the Franklin Expedition and the North-west Passage were settled, a lull of interest in Arctic research followed for a time; it was revived again by Dr. J. L. Hayes, of the United States, the companion of Kane, who returned to the scene of his labours animated with an ambition for gaining the Pole. His expedition of 1860-61 was passed in Smith's Sound, and was memorable for attaining a more northern point of land, in 81° 35′ N., than had been reached by any previous navigator. He brought back valuable observations on the physical geography and hydrography of this route into the unknown Polar Sea, with sanguine ideas of navigable waters north of Greenland.

Then sprang up the rage for Polar exploration and emulation for reaching the Pole itself. Captain C. F. Hall, of the United States, an enthusiast for discovery in the north, who was famed for his two prolonged residences among the Esquimaux to inure himself to the climate, living, and privations of that northern race, was single-minded, and devoted to the perils of Arctic life and discovery. Supported by public feeling and the President of the United States, he was appointed to the 'Polaris,' for an expedition towards the Pole; she was 387 tons, schooner-rigged, and propelled by steam-power. In July 1871 Hall started for the north, visiting the Danish settlements in Greenland, where dogs for sledging were procured. The season was unusually favourable, which enabled the 'Polaris' to enter Smith's Sound with few obstacles, and reach the high latitude of 81° 20′ N.; the navigation was persisted in, by struggling through formidable ice-floes, up to the high position of 82° 11′ N., and refuge was sought on the Greenland coast of the Robeson Strait, named Thank God Harbour, in lat. 81° 38′ N., long. 61° 44′ W. Here the career of this devoted voyager was ended by his untimely death. He made a reconnoitring journey in October, just at the approach of winter, in an extreme low temperature: the severity of the climate and the exertion proved too much for him; on his return to the 'Polaris' he was attacked with a severe illness, and died in a few days. The death of Captain Hall was fatal to the object of the expedition. To him is assigned the discovery of the Strait extending northward from Kennedy Channel, and named by him Robeson Strait. The most eventful crisis occurred in October 1872. During the drift of the 'Polaris' out of Smith's Sound, a severe nip in a gale threw the vessel on her beam ends; destruction was imminent; the crew took to the floe of ice to save themselves. Whilst in the operation of getting provisions out of the ship a disruption of the floe took place; suddenly the 'Polaris' was drifted away a distance, leaving 19 souls on the floe to their fate, exposed to the rigour of an Arctic winter; thus at daylight these unhappy people found themselves abandoned to their fate, with a very small quantity of provisions and clothing, with slender materials to provide shelter, and two boats. The chief officer of their party was Captain Tyson, and out of 19, 7 were Esquimaux. This awful separation happened near Lyttleton Island: influenced by the southerly current the floe drifted away through the long dark Arctic winter. The narrative of the privations and sufferings of these is unparalleled; how life was preserved seems miraculous, due entirely to the Esquimaux, who were expert seal hunters. As they drew south of Davis Straits the floe reduced by breaking away in a warmer sea, and they shifted about to different pieces of ice: from day to day their condition became more hopeless. On the 30th April, in lat. 53° 35′ N., off Labrador, relief came to them just in time to save them from starvation: the steamer 'Tigress,' employed in sealing, saved them.

The 'Polaris' suffered so much damage from the nip, that she was driven on to the coast to save her from sinking. After the floe party had disappeared, Captain Buddington and 14 men were found on board; the 'Polaris' was abandoned, and the party passed the winter in a house of their own construction. In the spring of 1873 they took to their boats, and after many perils were picked up near Cape York by the whaler 'Ravenscraig,' of Kirkcaldy.

Following upon the great discoveries so nobly made under the British flag by naval officers in the Arctic seas northward of the American Continent, and the failure of the United States Expedition to enter the Polar seas by way of Smith's Sound, a strong feeling sprung up on the Continent to emulate our glorious feats in the North, and under the advocacy of Dr. Petermann, the Swedes, Germans, and Austrians, several expeditions have been conducted into the Spitzbergen seas and to Novaia Zemblia since 1865. Let us not omit to accord our praise to the spirited yachtmen of this country, who have so nobly and ably encountered the perils of the Polar seas, even to the north of Spitzbergen, in the cause of discovery, and returned with valuable information. I refer to Lord Dufferin, Mr. Lamont, and Mr. Leigh

Smith; after several voyages the two latter gentlemen hold to the opinion that the nearest approach to the Pole lies in that direction.

On the east side of Greenland, the German Expedition of 1869-70, under Koldewey, passed a winter in a small steamer of 140 tons, the 'Germania,' with a crew of only 17 hands, on the same ground where our Captain Clavering, R.N., with Captain Sabine, had conducted scientific pendulum observations in 1823, on Pendulum Island, and laid down the coast from 72° to 76° N. Under Koldewey, Payer won his first laurels as a traveller, in exploring deep fiords abounding in grand scenery, with animal life, and an interesting flora. The 'Hansa,' tender to the 'Germania,' got separated from her before the winter in the packed ice. She was drifted along by the prevailing current from the Polar Sea, along the east coast of Greenland towards the south; after many perils this vessel was crushed; the crew escaped in open boats to the Danish settlement near Cape Farewell. Professor Nordenskiold has made several successful expeditions to Spitzbergen on scientific pursuits, which are of the highest value.

Then we have to recognize the Austro-Hungarian Expedition under Weyprecht and Payer, who set off to enter the Polar Sea to the north-east, acting on the views of Petermann respecting the extension of the warm current from the Atlantic in that direction; but at first starting from the north coast of Novaia Zemblia their small vessel was beset, and drifted in a helpless condition for more than a year in the frozen sea, and they involuntarily became the discoverers of Franz-Josef Land and adjacent islands, a group very similar to Spitzbergen. The feat accomplished by Payer in exploring on foot to the north of these islands is unsurpassed. The account of this celebrated voyage is familiar to you all, as well as their remarkable escape from their abandoned ship.

England could no longer look on idly and see other nations striving to eclipse her Arctic fame, and repeated applications from the Royal Geographical and other learned societies, also supported by this Association, resulted in Government granting the Expedition which has so recently been conducted with so much credit under Capt. Sir George Nares, seconded by Capt. Stephenson. It would be tedious to you now, and indecorous of me, to repeat all what Captain Nares and his noble followers have so gallantly accomplished, and which has been so fully and prominently related to the world. You must bear in mind that although we made such extensive discoveries in the search for Franklin, discovery was not then the object, and since the celebrated effort of Parry to reach the Pole from Spitzbergen in 1827, when he attained the high latitude of 82° 45′ N., no further attempt to explore the Polar seas had been sent forth. Smith's Sound was selected on the opinion of a majority of Arctic officers, grounded chiefly on the statements received from the United States Expedition respecting land trending north from Robeson Channel, with facilities for navigation in the summer.

The 'Alert' and the 'Discovery' set forth in May, 1875, with the unanimous good wishes of the nation for success. The chief object in view was to reach the Pole of our globe, to extend our geographical knowledge, and obtain scientific observations. The expedition left most amply provided for the perilous service, and in the passage through Baffin's Bay as far as Smith's Sound was highly favoured with an open navigation, and on the 28th July they reached Port Foulke at the entrance of Smith's Sound. Here commenced the trials and impediments which the Arctic seaman has to contend with; the rest of the navigation season was one repeated struggle amidst heavy ice-floes, icebergs, sometimes for days beset in packed ice. The ships were advanced through Kennedy Straits to the Robeson Channel of "Hall of the Polaris." The condition of the navigation this season proved very different, as the 'Polaris' reached lat. 82° in comparatively open water. On August 25th the 'Discovery' was placed in a harbour well suited for wintering and most favourably placed as the reserve station, should disaster happen to the 'Alert' in a high latitude of the circumpolar sea. The 'Alert' then advanced alone, contending against currents and massive floe-ice. On September 1st, aided by a south-west gale, a passage was opened which enabled Nares to clear the Robeson Channel, and attain the latitude of 82° 24′ N., the most northerly position ever gained by any ship. He found himself confronting the circumpolar sea, filled with packed ice, varying from 80 to 100 feet in thickness, which arrested all hopes of advancing further north, and, what was a greater disappointment, not a glimpse of land could be discerned northward. Struggling amongst the formidable floe-bergs, a station was gained on the coast in lat. 82° 27′, and under the protection of heavy grounded ice, the 'Alert' was secured for the winter. Thus was the British flag the first time carried into the circumpolar sea, so aptly termed the Palæocrystic Sea. The ship had been navigated with a skill and courage never surpassed, and advantage taken of every piece of open water to the limit where navigation ceases. A winter followed, in which the sun disappeared for 142 days, and a minimum temperature of 73°·7 below zero was registered.

In the spring of 1876 the sledge parties set forth on discovery and research—those from the 'Alert' taking up the exploration of the coast to the north and westward, and the great attempt towards the Pole over the Palæocrystic ice; to the 'Discovery' was confided the exploration of Greenland to the north and eastward. Commander Markham, after contending against obstacles in the way of hummocky ice never encountered before, against which progress was impracticable, gained the latitude of 83° 20′ N.; to him remains the honour of leaving the British flag in the most northern point ever attained by man. Lieutenant Pelham Aldrich succeeded in making 220 miles to the westward of the 'Alert's' winter quarters. The coast culminated to the north at Cape Columbia in lat. 83° 7′, long. 70° 31′ W.; the limit of his well-conducted journey terminated at lat. 82° 18′ N., and long. 85° 33′ W.

Lieutenant Beaumont's party crossed ths Robeson Channel to the late winter quarters of the 'Polaris'; the examination of Petermann Fiord was completed, and the continuation of the Greenland coast was extended to lat. 82° 54′ N., long. 48° 33′ W., to which the name of Cape Britannia was applied.

Thus the geographical results of this voyage are about 400 miles on the coast of this circumpolar sea, which has been discovered and accurately laid down, with all the physical features and productions of the country described. Besides these leading parties, others were employed in surveying many detailed parts of the shores and inlets of the Robeson Channel. I would observe that all hopes of gaining access to the Pole ended when the Palæocrystic sea was entered, and no land visible to the north. The two essential conditions were wanting for success, viz., a coast-line trending north and ice suitable for sledge travelling, neither of which existed.

Many valuable scientific observations have been made, and from which much benefit will be gained to science; these are in course of publication.

As an Arctic voyager, I may be permitted to express my unqualified approval of the conduct of Captain Nares in his wise decision to return home; in fact, nothing could have been gained by remaining out another season, and the able seamanship displayed in effecting the escape from such a perilous position is admirable; for, remember, that in the three previous expeditions into this dangerous channel Kane and Hall met with disaster, and Hayes can hardly be said to have penetrated Smith's Sound in his schooner.

Before quitting these glacial regions, I would venture to give my opinion with reference to future exploration. I never was sanguine as to the success generally expected by the advocates of the Smith Sound route. By the valuable information brought home by Nares as to the physical conditions of the Palæocrystic ice, which I believe to occupy all the circumpolar area within the eighty-third parallel, all ideas of reaching the Pole from that direction, or anywhere north of the Parry group, may be discarded; and I thing this formidable ice will arrest the voyager sooner or later in navigating towards the Pole. But, instead of nations racing for the Pole, let us accomplish what is practicable. To complete the coast-line of North Greenland would be interesting to all geographers (that is, to connect the coast between Beaumont's furthest and Koldewey's north limit of discovery at Cape Bismarck), and might be accomplished from a winter station on the east coast. A scientific survey of Franz-Josef Land would be of great service to the interests of science. Payer observed a navigable sea from his extreme north position at Cape Fligeley, between him and Oscar Land; research in that direction appears to hold out a hope of success in finding more land in that region. The Swedes are preparing an expedition to make a passage from Novaia Zemblia along the Siberian coast to Behring Straits. In conclusion, all must admit that England retains the proud distinction of being the foremost nation in polar research; and if Nares did not reach the Pole, his voyage has contributed largely to the sum of human knowledge.

Within the period now under review, ocean telegraphy has been developed by means of a cable reposing on the bed of the ocean; we converse, as it were, with our neighbours across the Atlantic, and our colonies at the Antipodes. In 1841 the Atlantic Ocean had not been fathomed; we are now contouring the bed of the ocean. I well remember the interest exhibited at this port in 1858, when the United States frigate 'Niagara' and our own 'Agamemnon' departed to lay down the first cable from Valentia to Newfoundland. The mode of operation on that occasion was—the two met in mid-Atlantic, the cable was spliced and lowered to the bottom, then each ship proceeded paying out the cable as she went towards America and to Ireland. After three failures the cable was laid; the joy was great; the Queen and President Buchanan interchanged messages, but the joy was of short duration. The cable spoke for twenty-five days, and in that time 4359 words passed between the continents; it then became weak in voice, and on September 1st ceased to speak altogether, though the cause of its silence was never ascertained. In 1865 a new cable was manufactured and the 'Great Eastern,' carrying 24,000 tons and drawing 33½ feet of water, was chartered to convey it. After 1200 miles had been laid, disaster occurred, and the 'Great Eastern' returned home with half the cable, the other half being at the bottom of the Atlantic. In 1866 the 'Great Eastern' again started, and this time complete success was achieved; the new line was laid from Ireland to Newfoundland, and the wonderful feat accomplished of fishing up the broken half from a depth of more than two miles of water. Again congratulatory messages passed between England and America, and since then the working of the cable has been entirely satisfactory.

Following on this achievement, the naturalist, geologist, and the physicist became eager to obtain evidences concerning the condition of our globe at these hidden depths, which form data for investigating the theories of oceanic physics and the system of ocean circulation. This desire culminated in the 'Challenger' Expedition under Nares, and a scientific corps under the direction of Sir Wyville Thomson. Captain Evans, R.N., Hydrographer of the Admiralty, in his address last year to this Section, demonstrated the position of the science known as the 'Physical Geography of the Sea,' up to the completion of the 'Challenger' Expedition; I will now do no more than review the work accomplished during that interesting voyage.

The 'Challenger' Expedition, complete with every appliance and equipment requisite for the investigation of the ocean depths, sailed from Portsmouth on December 21st, 1872; she crossed the Atlantic three times, namely, between the Canaries and Virgin Islands, between Bermuda and the Azores, and between the main coasts of Sierra Leone and San Roque, and also examined an axial stretch of the ocean basin from Halifax to the Virgin Islands. The expedition next visited Bahia and Tristan d'Acunha, and was at the Cape in December 1873, one year of the cruise being thus devoted to the examination of the Atlantic. The 'Challenger' next proceeded from the Cape to Kerguelen Island, and investigated its suitability as an observing station for the approaching transit of Venus, explored the high southern latitudes between the 80th and 100th meridian of west longitude, and from those shaped its course across the South Sea for Melbourne and New Zealand, which was visited at the beginning of July 1873. From New Zealand the course was laid by the Fiji Islands, Bass's Straits, and the Philippines to Hong Kong, which was attained at the end of 1873. In this part of the expedition the Bandas, Celebes, and Sulu seas were examined and were found to be curious submarine basins, circumscribed by runs of comparatively shallow water. From Hong Kong, Captain Thompson, who had there superseded Captain Nares upon his appointment to the command of the North Polar Expedition, returned to the Philippines, and thence passed to the north coast of New Guinea, and from it to Japan, where the Expedition was reported to be in the month of April 1875. From Japan the 'Challenger' crossed the Pacific to the 155th west meridian, then passed directly south along the middle line of the ocean for eighty degrees of latitude, taking the Sandwich and Society Islands by the way, and afterwards turned east across the remaining half of the Pacific, reaching Valparaiso at the end of November 1875. The Straits of Magellan were traversed during the first days of the year 1876, and the expedition was at Monte Video on the 25th of February, at the Cape-Verde Islands on the 20th of April, and at Spithead on the 24th of May 1876.

By this memorable expedition, Dr. Carpenter's views of the vertical circulation of the ocean were substantially confirmed. It was found that the old idea of a uniform deep-sea temperature of 39° was an error, which had been caused by the derangement of the readings of the old unguarded thermometers under the pressure of the water of the deep sea, and that a temperature of 32° prevails at deep ocean bottoms, even at the equator, the cold there being due to a constant underflow of dense water from the Polar seas towards the equator. But wherever the deep basins are protected from the cold lower currents by comparatively elevated ridges of rock, the deep soundings give warm water in the place of cold. This was remarkably instanced in the Gulf of Mexico, and in the ridge-protected basins of the Banda, Celebes, and Sulu seas. The temperature was found to be 50° at 1800 fathoms in the Sulu Sea, although in the neighbouring open China Sea it was 37° at only 900 fathoms. In the Celebes Sea the temperature was $38\frac{1}{2}$° at 2667 fathoms.

In the Atlantic the very interesting fact has been determined by the 'Challenger' soundings that the basin of the ocean is divided into two subordinate troughs by a submarine ridge running from south to north through the Dolphin Rise and the Azores, to the shallow water which bounds the Atlantic to the north. The average depth of the Atlantic seems to be within 2640 fathoms, or three miles. The deepest sounding in the Atlantic was in a depression lying 100 miles north of St. Thomas, where the bottom was reached at 3800 fathoms, or four and a quarter miles. The deepest sounding in the Pacific was midway between New Guinea and Japan, in 11° N. and 143° E., where the bottom was reached at a depth of 4475 fathoms, or 453 feet more than five miles. Very near to this the temperature of the deep sea was found to be 33°·9. In this deepest sounding one of the thermometers was broken, but red clay was brought up from the bottom. Throughout the long examination of the ocean depths by the 'Challenger,' the conclusion was amply confirmed that there is animal life at all depths.

Maritime meterology, which has resolved itself into a distinct subject of investigation, and is being conducted in this country under the direction of Mr. Robert H. Scott, F.R.S., and the Meteorological Committee, will be productive of useful and practical service in navigation. International Conferences were organized at Brussels in 1859, when suggestions for a uniform system of meteorological observations at sea were adopted for observance by the navies and mercantile marine of all nations. The patient and laborious collating from the returns and logs of ships made by Admiral Fitzroy have produced those descriptive 'Tract Charts' and Pilot Charts which tend to curtail the length of voyages and avoid disaster; and under Admiral Richards, Hydrographer of the Admiralty in 1868 and 1872, there was published a work containing a set of Charts showing the winds and currents of the oceans on the surface of the globe, which has been highly valued as a work of reference by the navigator. A journal is published by the Meteorological Committee, which elaborately discusses all the materials collected on the subject of ocean meteorology.

We must now direct our attention to the great continent of Africa, where the obstacles to be overcome by the traveller are very different from those enumerated in the Arctic wastes, but are scarcely less terrible to encounter. Again referring to the year 1841, speculations were then rife as to the sources of the Nile, the region of tropical lakes was unexplored, and the whole river-system imperfectly known. In place of desert in the interior high lands with fertility and a climate suited to Europeans has been found. To enter into the marvellous extent of work accomplished by all the distinguished travellers, from the early days of Livingstone to the last feat of Cameron, could not be compressed into this Address.

In 1845 we find Mr. Murchison, in one of his early addresses, observe, "Indeed it would be difficult to instance any part of this world whose streams have given rise to greater diversity of opinion respecting their course; thus, upon the whole, we have a most limited knowledge of Africa, and that little confined almost exclusively to the coast; in the interior we are nearly as ignorant as we ever were." But this ignorance did not last long. Very soon after this time we find Livingstone crossing Africa from Loanda on the Atlantic to Quillimane, near the mouth of the Zambesi, exploring the Lakes of Nyami and the Nyassa, discovering the grand and majestic Victoria Falls, rivalled only by the Niagara. Then come in rapid succession those giants of travel, Burton, Speke, Grant, Baker, and Barth, &c., unveiling to the civilized world the hidden mystery of all historic time, that great equatorial system, Victoria Nyanza, Albert Nyanza, Tanganyika—inland seas and head-waters of the great Nile. In 1849 Barth, Overweg, and Richardson travelled the desert of Sahara to Timbuctu, and navigated the Lake Chadd, studded with its hundred islands. Almost simultaneously we observe that Rebmann, Krapf, and Van der Decken start from Mombaz on the east coast in 4° S., and discover the snow-clad mountains of Kilimanjaro and Kenia, which rise to 22,000 feet high between Victoria Nyanza and the Indian Ocean, and are capped with perpetual snow. Of late years the heart of Africa has been traversed by those highly gifted travellers Nachtigal and Schweinfurth, who have collected such ample information on the ethnology, botany, and natural products of vast interior regions previously unexplored.

Livingstone's last work of enduring toil, after he left England in 1866, was the discovery of the lakes Moero and Banguelo, and following the watercourse of the Lualaba northward to Nyangwé. Previous to his death he had recrossed the Tanganyika to Ujiji, where he was met by the noble traveller Stanley, who had generously gone to succour him; but the worn-out traveller and missionary disdained to leave his work, and returned to the heart of his new discoveries to end his days. Thanks be to Stanley throughout this land for bringing home to us the last tidings of the great African traveller. Upon the death of Livingstone the public feeling of this country to civilize the African and to develop the productions of the country greatly increased. Under Stanley, Gordon, and Cameron, the great achievement has been attained of navigating the three great lakes. To Colonel Gordon is due the honour of placing a steamboat on the Albert Nyanza, completing the work which the gallant Baker, the discoverer of the lake, had so much at heart.

But last of all let us accord our tribute of praise to the young naval officer, Lieutenant Cameron, for his marvellous journey, as being the first European who has ever crossed tropical Africa from the Indian Ocean to the Atlantic, a distance of about 3000 miles, 1200 of which was over new ground never before trodden by white man. The geographical results are highly valuable. He made a survey alone of the southern half of Lake Taganyika, and gave it a true position, fixing its level at 2710 feet above the sea. From its western shore he discovered an outlet, the Lukuga. From Lake Tanganyika he plunged into the heart of Africa, nothing daunted by sickness or danger, and without friend or white companion he followed upon the track of Livingstone to Nyangwé, the last place visited by that great traveller, a town on the Lualaba, which he found to be 1400 feet above the sea, making it 500 feet below Gondokoro, thus setting at rest the idea that the Lualaba was connected with the Nile. From Nyangwé Cameron embarked on the Lualaba, a broad and rapid river flowing westward, in full hope that it would prove to be the Congo; unhappily a hostile chief denied him a passage through his country. Then he directed his steps southward to the capital of Kisongo, whence he discovered that the head-waters of the Lualaba are formed by a system of lakes. After a most adventurous journey under the guidance of an atrocious slave-dealer, who subjected him to many tedious delays and hardships, he reached the shores of the Atlantic near Benguela. On this route he defined the parting water-shed between the basin of the Lualaba and the tributaries of the river Zambesi. Cameron carried on a complete series of hypsometrical measurements across the continent from Bagamoyo to Benguela, a work of great value, showing at a glance a section of south tropical Africa from ocean to ocean. Another naval officer, Mr. E. D. Young, has also earned distinction as a traveller by exploring the Lake Nyassa, which he found to extend 100 miles further north than Dr. Livingstone had imagined. This officer had rendered good service in a former expedition, when he placed a screw launch on the Nyassa, and set at rest the villanous report of Livingstone's murder. Under the light of this brilliant series of explorations, tropical Africa appears to be a system of great inland lakes and rivers, which it may be hoped will end in forming the main trade-routes by which the thickly populated interior will be reached and civilized. The most interesting problem now to solve will be to find the head-waters of the mighty Congo, and connect it with the Atlantic. Schweinfurth, south-west of Khartoum, reached the parting watershed of the Nile-basin tributaries, and discovered the sources of a river trending into Central Africa, named the Ualle. Can it lead to the Shari discharging into lake Chad, or will it prove to be the Ogowé or Ogowai, which discharges into the Atlantic near the Gaboon river? The large measure of success which has attended our recent explorations in Africa is succeeded by a desire to civilize the unhappy people, and free them from the horrors of barbarism and slavery. Missions have been successfully planted on the Nyassa, and the Church Missionary Society have commenced operations to construct a road into the interior from Bagamoyo, and despatched a mission to be established on the Victoria Nyanza.

I would here desire to call the attention of this Section to the international effort initiated last autumn by His Majesty the King of the Belgians at a Congress held in Brussels, attended by Sir Rutherford Alcock and Sir Henry Rawlinson, and many other distinguished British geographers, for the purpose of organizing means for the systematic and continuous exploration of Africa, and with a view to the interest of all civilized nations of the world in such a desirable object. One result of the Congress has been that the Council of the Royal Geographical Society of London have founded an African Exploration Fund, under the patronage of H.R.H. the Prince of Wales, with an Executive Committee. This fund will be appropriated to the scientific examination of Africa, with a view to the exploration of regions yet unknown to civilized nations, and the attainment of accurate information regarding the inhabitants and physical features of the country, in order to consider the best routes for opening up Africa by peaceful means. The Council have prepared a circular, which will be issued amongst you, setting forth the course they intend to take in this great movement, and the mode of raising funds. A very instructive map accompanies this circular, in which the lines of recent exploration are laid down, and in which the unknown regions of the great continent are brought under notice at a glance.

With regard to the continent of Asia, I will not attempt that which would be merely a recapitulation of what has been laid before the world by that learned and distinguished geographer, Sir Henry Rawlinson, and other eminent *savants*, who have so ably summarized all the information from the laborious work so systematically carried on by scientific surveyors under the Russian Government. We have now full descriptions of the physical geography of all the countries under Russian dominion, including hydrographical surveys of the inland seas and lakes in Asia. The same applies also to the labours of the great Trigonometrical Survey of India; we are conversant with the topography of the Himalayas and other mountain-ranges bounding our Indian Empire. It is very satisfactory to find that the Indian Government have restored the Department of Marine Surveying in India; practical operations have already produced beneficial work in correcting old surveys on the coasts of India and Burmah.

Madagascar has hitherto been little noticed by the civilized world, with the exception of a trade supplying our holding of Mauritius with animal food; but with the intercourse now springing up in Eastern Africa, with the spread of colonization northward of Natal, we may expect to see British enterprise seeking a field in this large island. Madagascar has an extent of 818 geographical miles from north to south, and a breadth of 301 miles in its widest part. Since 1870 the interior of this island has been traversed and examined by the labours of Dr. Mullens; and other intelligent missionaries have furnished valuable information regarding the physical geography of the interior and the natives. The able paper of Dr. Mullens on the Central Provinces is well worthy of attention: there is a magnificent country, abounding in the necessaries of life, with a population bordering on 2,000,000, of whom some 300,000 are reported to be under civilized influence and instruction; they are spoken of as a kindly, gentle, and capable race, ruled over by a Queen who is herself a Christian and a devoted friend to the missionaries.

But of all the wonderful changes effected by the mind of man and engineering skill has been the separation of the connecting link between Asia and Africa, under the genius and perseverance of Lesseps, in the construction of the Suez Canal. Egypt has ever been the land of wonders, and this mighty achievement bears comparison with the colossal works of the Pharaohs. The Suez Canal has a length of 99 miles, and was fully opened for traffic in 1869; in the first eight months of last year 1009 vessels passed through the Canal, and the revenue dues amounted to £811,000. The Mediterranean is no longer separated from the Red Sea by a neck of land 72 miles wide, as the geography of our youth taught us.

The late survey of the eastern end of New Guinea is an instance, among many others, of countries lying contiguous to civilization which have never been surveyed until recent date; it is scarcely creditable to a great maritime nation to remain so long ignorant of a coast within 80 miles of her own territories, and in the midst of a region traversed in all directions by her commerce. New Guinea was first discovered in 1526, by Don Jorge de Menezes; it was partially examined by Dampier and Cook, but the most important survey has been made by H.M.S. 'Basilisk,' under Captain Moresby, from the eastern extremity of the island for 278 miles to that part of the coast where D'Entrecasteaux's observations began. Captain Price Blackwood and Owen Stanley gave some valuable information of the country within range of the south portion of the coast which they surveyed. Missionaries and expeditions of a commercial character from Australia have attempted to establish settlements, but without success: the climate is pestilential, the interior impenetrable, and the natives, who are of a degraded and barbarous condition, avoid intercourse with us.

A word on nomenclature. It is much to be regretted that voyagers and travellers do not attempt to attach the native name to a locality wherever it can be obtained, instead of fixing familiar names of our language in profusion over our new surveys.

The rapid progress and development of America, since 1841, arising from the discovery of auriferous deposits, the extension of the United States to the shores of the Pacific, the peopling of California, with its agricultural wealth, have brought so many discoveries from "Nature's mighty workshop" which it is impossible to enter upon now. The colonization of Vancouver's Island has connected more firmly our continuous dominion in the north from the Atlantic to the Pacific. The railway constructed across the Isthmus of Panama, from Colon to Panama, defines a line of demarcation between the two continents; the railway was opened for traffic in 1855, and has been the means of avoiding the horrors of the old voyage round Cape Horn, and brought the Pacific within a few days' voyage from Europe.

The empire of Japan was, in 1841, a land of exclusion: a reversal of ideas has pervaded this intelligent race, who now aspire to emulate Europeans in arts, commerce, and civilization.

Amongst the most instructive works which any traveller has ever produced upon China should be specially cited "The Scientific Researches of the Baron Richthofen"*, the important feature being the large extent of coal-field found by him in the interior, which may be developed at some future day, and effect a wonderful revolution in the habits, commerce, and intercourse of that singular and shrewd race with the whole world.

I cannot conclude without recognizing the marvellous services which the growth of steam navigation has rendered to geographical science. About three years previous to the meeting of the British Association here in 1841, the first great achievement of ocean voyaging by steam was when the 'Great Western,' a ship of 1400 tons, steamed all the way from Bristol to New York in 15 days. In 1850, the screw steamship 'Argo,' of 1850 tons, circumnavigated the globe in 124 days; in 1852, the 'Australian' steamed from Plymouth to Melbourne in 76 days. The levia-

* President of the Geographical Society of Berlin.

than ship, the 'Great Eastern,' of 18,000 tons burthen, was launched on the Thames in 1859; though, as a commercial speculation, she was a failure, yet this wonderful ship was destined, as it would seem, providentially, to complete the great work of laying down submarine telegraph-cables on the bed of the Atlantic, which has brought the Old and New Worlds into instantaneous converse. The enormous carrying powers of this ship, together with its great stability, facilitated most materially the operation of laying out these cables in a direct course. It was about the same year (1841) that Wheatstone had the boldness to state before a Parliamentary Committee his conviction that the Straits of Dover might be crossed by a telegraph wire laid on the bed of the sea. There may be some present here who can remember those early aspirations to the application of steam power and electricity, and who can now reflect on the marvellous progress of these two invisible agents, which have given to man the means of expanding his labour and profits in a threefold degree during his allotted probation here on earth.

Having now briefly reviewed the leading discoveries which have so enlarged our knowledge of this finite planet, chiefly by the enterprise and courage of this nation, and accomplished by men whose names will for ever be enrolled on the banner of fame, we may justly feel proud that the verdict of other nations accords to us pre-eminence in Geographical research. It is satisfactory to perceive that Geography has become a subject of general interest, and, as a science, is daily progressing and taking a more elevated position in the political as well as in the commercial world. With a view to give greater encouragement to the study of Geography in a more strictly scientific direction, the Council of the Royal Geographical Society have provided means for ensuring a certain number of lectures during each session from scientists of the highest order. Let us hope that our efforts on this occasion may tend to increase that spirit for advancing Geographical knowledge which has been so well exemplified in days past by the exploits of Drake, Raleigh, and many other naval worthies from this county; and, quoting from Cicero, I will conclude with these words:—

"I speak of that learning which makes us acquainted with the boundless extent of nature and the universe, and which, even while we remain in this world, discovers to us both heaven, earth, and sea."

On the supposed True Site of Mount Sinai.
By Major-General Sir J. E. Alexander, *C.B.*

On proposed Stations in Central Africa as Bases for future Exploration.
By Commander V. L. Cameron, *R.N.*

After reviewing the remarkable journey of Dr. Livingstone on the Zambesi, and other travels which had opened up the country during the past twenty years, the authorsaid that in this matter the Old and New Worlds might well shake hands, for Stanley's daring journeys were worthy of those of old-world travellers. Much still remained to be done, and a step was taken last year by the King of the Belgians in starting an international association for the exploration of Central and South Africa; but eventually this great association broke up, and it was found better to form an entirely British organization which might work independently, but in friendly relation to other efforts. The committee had selected routes starting from the east coast as a basis of exploration. His opinion was that it would be better to establish a direct line of stations to explore certain districts, not only for the purpose of mapmaking, but for the extension of trade and commerce and the general influences of civilization. In appointing persons to the command of these stations it would be necessary to exercise great care, as they must be invested with magisterial power. At present the natives showed great inclination to gather for protection around any settlement formed by merchants or slave-traders, who granted them immunity from their warlike neighbours in order to obtain necessary supplies. If, instead of the capricious rule of the slave-trader, the judicious rule of a British agent were established, they would soon find thousands of natives settling round, and as their numbers increased, greater care would have to be exercised in dealing with them. It was doubtful whether our Government would give their authority to such a system as this; and, if they should decline to do so, the next best thing would be to establish agencies under the sanction of the Sultan of Zanzibar. In proportion to the work done, the excessive cost of travelling in Central Africa was more apparent than real, whilst the country possessed enormous natural wealth at present almost entirely undeveloped. The india-rubber trade was comparatively new. In the year 1875 the exports were worth £40,000, in 1876 they rose to £100,000, while this year they were estimated at nearly a quarter of a million. The rise in this important trade was entirely due to the enlightened efforts of his Highness Seyyid Burghash in suppressing the slave traffic in his dominions, the capital formerly used in the slave-trade being now employed in this more legitimate commerce. Among the other resources of the country were Indian corn and various other grains, the export of which might form a most important food supply for the population of India. Considering the famines in that country, it behoved us to open up such an important resource—the products of Central Africa being vastly in excess of the native requirements. Apart from this great social question, it seemed that the continent of Africa had been purposely kept until this time in its present condition in order to supply the growing wants of the 19th and 20th centuries. He believed the establishment of one or more great corporations, somewhat on the basis of the Honourable East-India Company, although apparently the day for such great enterprises was past (the spirit of the age was against the granting of exclusive powers to such bodies), would be the most efficacious means of bringing the centre of Africa under the influences of trade and civilization. If from any cause the proposed stations could not be fixed, he would propose the opening up of a certain district, which, having been thoroughly explored, missionaries, traders, &c. would soon occupy, and thus form a basis for further exploration and settlement. All petty jealousies must, however, be put aside, or the *prestige* of the white man would be damaged. If the proposed stations were established they should be utilised as centres for meteorological and other scientific observations. The more rapidly the centre of Africa was opened up the more rapidly would the disgraceful traffic in human flesh and blood be abolished. To the English this should be a work of especial importance. Devon and the West country were justly proud of the veterans and explorers of olden times, the Raleighs, Grenvilles, and others; but it could not be forgotten that there had been one who had sullied the British flag by introducing the slave-trade, and that trade we, as Britons were therefore indirectly responsible for. Thanks were due to the Khedive and the Sultan of Zanzibar, and also to Dr. Kirk, his most able adviser, for the efforts which had been made to put a stop to the traffic in the east of Africa, especially when it was remembered that the Sultan of Zanzibar was acting against a strong opposition on the part of members of his own family and other persons of influence with him. The systematic exploration of Africa was a subject which now interested the whole world; little Belgium, readily responding to her ruler's call, had subscribed £12,000 for sending out an expedition. Portugal had sent out an expedition at a cost of £20,000, and other countries were giving attention to the matter. If we did not take care we should have the fruits of our own efforts taken from us by more enterprising neighbours. In this country, where all the finances of the Government had to be submitted to the House of Commons, we could not expect the Government to act so liberally as those of other nations; but this should stimulate us as individuals to greater efforts to forward the scheme for the exploration of Africa.

On Bashakard in Western Baluchistan. *By* Ernest A. Floyer.

The author made two prolonged journeys into the previously almost unknown interior of this remarkable country, whilst engaged in constructing the line of telegraph to India which runs through Baluchistan from Persia. Although small in area, Bashakard retains all the distinctiveness of a large country. It is so excessively mountainous that no animals except the donkeys of the country can carry loads in it. The paths are intricate and so little used by the sparse population that strangers cannot find them. The access of the natives of the surrounding country is thus, to a certain extent, barred; and there is in the disposition of Bashakardis a mixture of pride and cowardice, added to intense ignorance, which makes them slow to mix with strangers. The author went on to speak of the general grotesqueness and barrenness of the huge crags which compose this district, and which take from the oxides of iron and lead they contain almost every colour of the rainbow. The remains of massive forts and extensive burying-grounds were described; and the Fauna of the country stated to consist chiefly of ibex, mountain sheep, bears, and porcupines. The population was estimated at 2000, about half of whom are slaves. It is, however, many years since any new slave blood has been introduced, and Mr. Floyer was inclined to think that the ancestors of the present slaves did not come from Africa; for, though some of the men are very dark, he nowhere saw thick lips or woolly hair. A wealthy Bashakardi, such as the governor of a province, has about 100 slaves, a few of whom carry arms and remain near his person, while the rest are distributed about in six or seven little mat villages, where they sow maize, wheat, and beans, cultivate date-trees, and tend goats and a few small sheep. On the least rumour of fighting or disturbance of any sort, they retire into some lofty mountain fastness, where they have previously assured themselves of the existence of water. The country is divided into six provinces, which are simply so many clusters or ranges of mountains. These are—Marz to the north, Daroser (with the capital) in the centre, Gavr and Parmint to the east, Pizgh to the south, and Jangdā to the west. These provinces are each under a governor, all of whom till recently submitted to a head chief at Anguhran, the capital. Seif Allah Khan, however, the late ruler, in pursuit of a blood-feud of long standing, shot down on his own threshold four of the leading members of the family of Ghulam Abbas, Governor of Daroser; and this family having obtained help from the Persian Government, which always keeps an eye on such matters, Seif Allah Khan was driven into hiding, though his tribe were so powerful that he could not be dispossessed of his extensive date-groves. After this the Governor of Kirman sent a tax-collector (one sent some years before had been murdered), and, through the medium of the Governor of Pizgh, whom the Persians promised to make head chief, they collected about 200 tomans, being roughly three krans per head, from all the free population who could be induced to pay. The vicinity of Anguhran is almost the only flat space in the country. It is situated at the confluence of two huge torrent-beds, in the fertile silt of which, walled up from the winter freshets, are thousands of very superior date-trees. Here, as elsewhere, the only places available for cultivation are the deposits of silt in the beds of torrents. The climate is almost like that of England, though rather warmer; lime-, orange-, and fig-trees are grown, and willow; a kind of pepper and pomegranate-trees thrive. The peculiarity of the scanty vegetation of the hills themselves is the unusual abundance of powerfully-scented plants. The general elevation of the country is 2000 feet, sloping down to the east and up to the north. The only trade is the occasional export of Sunaiti, a small red wheat, to Minab and dates to Jask, in return for which the inhabitants get salt, beads, coarse powder, and salt fish, and a very little calico. They make and wear a very coarse cotton cloth kilt and rope sandals of bruised palm-leaves; their arms are sword, shield, gun, and dagger. The Bashakard dialect is similar to that of the Makran Baluch, described by Mr. Pierce in the 'Proceedings' of the Bombay branch of the Royal Asiatic Society; but it is more corrupt, and contains many words the derivation of which Mr. Floyer could not ascertain.

On the Lower Course of the Brahmaputra or Tsanpo. *By* Lieut.-Col. H. H. Godwin-Austen.

The author gave his reasons for supposing that the great river Subansiri was the outlet of the Tsanpo. Whilst engaged in the survey operations of 1875–6 in the Dufla Hills, he could not, after looking north into the mountain region from the two highest peaks then visited, avoid being impressed with this idea. From the two peaks of Tornputu, 7300 ft., and Shengarh, 6700 ft., lying on the high outer ranges, the great main valleys on the north were well seen, and could be laid down on the Plane Table with very considerable accuracy, even to very great distances, as all the conspicuous peaks up to the snowy range and several of its summits were intersected upon it. The finest view of this area was obtained from Shengarh, where he was detained for several days by heavy rain. During this interval a party of sappers and his Khasi coolies completely cleared the peak, which was covered to the summit with grand forest growth, so that the view was unimpeded in every direction on the bright clear day that rewarded their labour. Continuous observation revealed the run of the main ranges and ridges and the position of the deep valleys. The valley of the Subansiri was well traced, with its two main branches; one from the north-west, near lat. 28°, long. 93°, had its sources among the high mass of snowy peaks (23,000 ft.), so well seen from the valley of Assam near Tezpur, while another deep depression in the mountains lies just east of long. 94°, and joins the first near lat. 27° 40′. The first of these the author took to be the tributary crossed by the native explorer Nain Singh on his way into Tawang from Lhassa, and the other he believed might be the Tsanpo. Other considerations in support of this view were the following:—1, the temperature of the Lohit or Subansiri where it joins the Brahmaputra is lower than that of any other tributary of that river, this being especially noticeable during the rains, *i.e.* in June and July; 2, Mr. J. O. N. James, Assistant Surveyor-General, says it is borne out by the Revenue Survey Map of the District Sakluinpur, into which the Subansiri enters after leaving the hills; 3, Lieut. Harman, R.E., after seeing the Dihong at its junction with the eastern branch of the Brahmaputra near Sudiya, considers the Subansiri to have the largest body of water; 4, the Pundit Nain Singh could trace the Tsanpo, where he crossed it, for thirty miles east, and thence it flowed south-easterly, which would take it towards the great valley observed by the author; and 5, the hill people, on being questioned by Lieut. Harman, gave evidence which tended to show that the Subansiri and Tsanpo are the same, and that the Dihong is not the Tsanpo, as geographers at present generally believe.

On the River Kingani in East Africa. *By* F. Holmwood, *Assistant Political Resident at Zanzibar.*

This river, which was thoroughly examined by the author in July 1876, disembogues opposite the island of Zanzibar, and was long classed as one of those hopeful-looking rivers which it was trusted might become highways to the interior; but, like the Rovuma, the Wami, and others, it has been found, though not absolutely unnavigable, not to fulfil the expectations excited by the appearance and extent of its waters. The author ascended the stream in the Church Missionary Society's yacht for 120 miles. Its lower course was found to be broad and shallow; its waters in this part inundating the adjoining flat country during the rains, and giving rise to the virulent swamp fever, which desolates the coast region in the neighbourhood of Bagamoyo during the greater part of the year. In ascending the river the average depth for the first 20 miles was found to be 18 feet, shallowing to 12 feet for 10 miles further. Its breadth averages 200 yards up to the first ferry (Kivuko) and 150 yards up to Kingwere ferry. Beyond the latter point hippopotami abound, and the width of the stream contracts to 70 yards, the navigation being also obstructed by snags and sunken trees, which leave only narrow passages, through which the water rushes like a sluice. The banks in the lower part are inhabited by the coast Suahili people; beyond the district of Uzaramo commences, and the country becomes hilly. This continues for several miles, and then a wilder country is reached, where the important tributary, the Lungerengere, joins the main stream. The banks here abound in game, and gnu, waterbuck, buffalo, and rhinoceros are plentiful. The position of the mouth was fixed by Mr. Mackay, a member of the Expedition, by observation, at 7° 0′ 39″ S. lat. and 38° 28′ E. long. The Lungerengere was only 20 feet in breadth and two feet in depth, but it is not so tortuous as the Kingani. A few miles beyond this the main stream proved no longer navigable. It was 25 to 40 yards wide, and about 8 deep in the channel; but the obstructions in the deep water became so numerous that the author decided on returning. Beyond the junction of the Lungerengere the Kingani is called the Mpezi; the natives persisted in declaring it to be a separate river, and could not be made to understand any civilized notions on the subject, a circumstance which shows how untrustworthy must be all African geography founded on the reports of natives. The result of the exploration was the conviction that the Kingani, as a navigable river, is practically useless.

On a Visit to the Mungao District in East Africa in 1876. *By* Dr. J. Kirk, *H.B.M. Political Resident at Zanzibar.*

The Mungao district is the most southerly division of the Sultan of Zanzibar's dominions, and extends along one hundred miles of coast from Kiswere, in S. lat. 9° 25′, to the small stream that forms the limit of the Sultan's territory in the Bay of Tungi, at Cape Delgado. Previous to the survey carried on by Capt. Gray, of H.M.S. Nassau, in 1875, little was known of the different harbours of this part of the coast, and before 1870 the trade of Mungao consisted of a little copal, orchilla-weed, and cowries, but principally of slaves that came from the Nyassa lake. During the prevalence of southerly winds slaves were sent to Zanzibar, Somali-land, and Arabia; when the monsoon changed, Arab vessels transported slaves to the Comoro Islands and Madagascar. So late as December, 1873, Vice-Consul Elton described the condition in which he found the Mungao district as follows:—"Trade is at a stand-still; copal-digging is entirely stopped, the diggers being sold as slaves when on their way to the coast." Since then, Mungao had not been revisited until Dr. Kirk's southerly cruise, and he was much gratified at the improvement witnessed in the social condition of the people as the result of one year's cessation of the slave-trade under decree of the Sultan. He found that throughout the whole district the slave-trade was really at an end. The principal chief who carried on the wars for slaving purposes that depopulated the district so late as 1873 had become settled and industrious, and a commerce had sprung up that in one year had reconciled the people of Mungao to the new state of things, and opened up to them a new source of wealth—one which was wholly incompatible with wars and slave-trade. Last year the export of India-rubber from the Mungao district, under this new state of things, was 1,400,000 lb., which represents approximately £90,000 value. In this new industry the chief Machemba and his people, who before were the scourge of the district, had taken the lead. But there are also many other sources of wealth; for the region is suitable for agriculture, and abounds in copal, cowries, orchilla-weed, ebony-wood, calumba-root, and dye-woods; while inland there is coal of good serviceable quality, and iron in abundance. Wherever Dr. Kirk came in contact with the people, he was glad to find the want of labour generally felt and acknowledged, and to meet with no sign of the slave-trade, the Nyassa caravans now passing by a direct route inland, and not through Mungao, as before. The plans and charts of this coast lately published by the Admiralty showed that it abounds with spacious harbours, some of which are land-locked, with deep approaches, and capable of receiving the whole British fleet. The chief of them are Kiswere, Mehinga, Lindi, Mwania, Mtwara, and Mikindani. Any one of these places would afford a good station as basis for operations under the scheme set on foot by the King of the Belgians; but it would be necessary to ascertain which of them were free from the tsetse-fly, the presence of which would render impossible the use of bullocks for land carriage. Dr. Kirk found the fly dangerously prevalent in several of the best localities. It is not known, however, to exist at Lindi, which on this account could be recommended as the most suitable station and starting-point for the interior.

On the Line of Levels run from the Mediterranean to the Sea of Galilee. By Lieut. KITCHENER, *R.E.*

The levelling was commenced in June, 1875, under the direction of Lieut. Conder, R.C., but was interrupted a few weeks afterwards by an unfortunate disturbance at Safed, which for a time put an end to all survey operations in Palestine. The work was taken up again in March, 1877, under circumstances of some difficulty, and carried to a successful conclusion by Lieut. Kitchener. There had been no opportunity at present of examining the field-books and applying any corrections which might be necessary; but the reporter thought it might be stated that the line of levels, $35\frac{7}{8}$ miles, was run with two instruments, a 10″ spirit-level and a 7″ thedolite, read by independent observers, and that the result gave the Sea of Galilee a depression of 682·544 feet. The line of levels has been marked by 31 bench-marks, cut on the rock or on solid masonry in places where they are not likely to be destroyed by the natives, and the positions of the bench-marks have been fixed and laid down on the 1-inch map of Palestine which is being constructed by a party of Royal Engineers, under the auspices of the Palestine Exploration Fund. The levelling commenced on the shores of the Mediterranean at Haifa, and was carried thence across the Akka plain, past the villages of Jidru, Kefr Etta, and El Mejdel; from the last-mentioned place it was continued up the Wady el Melek, along the southern side of the plain of the Buttauf, and over the ridge to the Wady el Hamam, down which it proceeded, and, passing through a great gorge between cliffs over 1000 feet high, was carried over the plain to its termination at the edge of the sea.

On the German Expedition to Western Siberia. By Dr. O. FINSCH.

The object of the expedition was to explore the isthmus which separates the river Obi, near Obdorsk, from Kara Bay. The expeditionary party consisted of Dr. Finsch, Count Waldburgzeil, and Dr. Brehm. On their outward journey from Moscow they made a long detour southward towards the Altai before descending the Obi, passing through Kasan, Ekaterinburg, and Tjumen to Tobolsk; thence, crossing the Irtish on the ice (in early April), to Omsk, Semipalatinsk, and Lake Zaisan. Turning to the northward they travelled *viâ* Barnaul to Tomsk, and embarked on the Obi, at the latter place, for Samarow, where a *lotka* or decked boat, propelled chiefly by oars, was placed at their disposal for the work of exploration. Nine days on board this craft brought them to Obdorsk, whence they proceeded to ascend the Chuya, a considerable tributary which drains the eastern side of the isthmus, and seemed to hold out promise of a navigable route over a considerable portion of the interval separating the navigable waters of the great river from the Arctic Ocean, at a point accessible by trading ships from Western Europe. The object of the expedition (which was preceded in the same month by a Russian party having the same mission) was to ascend this river as far as practicable, and thence find the nearest and best road, by river as it was hoped, to the sea at Kara Bay. The navigation of the Obi downward from Obdorsk was exciting, owing to the immense waves of the giant river, which so terrified the native crew that they would gladly have returned had they not been bound by contract. The vessel kept close under the right bank, which presented high steep walls of clay or sand, the opposite (left) bank being low and fringed with forest, beyond which rise in picturesque beauty the snow-covered summits of the Ural mountains. Their first halting-place was Knidski-Yursti, a station composed of six Ostiak houses constructed of timber, and the chief residence of the venerable Ostiak prince, Iwan Teiscin. The reindeer herd of the prince had been reduced from 7000 in number to 700 through the rinderpest, which had caused great havoc amongst these valuable animals. Continuing their voyage they reached Kiochat, an important fishing-station; here were seen block-houses, huts built of twigs and turf, pointed tents or wigwams, called *Jums*, constructed of birch-bark, nets spread out to dry, fishing-tackle in great variety, and the varied people engaged in the fishery—Russians, Siranes, Ostiaks, Samoiedes, with their women, children, and dogs,—forming a scene of great animation in the midst of these northern solitudes. The boldness of the sea-gulls amused them greatly, flying about in numbers, and with hoarse screechings trying to rob the fishermen of their booty out of their very nets. From Kiochat they crossed the great Obi, and entered upon the tranquil waters of the small Obi, which at that season formed a perfect labyrinth of channels swollen by inundation, which rendered it difficult to map its course. The channels are bordered on both sides by tall willows. Here, as everywhere on their river voyage, the gnats proved a terrible annoyance, owing to their immense numbers and blood-thirstiness. Fishing-stations were met with on the lesser Obi at tolerably regular intervals of about ten miles. On the 18th of July they arrived at a station near the western mouth of the Chuya, but were unable to obtain any information as to the course of the river from the natives residing there.

They continued their journey down the Obi until they reached, at Yanburri, the eastern mouth of the Chuya. Yanburri is the last fishing-station on the Obi. All these stations are tenanted only in the summer months, from June to the middle of September. None of them are permanent, and the names marked as such on maps are only misleading. Ascending the Chuya they found the banks presenting the character of tundras. At a native village on the river they procured two guides, one an Ostiak, the other a Samoiede, and proceeded onward to the Sort-johan-johort, or bifurcation, where they arrived on the 20th. After four days' further travelling they reached Junshi, a settlement of the Ostiaks, from the head-man of which, who had lived here for four years, they obtained some valuable information regarding the stream. He told them the waters would soon begin to subside, and that their vessel would be unable to proceed on account of the shallows and sandbanks. They had not yet reached the northern limit of the growth of trees; on the contrary, the larch still flourished, and the low flat districts were covered in places with an impenetrable growth of willows and alders. The river itself is excessively tortuous, the bends being very numerous and so abrupt that at the end of a day's journey they were not out of sight of their starting-place of the morning. On the 25th the country became more hilly and the river narrower and shallower, and on the following day they reached the limits of navigation. The further journey was continued by land towards the Podarata. Trees were now no longer met with, and a desolate tundra was entered upon, the surface of which was covered with moss and the small dwarf birch. On the 30th they reached the camp of an Ostiak chief, whose reindeer herd had been reduced from 2000 head to 500 by the terrible rinderpest, which threatens to destroy the whole of the reindeer in Northern Siberia and thus deprive the inhabitants of almost their only means of subsistence. The party saw on the day of their arrival eighty fine animal animals lying dead near the native huts, and thirty more died before the next morning. The chief ceded nine reindeer and three sledges to enable the party to continue their journey over the monotonous tundra, which was here and there varied with pools and bogs, forcing them to make long detours. Animal life was not very varied, the lemming, gulls of two species, the golden plover, and the ptarmigan being the chief species met with. On the 2nd they sighted the waters of Kara Bay, and in the evening arrived on the banks of the Podarata, which flows into the bay. It had been hoped that this river would prove navigable for a considerable distance, so that a portage of moderate length to the Chuya might only be required in the expected trade-route across the isthmus; but it was found to be too shallow a stream for such a purpose. All their efforts to reach the seashore proved ineffectual. From a look-out on an eminence they saw before them a vast swampy plain, reaching to the sea, intersected by rivulets and bounded on the west by the mountains of Sadapai. Only to the east it appeared practicable to reach the bay by a long detour. The Podarata seemed to lose itself in the wilderness of swamps before reaching the bay. Provisions failed, and the natives refused to go any further, and so they resolved to return.

Nor was the Russian Expedition more successful. Returning south, the German party skirted the low, bare, granitic range of Yangana-pei—a spur of the Urals. These elevations, and the hills which traverse the mossy tundras, proved to the party the utter impossibility of the suggested canal across the isthmus. Moreover, the long winter, the soil thawing hardly more than two feet in depth during the summer, and the unnavigability of the two rivers, which swell rapidly, like mountain torrents, after every rainfall, and flow in such tortuous courses, seem to forbid the realization of the scheme. The portage between the Chuya and the Podarata was found to be forty-seven miles—much longer than had been estimated. The party reached Obdorsk on their return on the 19th of August, and finally quitted it *en route* for Europe on the 3rd of September.

On a Journey overland to India in 1872, viâ *Meshed, Herat, Candahar, and the Boulan Pass. By* Capt. H. C. Marsh (*Bengal Cavalry*).

The chief interest of this paper lay in the description which the author gave of the scenery and people of the region he travelled through and the manner in which he was received by the civil and military authorities of Afghanistan, who treated him as a British officer, although travelling in his private capacity. He was well received and kindly entertained at Herat and Candahar, but was refused entry into Cabul on account of his not having the required permission to travel from his own Government, and was compelled to take the lower road into India *viâ* Quetta, Kelat, and the Boulan Pass. It was with great difficulty he was able to find guides to conduct him through the pass, owing to the fear of the robber tribes who infest it; and, having at length engaged one native courageous enough to undertake the task, he completed the journey unmolested, by a hurried march of forty miles without stopping.

Recent Tours in Unfrequented Parts of Greece.
By J. S. P. Phené, *LL.D.*

From Guayaquil to the Napo by the Upper Patassa Route.
By Alfred Simson.

That part of the author's journey lying between the rivers Pastassa and the Napo had never, as far as is known, been before traversed by a European. He began his journey by crossing the Andes by the little-frequented Tachuelo Pass, which lies to the south of the Arenal, the usual route followed in going to Quito and the Napo. The summit of the pass, 14,000 feet above the sea-level, is a small breach in a ridge, or wall, of solid bare rock, access to which is attained by a breakneck path winding over loose porphyry *débris*. The descent on the eastern side is also fearfully rough, the toilsome day's journey terminating at the town of Cajabamba. The road thence passes through Riobamba, and along the ledge of the Chambo valley, and across the torrent of the same to Banos on the Pastassa. This remote village is built at an elevation of 5204 feet above the sea-level, and enjoys a mean annual temperature of $63\frac{1}{2}°$ Fahr. It lies in a cauldron-shaped valley, enclosed by the steepest mountains, the only outlets from which are the narrow gorges of the river. At night one cannot get rid of the depressing sensation of being at the bottom of a well, surrounded by high walls, with the sky only visible overhead. From Baños Mr. Simson started, with sixteen Indian porters, for Santa Inez, by unfrequented paths through dense forests drenched by almost continual rains, where landslips down the mountain-sides often carry away all traces of the solitary track. Below Santa Inez several tributary streams, descending from the Andes, fall into

Pastassa, and present great obstacles to the traveller, being unfordable and liable to sudden rises, when they become wholly impassable torrents of enormous volume. The principal of these is the Topo. This much-dreaded stream forms the chief obstacle to communication between Ecuador and the countries to the eastward. The rise of its waters is sometimes so sudden that small parties of traders, with their train of Indian porters, have been separated whilst crossing it, and sometimes imprisoned between it and the next torrent, running parallel, for two or three weeks without the possibility of effecting an exit either way. It rushes, or rather springs, down its bed at a frightful pace; and as this is filled with unevenly dispersed boulders piled up between high rocky banks, the waters leap up to a great height, filling the air with spray. It was in this condition as Mr. Simson and his party approached it after a wet and stormy day's march. The spray and even the heads of the crests thrown up from the boulders washed over the rude suspension bridge by which the steram is usually crossed. These sudden floods are caused by the sudden melting of the snow in huge rifts on the eastern flanks of the Ecuadorian Andes. The waters fell on this occasion as suddenly as they rose, and the author continued his march down the left bank of the Pastassa until he reached a small village of the Jívaro tribe of Indians, near the little river Pintuc. Here he commenced his westerly march across the country to the banks of the Napo. The path lay through the same continuous forest which clothes the whole of Eastern Ecuador, but the steep mountains had here subsided into lower elevations. A peculiar feature of the country was the constant recurrence of long ridges with narrow summits, called by the Spaniards *cuchillas* (knives). These run generally for ten or fifteen miles, and have an elevation from their base sometimes as great as 500 feet. On one side they are almost perpendicular, and on the other they descend at a sharp angle. They are composed wholly of loose vegetable earth and loam, and are held together by the entangled roots and vegetation with which they are covered. The explanation of these curious ridges, which occur often between parallel rivers, is not far to seek, in a country where the denuding forces of copious precipitation and flooding waters are displayed on so magnificent a scale. They are simply those portions or "cores" of land which have resisted to the present time those denuding agencies that have been for ages at work grinding down the surfaces of the Eastern Andes and spreading the materials over the plains at their feet. The coarser portions of the detritus are spread over the region immediately contiguous, forming the gradually sloping country through which the Nago and Pastassa flow, which has been worn into valleys, hills, and *cuchillas*; and the finer silt has been carried by the streams down to the Amazons and thence to the Atlantic. The route followed by Mr. Simson crossed the Bobonaza to the little settlement of Canelos, and thence to Curaŕai. The last-mentioned stream, scarcely known to geographers, has its sources on the outermost slopes of Llanganati, and after receiving the waters of the Villano, Nushinu, Supinu, Nugânu, Pundinu, and others, empties itself into the Napo on the right bank. The party reached the Napo, opposite Aguano, after eighteen days actual walking from Baños. The Napo at Aguano was found to be a noble river, broader than the Thames at London Bridge, even when not flooded. At this point the distance is 3100 miles from the ocean, and no obstacle to navigation exists the whole way.

On the Ascent of the River Putumayo, South America. *By* Alfred Simson.

On his journey down the Amazons from the Napo, Mr. Simson seized an opportunity which offered to take the command of a small steamer lent by the Brazilian Government for the purpose of pioneering the way up the little-known river Putumayo, an affluent of the Upper Amazons on the left bank. The Expedition originated with some energetic merchants of Popayan, in New Granada, who had entered into an agreement with the Brazilian Government with the object of opening up this stream to steam navigation and trade, in the conviction that it could be made an easy outlet for the products of the rich province of Pasto in New Granada surrounding its headwaters. One of these enterprising men had previously descended the river in a canoe, and being struck with its adaptability to steam navigation, had purchased a small steamer for the purpose of regular trade communication. The Brazilian Government cooperated by lending a steam-launch which was to precede the steamer, survey the navigable channels of the river, and form depots of firewood at regular intervals for the use of the vessel that was to follow. Mr. Simson's adventurous voyage was completely successful. He ascended the river to a point 1200 miles from its mouth, and found it free from serious obstacles. Its course, however, is extremely tortuous, and the lower parts subject to malarious fever. Throughout the whole distance it flows through an alluvial region clothed with dense forest, at present entirely unexplored. The Putumayo joins the Amazons at a point distant 1700 miles from the ocean; and as lines of large steamers have been for many years established on the main stream, the establishment of steam-navigation on the Putumayo will now enable any one desirous of making the voyage to ascend from the Atlantic by steam to the foot of the Andes of New Granada.

An Account of the Latest Expedition across Central Australia. *By* W. H. Tietkens.

In this paper the author gives a detailed account of an exploring expedition fitted out by the Hon. Thomas Elder, of South Australia, and headed by Mr. Ernest Giles, Mr. Tietkens being second in command, the object of which was to cross the continent from the settlements of South Australia to those of Western Australia. This object it carried out after seven months of laborious march. The success of the expedition was rendered possible only by the use of camels instead of horses, the scarcity of water, that bane of Australian explorers, and the extreme hardships of a march through dense scrub being more than the horse can endure.

The expedition, consisting of the above-named officers, including Mr. Young, four men, and eighteen camels with their drivers, started in July 1875 from Youldeh (S. lat. 34° 10′ and E. long. 131° 46′), and after camping at Ooldabinna (S. lat. 39° 7′ 4″ and E. long. 131° 15′ 4″), and at a native dam a few days journey to the westward of that place, marched for sixteen days, a distance of 323 miles, without finding any water. At this perilous moment, when retreat was impossible and advance almost certain destruction, even the camels being much distressed, Mr. Tietkens most fortunately discovered a spring which was named by Mr. Giles the Victoria Spring; its position is in S. lat. 30° 25′ 30″, E. long. 123° 31′ 13″. About ninety miles to the east of this valuable spring the expedition had traversed a tract of land which Mr. Tietkens considers the only district on the whole line of exploration which would be fitted for settlement. An undulating limestone country, well grassed, with occasional clumps of Myall (*Acacia pendula*), and within easy distance of the seaboard, renders it especially adapted to the staple industry of the country, that of wool-growing. The experience of this latest expedition confirms that of previous explorers with regard to the arid and waterless aspect of the interior of Australia and its absolute unfitness for permanent settlement. The discovery of this fertile, though apparently waterless, district must therefore be regarded as a great gain.

After a march of eight days through the ever-present scrub, from the Victoria Spring, the expedition came upon a native well called Ularring (S. lat. 29° 25′, E. long. 120° 31′ 4″), and were here attacked by a large party of natives, narrowly escaping, by prompt action only, the loss of several men, including Mr. Giles. The possession by some of these natives of articles used in civilized life showed the expedition that they were at last nearing the settlements. The soil in the vicinity of Ularring being excellent they planted several seeds of Giant Bamboo, Tasmanian Blue Gum, and various acacias. These were presented by Baron Ferd. von Mueller, a distinguished explorer and botanist.

After a rest of four days at the well, the explorers again plunged into the distressing scrub, which continued without intermission (a distance of 153 miles) until they reached Mount Churchman; this being a point on the borders of civilization, they felt that their hardships were nearly over. They soon after reached a station belonging to a Mr. Clunes, whose shepherd hospitably received and entertained them. Thence to Perth the progress of the expedition was a triumphal procession.

The results of the observations made during the journey may be shortly summed up as follows:—

The main geological feature of the country was red granite; early in the journey limestone was crossed, and once to the south of the route a quartz matrix was hit upon.

The phytology was most interesting, and many specimens were collected by Mr. Young. The vegetation consisted chiefly of *Eucalyptus, Casuarina, Callistris,* and various kinds of acacia. The variation of the thermometer during the journey, which began in June and ended in November, was very considerable. On several occasions it was as low as freezing-point before sunrise, though during the day in October and November (the Australian spring) it rose to 98° in the shade. In E. long. 118° 30′ and S. lat. 29° 53′, on the 26th of October, dew was first noticed, and continued to fall throughout the remaining distance to the settlements.

ECONOMIC SCIENCE AND STATISTICS.

Address by The Right Hon. the Earl Fortescue, *President of the Section.*

It is with great diffidence that I present myself before you as Chairman of this Section. This is the first occasion on which I have accepted any post of any thing like this kind since, more than 20 years ago, in the course of personal sanitary investigations to collect materials for my resolutions in the House of Commons about the health of the army, I contracted a disease which destroyed one eye, permanently injured the other, and rendered me for years an invalid unable to winter in England. Nor should I have been induced now to accept this honourable post were it not that the British Association this year is holding its meeting, not merely within my own county of Devon, but also in a town which has the strongest claims upon my gratitude. For it was Plymouth that first gave me a seat in Parliament, and continued to return me triumphantly as long as I desired to represent it. Great, indeed, is the increase in extent and the improvement in appearance of the three towns since those days. I hope and believe that their moral and sanitary improvements have been equally great, though not, of course, as apparent to the mere visitor's eye. It was in Plymouth, too, that, about 32 years ago, I read in the Mechanics' Institute a lecture on the Health of Towns, the first paper I had ever prepared for publication; and it was in the preparation of that lecture that I first became fully sensible of the inadequacy of benevolence alone, without some knowledge of political economy, to produce really beneficent results, and that I first practically learnt the great value of Statistics, and their indispensable necessity as the surest tests of past and safest guides to future action and legislation. My distinguished predecessor in this chair last year said (and having myself, as a member of the Council of the Statistical Society, received an intimation to the same effect, I will adopt his words):—"I understand it to be the object of the Association that in the treatment of the subjects presented to us we should study, in this as in other departments, to follow as far as may be a strictly scientific method of inquiry, not lapsing into the discussion of political details, but attempting to ascertain the principles on which economic results are founded, and to define the main lines of economic truth. It may not always be possible to draw the boundary between science and practice; but I am sure that we shall all try as much as possible to avoid matters which involve party or personal questions, and to maintain a calm and scientific attitude in our treatment of the many subjects which come within the range of this Section."

Sir G. Campbell speaks of "the range of this Section." But I must observe that the further man advances in scientific research the more apparent becomes what, to use a word borrowed from the French, may be called the general solidarity of science, and the consequently ever-increasing difficulty of drawing hard and fast lines between its different departments.

For instance, Chemistry has of late thrown great and unexpected light upon Astronomy, after having been extensively brought to bear upon the investigations carried on respecting the nutrition of animal and vegetable life and the causes and effects of disease in both; while the animal and vegetable kingdoms have been discovered to approach each other so closely in their lower forms that their exact boundaries can hardly be determined.

And so I may be allowed to remark, even with regard to this Section, whose double title faithfully represents the inseparable connexion between Economic Science and Statistics, that it has more connexion in several ways with some of the other scientific departments of the Association than might in the first instance be supposed. For example, facilities and cost of transit to persons, goods, and information have a very practical bearing on scientific investigation generally, and especially on investigations carried on in concert by a number of different persons in different places, which it is one great object of this Association to promote; and therefore this Association collectively and departmentally has an appreciable interest in the productiveness, as to direct pecuniary returns, of means of transit, and in the question whether profit or public convenience ought to be made the chief object in the regulation of railways, roads, canals, postal arrangements, and electric telegraphs. And so, further, this Association is interested in the economic laws governing the service for extending, improving, and working these means of transport; and further yet I must add, after what happened last month in the United States, it is interested in the liability of that service to disturbance by the action of the servants employed in it, when misguided by the delusion that because they can affect the cost of production they can control also the demand for what is supplied, and therefore its marketable value.

But to return to the connexion between Economic Science and Statistics. The mere numerical record or collection of bare facts not marshalled on any system remains an unfruitful heap until the facts reduced to order can be brought to bear upon the elucidation of some general principle. I was therefore rejoiced when the London Statistical Society, to which I have had the honour of belonging more than thirty years, recognized this truth, and from its device of a sheaf with "Aliis exterendum" under it, omitted the words implying the Society's repudiation of the duty of thrashing out the corn and winnowing away the chaff. Notwithstanding its modest disavowal, however, I venture to confidently assert that from the very beginning the records of that Society show a vast amount of pure and valuable grain—not merely collected, but well threshed and winnowed out by its members, and stored away in the condition most available for use.

My predecessor well observes, in language better than I should have been able to find for myself, "At first sight Statistics expressed in figures might seem to constitute the most exact of sciences; but in practice it is far otherwise. In nothing is so great caution necessary; there is too great temptation to reduce to figures facts which are themselves not sufficiently ascertained; too often an exactness is claimed for these figured results which is altogether fallacious and misleading......It is especially necessary to distinguish between figures which are really ascertained, and those which are merely drawn by deductions from rough and conjectural facts......There is very often fear that Statistics are sought out and adapted to suit a preconceived theory. Another misuse of Statistics is this, that when they are used to test certain capacities and qualifications work is directed and shaped to meet the statistical test, and the results thus obtained become misleading. In such a case it is necessary very frequently to change the form in which the statistical test is applied."

But if, on the one hand, the mere record of bare acts till systematized remains practically useless, and if imperfect or misapplied statistics are misleading, so, on the other hand, principles deduced from purely abstract reasoning upon economical questions (which, unlike pure mathematics, deal with many and varied elements) always require in their application to be constantly tested and retested by statistics; for the truths on which they are based are often far from the only truths having a real bearing on the particular questions.

As Sir George Campbell further justly observes:—"It is by collecting, verifying, and classifying facts that we are able to approach economic truth. There was a time when it seems to have been supposed that political economy was a science regulated by natural laws so fixed that safe results could be attained by deductive reasoning. But since it has become apparent that men do not in fact invariably follow the laws of money-making pure and simple, that economic action is affected by moral causes which cannot be exactly measured, it becomes more and more evident that we cannot safely trust to a chain of deduction; we must test every step by an accurate observation of facts, and induction from them. This is, it seems to me, the highest function of statistical science. We recognize that men are not mere machines whose course may be set and whose progress may be calculated by a simple formula. Men are complicated beings, whose minds and motives of action we do not yet thoroughly understand; we cannot foretell what they will do till we are sure that we know what in fact they actually have done and do in a great variety of circumstances." And therefore deeper reflection and fuller inquiry have often revealed other truths, which in many instances have largely modified and, in some, even to a certain extent reversed the conclusions practically to be deduced in the particular case.

I will take one striking example of the subsequent large modification, not to say reversal, of the earlier views of political economists, owing to the deeper reflection and especially the wider information brought to bear upon the question by, in the first, one single eminent authority among them.

Malthus, in his famous work on Population, lays it down as a law that while population naturally increases in a geometrical, subsistence increases in an arithmetical progression only. He was followed in this view by a great majority of the political economists of his day. And Mr. J. S. Mill, in the last edition which I have seen (that of 1862) of his 'Principles of Political Economy,' says, "Having a large family, so far as concerns the public interest, is a thing rather to be discouraged than promoted;" and again, "That the producing of large families ought to be regarded with the same feeling as drunkenness or any other physical excess." Such writings led men to believe that wars and pestilences were sharp but salutary remedies for the great evil to be feared, namely, over-population, and were the sad but indispensable supplements to the inadequate operation of what Malthus and his school called the preventive checks of prudence and morality. We have, indeed, recently had, professedly based on Malthus's doctrines, to which public attention has been recalled, a preventive check of immorality propounded. But on that I need say no more now than that, however plausible it may sound, it would be sure in the long run to weaken the national strength and impair the national well-being, by lowering the national standard of duty and degrading the national character. History shows how true it is that "righteousness exalteth a nation, while sin is a reproach to any people."

But to return to the warnings of Malthus and his school against the danger of over-population. They founded their views almost entirely on deductive reasoning without appealing to any adequate amount of actual experience, and therefore failed to take into account what, in most cases, practically modifies, and even neutralizes, the action of the principles which they set forth.

Mr. Chadwick demonstrated, in several of his early writings, and especially in that most remarkable work the 'Sanitary Report of 1842,' that excessive sickness, with premature disability and mortality in a population, did not (except, of course, in very extreme cases) tend in general to diminish the aggregate number, but only the average efficiency, of the living, and the average productiveness of their labour. He showed, with the aid of the comparatively very imperfect statistics then available, that in the unhealthiest districts of the country the proportion of persons incapable of maintaining themselves,—of children, of invalids, of the aged (for some of the most remarkable instances of individual longevity are to be found in them),—was far larger than in the healthy districts. He showed, comparing the healthiest with the average districts, that the cost of excessive sickness and premature disability and death, including the consequent loss of productive labour, involved throughout the kingdom an annual loss of over £14,000,000, even according to that defective standard—a loss, I may observe, which has gone on uninterruptedly to the present day; for, notwithstanding all our wise sanitary legislation and great expenditure on sanitary works, our annual percentage of excessive mortality throughout the kingdom resulting from preventible disease has hardly been appreciably diminished, so largely has population increased during that time in places and under circumstances where no commensurate sanitary precautions had been adopted. Indeed London has not had its rate of mortality diminished under the costly mismanagement of the Metropolitan Board of Works.

Mr. Chadwick, followed and aided by an ever-increasing proportion of economists, has thus more than modified—he has to a great extent reversed—the practical conclusions to be drawn on the report of excessive sickness and mortality, and has demonstrated the concurrence of the demands of economical prudence with those of Christian duty on this important subject. But, further, he contended that in an energetic and skilful population, freely allowed to obtain what they could get more advantageously from other countries for what they could produce more cheaply at home, the tendency of the demand for labour would be absolutely to outstrip the ordinary growth of population. He predicted years before it occurred that very scarcity of labourers in England, compared with the demand for them, which made itself so much felt a few years ago in every branch of industry (except perhaps the work of clerks among men, and governesses among women), and which, though less pressing quite latterly, owing to the recent almost universal depression of trade throughout the world, still presents a marked contrast to earlier times, and keeps wages at a point, if slightly lowered of late in some branches, yet in all immensely higher than the old standard.

Dr. Farr, in his truly philosophical supplement to the 35th report to the Registrar General in 1875, shows that as the death-rate rises so does the birth-rate, that the christenings for London from 1651 to 1660 were 64,000, while from 1661 to 1670 (including the great plague) they were 106,000 in round numbers. He shows that within certain limits this continues. But when these are passed and the death-rate becomes excessive, as 32·5 per thousand in Manchester and 38·6 in Liverpool, then the birth-rate recedes to 37·3 per thousand in Manchester and 37·6 in Liverpool, so that but for immigration Liverpool would gradually be depopulated.

It is curious that while the average number of living children in France is under 3, and in some communes even under $2\frac{1}{4}$, per family, it was about $4\frac{1}{2}$ in her two German provinces, Alsace and Lorraine. That distinguished economical writer, the late M. Wolowski, mentioned to Mr. Chadwick the superior efficiency and value of Alsatian labour as compared with French labour generally. It would almost seem as if a large family, requiring acquisition of means to supply the increased demands consequent upon it, acted as a stimulus to increased exertion; while a small family, requiring only conservatism to supply an unaltered demand, permitted more stagnation. The larger families seem to have been chiefly found among those who worked for wages, the smaller ones among the small landowners—the latter being less adventurous and energetic, but decidedly the more self-denying and saving. The consequence of this state of things in France is certainly remarkable. The population has remained for some time nearly stationary. Indeed, particularly in years of war, as in 1854–1855, it has actually declined a little, while it decreased in the two years 1870–71 together about half a million, independently of the loss of Alsace and Lorraine. Still, since the commencement of the century, it has decidedly increased, though more and more slowly. The number of births per marriage, which at that time was 3·19, had gradually fallen to 2·66 in 1868. Dr. Cros, in a paper in the 'Hygiène Publique,' on the "Depopulation of France," remarks that even the actual small surplus of births over deaths is entirely owing to the illegitimate births, as by the age of 20 only 1·92 per marriage would be living of those born in wedlock, *i. e.* less than the number required to replace the two parents. He mentions that eminent statist, M. Legoyt, and a number of other French writers, as having from time to time for some years called attention to the diminishing tendency to increase in the French population; and, while making various suggestions of more than questionable soundness to check what he, unlike Malthus and Mill, describes as the greatest national misfortune, speaks quite despondingly of the relatively retrogade position of France in the world, as compared with the Anglo-Saxon race increasing at the rate of a million a year. The pressure of population in France has never been such as to lead to any great amount of emigration, though there was some which prospered fairly in the old Bourbon times. In Algeria, the last conquest of that dynasty, and now the only considerable Colonial possession held by France—for it may be doubted whether Cochin China has not too recently been acquired, and whether its occupation is not still too largely military, fairly yet to count as a colony—in Algeria the few colonists have not generally prospered much, or spread far beyond the towns; indeed the majority of them are not French, but Maltese and other foreigners. And whereas in the days of the great Lord Chatham her colonies in North America, with Canada on one side and Louisiana on the other, were more extensive than ours—whereas, besides having several islands in the West Indies, she balanced us in the East Indies, and in France herself she had more than double the population that we had in the British Isles,—in less than a century she had been practically swept out of the East Indies, and had lost most of her islands in the West Indies. Only a few French settlers remained in America, and those all under Anglo-Saxon dominion, those in Louisiana being subjects of the United States, those in Canada of England. For we had conquered Canada and extended our dominion to the Pacific Ocean, though we had by our folly lost the United States; we had taken the Cape from the Dutch, and pushed our settlements far into South Africa; we had increased largely by conquest our possessions in the West Indies; almost the whole of Hindostan had been gradually either incorporated in our dominions, or practically accepted our supremacy; and last, not least, we had colonized the Australian continent and New Zealand, both of which were yearly increasing prodigiously in wealth and population. And yet, notwithstanding the large emigration from the British Isles to the United States as well as to our own colonies, the number of inhabitants in them had nearly tripled, from about 10,000,000 in 1760, to more than 29,000,000 in 1861, though in France they had only increased from nearly 22,000,000 to rather more than 37,000,000 during the same interval. Indeed ours have now increased to more than 32,000,000, which is only about 4,000,000 less than those of France since she has lost Alsace and Lorraine.

To show the complete reversal, among political economists in general, of the once almost universally received doctrine as to subsistence and population, I must quote, abridging it slightly, another passage from the same supplement by Dr. Farr which I cited before:—

"In the earlier years, though not recorded, the produce in America increased undoubtedly as nearly in geometrical progression as the population counted at each census; and if the early censuses prove that population increases, the recent censuses prove that subsistence increases in geometrical progression........There is a limit to the increase of both people and produce; but the tendency now is, as men endowed with skill, weapons, tools, and marvellous machines are diffused over the world, to create subsistence faster than population........Malthus lays it down that (1) 'population cannot increase without the means of subsistence;' that (2) 'population does invariably increase where there are means of subsistence;' and that (3), as stated in his last edition, 'the checks which repress the superior power of population, and keep its effects on a level with the means of subsistence, are all resolvable into moral restraint, vice, and misery.'........The theory is as misleading in practice as it is defective in statement, and, as expressed, erroneous in fact. It assumes that the restraint of population is the corner-stone of policy. Had this principle been accepted by the people, the population of the kingdom, instead of amounting to thirty-two millions, would have remained, as it was at the beginning of the century, sixteen millions. England, in the presence of the great continental states, would have been now a second-rate power; her dependencies must have been lost; her colonies have remained unpeopled; her industry crippled for want of hands; her commerce limited for want of ships."

In truth I know of no book on political economy, certainly in English, thoroughly to be relied on as a guide; but, then, my power of reading has been for years so impaired that I find myself more and more left behind in this and other subjects which I used to study. I have always thought that the valuable works of the late Mr. Mill owed more of their influence to his marvellous clearness of conception, and still more of expression, to the delightful simplicity and unaffected grace as well as lucidity of his style, than to the soundness of his views on several points of political economy. I have already mentioned the increasing dissent from his views on the question of over-population. His chapters on Value have been objected to by some eminent economists, his opinions on freehold cottier farmers (among whom he erroneously classes Norwegian peasants owning 30 acres of land and upwards, with eight or ten cows) are protested against by others, and his views about unearned increments by still more. He touched very slightly on the important question to which I, a little while ago, adverted in relation to means of transit—the question, I mean, of what services or supplies are in their nature monopolies, and on what principles ought such to be dealt with by the State. His early edition before 1844, I remember, gave a decidedly defective answer to the first question; and I have not found, though that may be because it has escaped my observation, any more satisfactory answer to it in the last edition I have seen, that of 1862. If I remember rightly, he, in the early one, ascribed the character of a monopoly requiring State interference to the extreme costliness of the fixed capital or plant required for providing that particular source of supply for the public; but ignored the other more essential element requisite to the character of a natural and practically inevitable monopoly of that kind, namely, that of the local, as distinguished from the general, value of the particular service or supply rendered.

The largest copper- or iron-mine in the world, if it had a million of fixed capital or plant invested in it, would not have, and ought not to be dealt with as having, a monopoly, because the article supplied has a general value in the market of the world. On the other hand, the gas- or waterworks of the smallest town or village, with a plant of less than £1000, would have, and ought to be treated as having, a monopoly, because the whole value of the water and the greater part of that of the gas supplied depends upon its position, and the greater part of the cost of supplying either consists of the interest on the capital invested in the fixed and permanent works. The water, which is to be had for nothing but the trouble of dipping for it in the brook below, derives its whole value from the convenience of its position in the waterpipe, which brings it into the house from the reservoir or forcing-pump. The value of the service of a coach or omnibus depends equally on its localization; it, like a railway, takes people who want to go from some particular place to some other. But then the cost of its service consists chiefly in circulating or easily transferable capital in the shape of the vehicle, horses, and harness, equally available at a slight expense to render similar service elsewhere; whereas the materials of the reservoirs and the pumping-engines and pipes in the case of waterworks—and, may I not add, its local act, till lately one of the most costly items—would only, if transferable elsewhere at all, be so at an expense very heavy in proportion to the concern.

About these local services and supplies, I know not how to put the argument more tersely than I did in my address in this town in 1845:—

"In cases where, for the supply of a limited demand, the fixed capital invested bears a very large proportion to what is called reproductive or circulating capital, no effectual competition can take place. Unless the exorbitant charges provoke, or the exorbitant profits tempt, some other party to contend with the original one for the occupation of the whole or a part of a field not large enough for two, the monopoly is complete, limited only by the willingness of the public to consume at the rate charged, and by the dread of the establishment of a rival party. As the probability of this latter occurrence varies, so will the prices; they will fall when the danger is imminent, and be slowly raised as it subsides. If another capital is invested, for a time competition is sharp; but before long the two parties find it their interest to coalesce and to charge the public for a supply produced by the application of two fixed capitals where one would have sufficed for the work, as high a price, on the same principle and subject to the same limitations only, as those hwich affected the returns upon the original capital."

Sir Robert Peel used to speak of the "torpid hand of Government," and deprecated the State or public bodies doing what trading companies could do instead. I well remember, not long after his passing his comparatively free-trade tariff, when we thought he was meditating, though not yet determined on, the Repeal of the Corn Laws, how, speaking one day on some gas or water bill and therefore not reported by the papers or Hansard, he described what, in his opinion, was a proper remedy for a bad, inadequate, or unduly dear supply—namely, to establish another company to compete with the one complained of. And I well remember how, with most unwonted audacity (for at no time of my life have I but with extreme reluctance, and never, I may add, with any success, attempted a speech in Parliament), I on that occasion jumped up and said that when he had studied the question of Free Trade a little more he would find it was perfectly applicable to foreign corn and sugar to which he refused to apply it, but not without stringent restrictions to water, gas, and railways, to which he was then applying it—that, unlike the former, the latter were all in their nature monopolies, and ought, for the sake of the public, to be very carefully restricted as such *. He ended by applying Free Trade to foreign corn and provisions, but protesting against its application to foreign, as distinguished from colonial, sugar, and persisting to the last in his unsound and disastrous encouragement of unrestricted competition in railways. His various successors in the Government have ever since left each proposed line of railway to be unsystematically dealt with in the most costly manner each on its own merits, by successive separate committees of both Houses, not only selected at haphazard, but without being furnished for their guidance with any clear principles laid down by Parliament, not even as to whether the fact of a proposed line being a competing line should be considered a recommendation or an objection. The natural result of such a continued lottery in legislation has been an immense needless increase to the cost of railways in the shape of parliamentary expenses both in proposing and opposing lines—expenses which have unfairly kept down the average dividends to share-

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* Memorandum sent me by an eminent economist and statistician:—

"In 1824 a matured plan of a general public system of railway communication was brought before Sir R. Peel by Mr. Thomas Gray of Exeter. The plan was based, not upon any mere imagination as to mechanical power, but upon tried and ascertained instances of what had been done and was then doing by steam-power in railway transit on iron tramways in mines and collieries; and it proposed the general application of these means, rudimentary it was true, but improvable on more matured trial, as was afterwards abundantly proved. Now any one who had a perception of the primary economical importance of cheap and quick transit to a nation, especially to a manufacturing nation, would have regarded the proposal with lively interest. But he dismissed it with apathy. Gray pressed it then upon the commercial community of Lancashire, by whom it was taken up, with what ultimate results we know; but they took it up solely at first for the transit of their goods, and not for the transit of passengers mainly as Gray proposed, and which proved afterwards its great success.

"After the great demonstrations afforded by subsequent experience of the gain in economical power to a nation of this new means of communication, and of what should have been the new 'King's Highway,' or public means of transit at the lowest cost, the cost of the service instead of a trading profit (in which view it was successfully taken up in Belgium and in other parts of the Continent), he still was apathetic, and left it to be pursued by private enterprise—an error recognized as lamentable in its consequences by Robert Stephenson and railway authorities themselves, as well as by leading political economists. The consequences of that economical error are recognized as now burthening the freedom of transit in this kingdom with some six or seven millions of extra cost, with reduced dividends to the capitalists, with reduced speeds, and, from misfitting trains, increased dangers of life in transit, and all the gross evils of disunity of our communications amongst upwards of a hundred Directorates. Bismark in Germany, and Minghetti and other statesmen in Italy, are now retracing the errors of our example, and resuming those public duties which only economical ignorance abandoned or neglected."

holders, and will for all time necessitate the imposition of otherwise needlessly high fares and rates on passengers and goods in this country.

Now the rates on goods traffic especially involve—and this must be my apology for dwelling so long on the subject—a very serious question of national importance, once put in a striking aspect by my enlightened, truly noble, and much-lamented friend, Lord Taunton, who I always thought would have been more adequately appreciated by the public, if even in his time, as compared with Lord Althorp's, the ever-increasing influence of mere oratory, irrespective of political knowledge, statesman-like foresight, and calm judgment (in a word, of wisdom as distinguished from cleverness), had not already begun to obtain an undue ascendency in this country. While still Mr. Labouchere, he carefully pointed out to the House of Commons that, after we had wisely abolished the customs duties on all exports whatever, and on all imports of raw material, in order to give our manufacturers fair play in their severe competition with foreign rivals, it was essential to protect them from being burdened with unduly heavy import and export duties in the shape of high rates on goods traffic by railway—taxes none the less onerous because they went into the pockets of railway shareholders instead of into the Treasury in relief of general taxation. In fact the influence of high railway rates on commerce is considerable. In Belgium, the Government owns and works the railways, and, trusting to their indirectly raising the revenue by increasing the national prosperity, does not seek to make them a source of direct profit. The consequence is, I am assured, that an increasing amount of through traffic is being diverted through Belgium and its ports, the natural course of which would have lain through France but for her high goods rates.

The sound view with regard to these questions of local public service and supply would seem to be that long ago indicated by Mr. Chadwick—namely, that they should be recognized as, in their nature, monopolies, but, as such, considered to be the property of the public to be alienated in part for a time, or retained in their own hands by the State or local authorities as may seem most for the public advantage. That this view is gaining more and more acceptance is evident from the number of municipalities which have already either set up for themselves or have bought from their original proprietors the waterworks and the gasworks of their towns, and are working them for the benefit of the inhabitants. Some have already done this with one or both for many years; many more are taking steps to do so; and the Metropolitan Board of Works, who have long only too well verified, by their mismanagement of much of the business entrusted to them, my predictions during the debates on the Bill for their establishment in 1855, have now for some time been wisely contemplating buying up both the water- and gasworks of the Metropolis, and consolidating under one management what now occupies the staffs of a number of companies. The very able report just presented to the House of Commons by the Committee under the efficient Chairmanship of Sir Selwin Ibbetson, after taking evidence for two Sessions on the subject of the fire brigade of the Metropolis, gives, in my opinion, conclusive reasons in favour of its various recommendations—the most material of them being that the Metropolitan Board of Works should purchase all the waterworks within its district, establish a constant supply at high pressure, and place hydrants all over London, putting the duty of extinguishing fires in the hands of the police, with a special superintendent and a special staff to attend particularly to this new branch of police work. Further reflection and inquiry (and I may add, especially, the warning afforded by the working of the Metropolitan Board of Works) have confirmed me in the impression which I expressed in these terms in this town in 1845:—"On the whole, it seems to me that the necessary works for similar purposes are best constructed by individuals or companies—for the action of self-interest will induce them to do it better and more watchfully—with a monopoly granted to them for a certain time on certain terms; after which the works themselves should revert to the town, or become purchasable by the town for a certain amount: that afterwards they should either be managed by the corporation, or, better still, be let by public auction by the corporation to parties, either with certain fixed conditions attached to them at an annual rent to be decided by competition, or else be let at a fixed rent to whatever party will undertake to guarantee the cheapest and best supply to the town. These systems seem to me to combine to the greatest degree practicable the energy and economy observable in undertakings carried on by interested parties as compared with public bodies, with due security from the unreasonable charges or ruinous and wasteful competition of companies or individuals undertaking for profit works which are too important to the public, and at the same time too much monopolies in their nature, to be advantageously entrusted unreservedly and for ever to interested parties."

When these or other public works of some analogous kind (as gas, docks, piers) thus become the property of the municipality, the expenses become a local charge upon the inhabitants—either wholly borne by those who personally use the supplies or accommodation thus afforded, leaving only so much as may be used for purely public purposes, as, *e.g.*, the gas for street lamps, to be paid out of the rates; or else chiefly borne by the public, when the payments for what is used by private individuals are regularly supplemented out of the rates, the rates being the security on which the requisite capital had to be raised.

And this brings me to a subject on which I intend troubling you with a few words, because it is very important, very pressing, and can no longer be considered to partake at all of a party character; for the idea of a more consolidated management of local public business in our towns, and still more in our country districts, under the long-established Municipal Corporations in the former, and under new County Boards of a more or less representative character in the latter, has now been for some years advocated as warmly by Conservatives as by Liberals. And the same happy absence of party character applies to another proposal, not so long prominently brought forward, of making the Union the unit of English administration after such an adjustment of boundaries that it should never trangress those of the county. I rejoice much that this should be so; for sure I am that to deal at all satisfactorily with the complicated question of local government in England, with its rapidly increasing cost, with its chaotic multitude of administrative bodies, all with their intermixed administrative areas and separate officials, will require all the combined efforts of the most high-minded and enlightened of both political parties.

In the remarks I am now about to offer, I shall rely mainly on the admirable paper read before the Statistical Society by Captain Craigie, the fruit of much research and ability, both in the collection and arrangement of facts and in the conclusions founded upon them. I must draw upon his admirably arranged tables (most of them laboriously prepared by the collation of several returns, not simply copied from any one) for the facts which I am about to mention.

Authorities.	On Pauperism.	On Lunacy.	On Education.	On Police and Crime Repression.	On Traffic, including Roads, Streets, Bridges, Ferries, Markets, Harbours, &c.	On Public Works, Local Improvement, and Sanitary Outlay.	On other Objects.	On Interest and Repayment of Debt.	Total Expenditure in millions.	
									1874–75.	1867–68.
	£	£	£	£	£	£	£	£	£	£
Poor Law	—	—	—	—	—	—	—	—	8½	9
County	—	—	—	—	—	—	—	—	3	2¼
Town	—	—	—	—	—	—	—	—	14½	7
Metropolitan	—	—	—	—	—	—	—	—	6¼	6
Road	—	—	—	—	—	—	—	—	2¼	2¼
Maritime	—	—	—	—	—	—	—	—	3¾	2¾
Miscellaneous	—	—	—	—	—	—	—	—	1	¾
School Board	—	—	—	—	—	—	—	—	2¼	—
Total in millions	6¾	1½	2¼	3¾	6¾	9½	3	8½	41¾	30¼
Increase in millions		½	2¼	½	¾	3¼	1	4	11¾	
Decrease in Pauperism	¾									
Percentage of total in 1874–75	16·0	3·4	5·2	9·0	16·0	22·9	7·1	20·4		
Ditto in 1867–68	24·5	3·0	0·1	10·6	19·6	20·7	6·4	15·1		

"I would suggest as the primary and absolutely indispensable step of all attempts to reform local administration, that a more uniform form of accounts, a thorough official audit, and a consistent series of returns for a single period be annually required from every local body, as an absolute condition of its right to levy local taxes. But, further, I have tried to trace the heads of local expenditure which have most developed since 1868, and I have endeavoured to give in some sort a rough and, I fear in many points, a rather crude sketch of the distribution of certain important heads of local outlay at the present time, a sketch which tended to impress me with the value of keeping distinct the twofold functions of local authorities—that of the agents of the State carrying out in local limits national duties affecting the common weal, and that of undertaking the regulation and execution of purely local enterprises of special benefit to particular communities.

"Lastly, I have glanced very briefly at the medley of governing bodies, areas, and officers which go to make up our system of local administration. And here I would ask the most earnest consideration for the possibility of reducing the cost of local government by greatly simplifying its machinery, by devolving on district and on county authorities, as circumstances prescribe, the several local functions which have to be carried on. Adopting as the unit some such area as the union, and bringing that area into harmony with county boundaries, it would present a district within which it would be perfectly competent to transact all highway, sanitary, and poor-law work, embracing such special local needs as are now discharged in lesser areas by minor bodies, such as lighting and burial boards.

"These districts, apart from the separate organization of the larger municipalities, might then be drawn together for common action, within their county limits, by a strong representative provincial authority, charged, as it might most economically be, with all work not necessarily magisterial, and therefore retained in the hands of officers of the Crown."

After thus briefly quoting his tersely expressed conclusions, I will proceed to enforce with some observations of my own his last, relating to the chaotic state of local administration in England, to which for years I have frequently endeavoured to call public attention in Parliament and elsewhere.

The confusion of administrative areas, and, till quite lately, in several cases of duties also, of the different administrative bodies for different purposes is quite marvellous, with the natural consequence of much needless waste of time, trouble, and money. The boundaries cross each other in all directions—the boundaries of counties and unions, the boundaries of unions and highway districts, the boundaries of unions and magisterial divisions. Neither the municipal boundaries nor those of local boards under the Public Health Act are always conterminous with those of parishes; nor even without exception are the boundaries of counties and parishes, much less those of the drainage-areas for rating in the Fen districts under private Acts. Lastly, school districts have introduced (I think needlessly) a fresh set of administrative authorities and areas and of rates; while the ecclesiastical archdeaconries and rural deaneries are independent of all civil divisions except parishes. For example, one third of my deer-park with its lodge and many of my cottages and some of my largest coverts, being within a municipal borough, are in a different administrative area for roads and police and magisterial jurisdiction and for education, and were two years ago in a different rural deanery, from the rest of my deer-park and my house, though in the same area for poor relief.

Captain Craigie shows in a Table that the number of separate local authorities whose accounts are abstracted in the returns, to which he has referred in his paper, are more than 12,000, and that the number of persons returned in the census of 1871 as officers in the employ of the Local Government of the country was alone 50,000, with salaries which, after careful inquiry, he puts at nearly two millions and a half. As I had contrasted, in 1852, in my published letter to the electors of Plymouth, so Captain Craigie now contrasts the high salaries of some of the municipal officials with the comparatively small ones paid to officers of the Imperial Government. The Town Clerks of Manchester and Liverpool, for instance, he says, now receive much larger salaries than the President of the Council or the Local Government Board, or the Secretaries of the Treasury or the Admiralty. He shows that the debt of local authorities in 1875 was already over

94 millions, of which the towns owed nearly 40 millions, the Metropolitan Board 18, Maritime Boards 21, and School Boards 4, together 83 out of the 94, and that these debts are rapidly increasing. It is remarkable how many of these numerous administrative bodies have been created, and of these administrative areas have been laid out, and of this immense local debt has been contracted in our own time.

I remember when the parish was *bonâ fide* the unit of English administration, with few other bodies besides, except municipal corporations and Courts of County Quarter Sessions, administering the local affairs of the country. The parish then had to maintain its own poor, keep the King's peace and its own, mend its own roads, and repair its own church, after a fashion. It has none of these things to do any longer. Indeed it has recently been wittily proposed to define the parish as a place where a Church-rate can be made, but cannot be levied. I feel satisfied that the first step towards introducing order, economy, and efficiency into this chaotic mass of administrative business, into this labyrinth of administrative areas, into this army—I am afraid, with regard to too large a part, I ought to rather say this mob—of officials, would be to establish County Representative Boards, and make the union instead of the parish the unit of English administration, giving it most of the power which Municipal Corporations already enjoy, in addition to that which, and which alone, it was, in our own time, originally created to fulfil—that of administering legal relief to the poor. I remember well being attacked, during one of my contested elections, as an advocate of centralization and the enemy of local self-government, because I denounced the abuses of Vestry administration and supported the interference of the Central Government with the mismanagement. I answered that I did so because I wished local self-government to be economical and efficient, and therefore strong in the confidence and affection of the people. And this will be best secured, I believe, by placing it under a certain amount of central control, in order to maintain unity of principle, not, of course, uniformity of detail, throughout our local administration, so as to protect both minorities from anomalous treatment and exceptional oppression, and posterity from unjust and unwise burdens, at the will of perhaps merely temporary local majorities, and, further, to afford reasonable security to officers engaged in difficult and often necessarily unpopular duties. I may add, as the justification for empowering the central authority to require very full returns and accounts from the local ones, that this would tend to avert the wastefulness of obliging each local authority in succession to buy much of its experience by its own errors, instead of having a central body to collect information from each, and afterwards circulate it for the guidance of all.

I must now conclude, with many apologies for the length at which I have intruded upon you. But, in truth, some unexpected business has unavoidably engaged much of the time unduly near the day of meeting, which I had destined to the preparation of this address, and I have not had leisure to condense it as I ought and otherwise should. I doubt not that the papers to be read in this Section will make you some amends by their superiority in terseness, as well as in all other respects.

Memorandum.

In the course of the discussion of one of the papers subsequently read to the Section on the question of Population, I took occasion to disavow for Mr. Chadwick, Dr. Farr, and other economists who take our view of the doctrines of Malthus and Mill on this subject, any idea of in any way countenancing improvidence in marriage or in any thing else. But as I have issued this Address in a separate form, I think it right to add a few words here in my friends' vindication and my own.

Under the old Poor Law as it had been for many years administered, children, whether legitimate or illegitimate, gave the parent a generally recognized claim to parochial relief proportioned to their number; and the amount of wages was extensively regulated, not by the action of supply and demand, nor by the amount of work done by the labourer, but simply by the number of his family. Mr. Chadwick drew up for the Commission of Enquiry that remarkable Report which laid the foundation of the new Poor Law Act of 1834—an Act of which it is not too much to say that it arrested, nay, reversed, the tide of improvidence and idleness resulting from the old law, which then threatened the general pauperization of the rural and, to a considerable extent also, of the urban population. In that and all his subsequent writings Mr. Chadwick has always sternly denounced improvidence, idleness, and waste, and consistently advocated enlightened economy and industry alike in national, local, and individual work. Indeed it is a question whether he will be better known to posterity and is now better known abroad, where (as is shown by his Membership of the Institute of France) he enjoys more consideration than he does in his own country, as the chief author and, practically for years, the chief administrator of the new Poor Law of 1834, or as the pioneer in the kindred work of Sanitary Reform. Dr. Farr, coming after him, has always taken the same line. And I, their humble disciple, may venture to say for myself that I have always fearlessly denounced, whether officially while Secretary to the Poor Law Board, or publicly and privately, before and since, all legislation or administration tending by its laxity to facilitate improvidence, idleness, or waste; and, on the other hand, have done my utmost to promote all legislation, and personally to labour in all local administration, and to support all institutions tending to facilitate and encourage health, industry, and thrift among our people. With this object I accepted the office above mentioned and the laborious and unpaid one of Chairman of the Metropolitan Commission of Sewers; with this object, except while serving in the Poor Law Board, I have constantly acted as a Poor Law Guardian ever since I came to man's estate; with this object I, more than a quarter of a century ago, became President of the Western Provident Association; with this object I recently took shares in, and became one of the original Trustees of, the Penny Bank founded by Mr. G. Bartley.

But the clear and fundamental difference between the old school of Malthus and Mill and the newer and, in my opinion, far sounder one, to which, under the wise leadership of Mr. Chadwick and Dr. Farr, I have long felt it an honour to belong, is that we look to morality, intelligence, industry, and thrift, coupled (where expedient) with emigration, instead of, like Malthus and Mill and their disciples, to the mere restriction of the number of children, as the chief source of national, family, and individual well-being.—F.

Thrift as an Element of National Strength. By G. C. T. Bartley.

The results of thrift are so universal in the present that they are apt to be forgotten by their very familiarity. The houses we live in, the roads along which we travel, the everyday things we use, even in most places the water we drink, have only come down to us by the thriftiness of past generations. The effect thrift has on population is various; for where it is excessive, as in France, and where it often merges into the evil of hoarding, it may be said to tend to check increase by unduly postponing marriage. The application of the results of thrift is a most important part of economic science. At the end of the last and the beginning of the present century a great proportion went to maintain wars; but for the last fifty years in England it has been devoted generally and very largely to the production of works, railways, docks, &c. &c., and without doubt it is this which has influenced as much as any thing else the progress of this country. Future progress must depend largely on the same habit; and hence the importance of promoting thrift, especially in children, by such agencies as penny banks &c. This thrift must not be confined to money, but must include economy in time, the best use of materials for dress, food, &c., and instruction in such matters should therefore form a part of our national system of education. Experience shows, as proved undoubtedly by the National Penny Bank, that the promotion of the habit of thrift depends largely on the facility for its exercise. Thrift may be called not only the science of domestic comfort and happiness, but of national progress.

Notes and Recollections on the Cultivation of Tea in the British Himalayan Provinces of Kumaon and Gurhwál. By J. H. BATTEN, *F.R.G.S.*

The author pointed out on a large map (which had been prepared and set up by Mr. A. Burrell, for the purpose of illustrating his own statistics of the general distribution of the tea-plantations throughout all India) the particular districts to which his paper referred, and, amongst other prefacing remarks, observed that the highest mountain in Her Britannic Majesty's own dominions, Nunda Devi, having an elevation of 25,661 feet, was situated in Kumaon, the highest Himalayan peaks, Mount Everest, Kinchinghingee, and Dwalagiri, being in foreign native territory.

The main object of the paper was to show that the origin of the tea-industry was owing, in those districts, not to any discovery of the indigenous plant there (for he went into botanical details to show the absence of any true *Thea* or *Camellia* west of Sikkim, and the mistakes which had been made with regard to certain plants alleged as producing tea), but to the ability and zeal of certain distinguished men, displayed after Kumaon, Gurhwál, and Dehra Dun had been under British government for some years. These men were, primarily, Dr. Wallich, Superintendent of the Calcutta Botanical Gardens, and Dr. Royle, similarly placed at Sahâranpúr, in Upper India, who had urgently represented the feasibility of introducing tea into India, with Lord William Bentinck, the Governor-General, who, with characteristic wisdom, had formed an influential committee for the investigation of the subject. Then, in communication with that committee, appeared on the scene Dr. Hugh Falconer (successor of Royle at the Sahâranpúr Garden), whose special merits in recommending the Sub-Himalayan districts, and subsequently in extending the tea-nurseries, introducing Chinese tea-manufacturers, and in bringing the first manufactured Hill tea to England in 1843, were fully recorded. Mr. G. W. Traill, Commissioner of Kumaon, was highly commended for his happy selection in 1835, with the assistance of Mr. Blinkworth, plant-collector for Dr. Wallich, of the two earliest experimental tea-sites, at Almorah and Bhimtal, and for having sown the first tea-seeds imported from China, and having nurtured the first tea-plants, destined to become the parents of all that followed. Next in order Dr. William Jameson was duly celebrated as the *central name* notoriously associated with the great official exportation, which between 1843 and 1867 spread the tea-plant broadcast over the Hill districts, and made Himalayan tea a great fact in the commercial world of Asia and Europe. The episode of Mr. Robert Fortune, the gardener traveller of China and Japan, visiting and reporting on the tea-plantations, and suggesting appropriate sites, was mentioned as an important era in the history of this industry.

Mr. Batten, after quoting his own official reports on the suitability of the Katyur and other districts in Kumaon for future plantations, and giving due honour to some of his own colleagues, after pointing out certain tentative mistakes which had occurred in the course of the early exploitation by Government in the matter of land taken up for tea, concluded his paper by presenting a statistical list of the existing tea companies and private planters in Kumaon, Gurhwál, and Dehra Dun, with their several locations (more than 50 in number), and by contrasting the state of affairs in 1877, when in the former province alone the estimated yield of tea for the year amounts to 690,000 lbs., with the petty beginnings of cultivation under Traill and Falconer, where less than ten acres represented the whole tea-sown soil of the Western Himalaya.

Notes on the Statistics of Victoria (Australia). By JOHN BEDDOE, *M.D., F.R.S.*

The following brief notes are abstracted or condensed from the 'Victorian Year-book' for 1875, by Henry Heylin Hayter, Goverment Statist.

The estimated population for the year consists of 447,000 males and 376,000 females. The proportion of females to males is less than in Tasmania and South Australia, but greater than in the other Australasian colonies.

Births are stationary; the birth-rate is decreasing, but is still higher than in

England; the death-rate varies much from year to year, and was high (18 per 1000) in 1875, but does not seem to be on the increase, notwithstanding that the average age of the population is probably increasing. In the years 1854 and 1860 the death-rate exceeded 20 per 1000, a rate never since reached.

Marriages increase very slowly; the marriage rate decreases, and is now quite moderate, about 6 per 1000.

Immigration and emigration fluctuate, but of late years there is a slight excess of immigration, at least by sea. The Chinese immigration is not large, but exceeds the emigration, and may be about sufficient to maintain the numbers. Immigration generally is much less active than in New Zealand, Queensland, and New South Wales, but more so than in South Australia. In Tasmania and West Australia emigration is excessive, and Tasmania, especially, is a constant feeder of the Victorian population.

The population of live stock increases rather beyond the growth of the human population; cattle increase faster than sheep. The colony falls below New South Wales, absolutely, in number of horses, cattle, sheep, and pigs, below Queensland in cattle only; it equals New Zealand in number of sheep, and exceeds it in other animals; and it exceeds all the other Australasian colonies in the amount of live stock. The imports of live stock from New South Wales are considerable.

Relatively to population, however, Victoria is less rich in live stock than any of the other colonies, except Tasmania and South Australia as to cattle. In extent of cultivated land Victoria stands relatively high, and the cultivated area rapidly increases; but the increase is almost wholly taken up in green crops. South Australia stands out from its neighbour, and indeed from all Australasia, by its great extent of wheat cultivation, which constantly increases.

The quantity of wine made has not increased of late.

The export of gold has fallen off pretty steadily since 1868; that of wool increases; that of tallow falls off; that of hides and skins is pretty steady. The imports of butter, cheese, flour, and beer and tobacco decrease. In these, as in many other respects, the colony grows more independent and self-supporting.

The population and ratable value of towns, the number of manufactories, the amount of deposits in savings'-banks, the number and funds of friendly societies, the number of scholars, all increase out of proportion to the population of the colony; so does the number of letters and newspapers passing through the post-office; so does the number of churches and chapels, but not quite so fast.

Crime decidedly tends to diminish; commitments and convictions are fewer. Of the criminals, an unfairly large proportion are Irish Catholics, Irish Protestants contributing apparently few. Pagans, *i.e.* Chinese, yield more than their share of serious crime.

The general result of all this may be thus briefly stated. With the falling off, both absolute and relative, of the production of gold, and the diversion of labour to other channels, the colony is gradually settling down into a more stable condition; and though the production of wealth may not increase, there is greater economy, security, and general prosperity.

On Agricultural Statistics. By WILLIAM BOTLY.

In the past year there had been a decrease in cattle of 165,598, and in sheep of 1,239,369, but an increase in pigs of 239,262, with a decrease in horses used in agriculture of 12,441, accounted for partly by the steam-engine superseding the horse, and partly by the decrease of land under the plough. Corn, flax, roots, &c. showed a decrease of 201,010 acres, whilst pasture &c. increased by 279,671 acres, of and to which increase the waste lands contribute 78,661 acres. The import of butter from Denmark, the United States, Belgium, France, and Holland, in 1875, was 1,251,118 cwt., of the estimated value of £7,285,927; imports of meat 531,008 cwt., of the declared value of £1,465,552. Imports of wheat and other cereals &c. in 1876 were 77,522,558 cwt., estimated at no less than £51,550,122. Thus one half of our consumption was imported, each person averaging a consuming power of 114 lbs. of animal food per annum, exclusive of poultry, fish, game, and rabbits. Agricultural statistics had, from a very early period, been considered the means of averting scarcity, famine, and disease; and instead of the returns being merely permissive, they would most probably eventually, of necessity, become positive and compulsory.

On the Growth of Population with Relation to the Means of Subsistence.
By STEPHEN BOURNE, *F.S.S.*

[Ordered to be printed in extenso.]

From the time when Malthus propounded his theories on population, the minds of many have been concerned with the question whether such a growth as he deprecated is not indeed an evil to be warred against.

These theories appear to have been:—

1. The growth of population must follow or be regulated by the means of sustenance.

2. That the tendency of population was to increase in geometrical, that of subsistence in arithmetical, progression, and therefore that without some corrective the one must of necessity outstrip the other, and the world become unable to support the lives thus produced.

3. That this correction was found in the natural or unnatural occurrence of famine, pestilence, and war, at the cost of much misery, which it would be wise to prevent by restraining the natural increase of population through the avoidance of early marriages.

In later times our sense of decency has been shocked by the outspoken denunciation, not of marriage, but of its consequences, and the bold inculcation of means whereby the gratification of natural inclinations may be conjoined with the violation of nature's laws and the frustration of nature's ends. Upon the consideration of such a question it would be manifestly improper to enter here. If, indeed, any place or time be fitted for such discussion, it must be some other than this one. But whatever opinion may exist as to the means thus proposed for our adoption, it is a thoroughly legitimate subject for inquiry, whether the growth of population is, as these so-called *philosophers* assume, an evil to be averted; or, as others assert, a burden to be borne; or, as many believe, a source of wealth to be prized.

Again, looking at the trepidation which Malthus felt at the misery certain to follow upon any large accession to the seven millions of inhabitants which England then supported, and comparing the condition in which it now holds and maintains more than three times that number, we may smile at the folly of his forebodings. Yet the question is still an open one, whether the limits of sustenance may not have been reached, and the time have arrived when to follow his counsels would be true wisdom. It is a desire to see what light can be thrown upon these two subjects for investigation that has suggested the attempt made in this paper to ascertain how the various sections of our population are distributed as to occupations, and the proportions engaged respectively in providing food, other necessaries, and luxuries.

Taking as a basis in our inquiry the Census Reports for the year 1871, we shall find the population for the three divisions of the United Kingdom thus stated:—

England and Wales	22,712,266
Scotland	3,360,018
Ireland	5,412,377
	31,484,661

Since that date it is estimated to have increased by 1,604,576, so that at present it amounts to slightly more than 33 millions. But as there are no means of distributing these additional inhabitants amongst the several occupations, it will be necessary to confine our attention to the figures furnished for the census year. These are divided by the Register-General into six classes, in this order:—

i. Professional	891,160
ii. Domestic	6,804,769
iii. Commercial	1,035,737
iv. Agricultural	2,989,154
v. Industrial	6,425,137
vi. Indefinite	13,338,704
	31,484,661

The individuals composing these classes are alike in one respect—that they are all consumers, and need to be provided with the means of subsistence. They differ, however, greatly in another—in that only a portion are producers, and on the productive power of this portion must the whole rest for support. It is impossible minutely to separate the one from the other; but we cannot greatly err in adopting the above division into classes, and for the present purpose may include the third, fourth, and fifth as the productive, and the remaining three—the first, second, and sixth—as those whose labour does not actually contribute to the supply on which they, in common with the producers, depend for sustenance. This, in a sense, the commercial class does. Strictly speaking, the merchant may be no more essential to the welfare of the community than the schoolmaster; but the one assists in procuring the means whereby life is supported, whilst the other, in this respect, does not consume a portion of that on which existence depends. Thus, separating the population into two divisions, we shall have:—

Producers	10,450,028
Non-producers	21,034,633
	31,484,661

the latter being very nearly double the former. Further dividing the class of producers, we find those engaged in agricultural operations to be 2,989,154, and the industrial and commercial together 7,460,874; in round numbers three, and seven and a half millions respectively.

I. The agricultural class embraces those engaged in the cultivation of the soil, whether "in fields and pastures, 1,447,481;" "in woods, 7861;" or "in gardens, 103,695," including not alone the actual agricultural labourers, shepherds, farm servants, and gardeners, but all those returned simply as landed proprietors, all farmers, graziers, bailiffs, agents, and others whose sole or principal employment is upon or about the land. It further comprises all persons engaged about animals, such as horsekeepers, gamekeepers, drovers, cattle-salesmen, fishermen, and others, the business of all of whom is the capturing, rearing, and dealing in beasts, birds, and fishes—the whole class thus comprehending all whose manual or mental labour, whose time, thought, and capital, are devoted to calling into existence and utilizing the various products of animal and vegetable life. It is obvious, however, that not all of these are engaged solely in the production of human food, which numbers, for our present purpose, it is important to ascertain. The value of the wool and flax grown at home has been estimated at 6 per cent. of the whole produce, that of the oats at 13 per cent., of the barley at 11 per cent., of the peas, beans, and rye at 4 per cent.; in all, 34 per cent. The corn and hay for the support of horses not employed in farming operations is of considerable value, whilst a large number of woodmen and gardeners, grooms and gamekeepers, are solely engaged in ministering, not to subsistence, but to enjoyment, or in other useful operations. To discover the exact proportion thus employed would be difficult; but it cannot be deemed an undue estimate if we say that one fourth at least must devote their labours to other objects than the raising of food. If we make a deduction to this extent, it follows that two and a quarter millions of the population are sufficient to produce all the home-grown food. This is estimated at about three fifths of the whole consumption of the kingdom, the remainder being derived from foreign supplies, received in exchange for the produce of our mines and manufactories. Assuming, as may fairly be done, that each individual employed in manufacturing operations will produce goods for export equivalent at least to the food which he could raise directly from the soil, we arrive at the conclusion that two thirds of two and a quarter millions, say one and a half million, should be deducted from the industrial and added to the food-producing class, and that three and three quarter millions are actually engaged in producing or procuring food for all the inhabitants of the United Kingdom.

But we must go a step further. There are other things which are absolutely essential for those who thus labour—houses to live in, clothing to wear, and several minor articles of food, over and above that which is raised at home. To provide these, some of our mechanics and operatives must devote their time either directly to their production, or directly to producing that which will procure them from abroad. For reasons which will be better explained when speaking of the industrial class, the number thus employed may be computed at half a million of workers. The result of these calculations may thus be stated in round numbers:—

Census return of agricultural class	3,000,000
Less $\frac{1}{4}$, producing hay, wool, flax, hides, oils, &c.	750,000
	2,250,000
Add, manufacturers of goods to be exchanged for food	1,500,000
Ditto, of necessaries for food-producers	500,000
Giving a grand total of	4,250,000

whose labour in one shape or another sufficed to maintain in food the 31,500,000 ascertained inhabitants of the kingdom in 1871.

II. The industrial class, numbering six and a quarter millions, includes all persons engaged in art and mechanic production, and those working and dealing in textile fabrics and dress, in food and drinks, and in animal, vegetable, and mineral substances. To these we may, as before stated, add the commercial class, one million; not that they are actual producers, but because their employment is necessary for the distribution and exchange of that which others produce, and which without such assistance could not be utilized. To these seven and a quarter millions we must add the three quarters of a million of the agricultural class whom we considered as employed in producing other articles than food, but deduct the one and a half million the product of whose labour we reckoned as applied to the purchase of food imported from other countries, leaving six and three quarter millions of workers engaged in producing, for the benefit of the whole population, substances *not* to be consumed as food. In like manner, however, as we added to the food-producers half a million for those providing articles necessary to their existence, so must we deduct this half a million from the industrial producers, together with, say, three quarters of a million similarly employed upon necessaries for these workers themselves.

These two numbers, thus transferred as necessary for the workers, are to a certain extent conjectural, yet not altogether arbitrary. A close examination of the suborders and divisions of the census return under the various occupations of the industrial class leads to the conclusion that, after making the deduction for goods manufactured to be exchanged for food imports, one half of the workers may be assigned to the production of articles of necessity; and as this would give some three or three and a half millions, the proportion for the consumption of the workers themselves would be about a quarter of a million for the agricultural and three quarters of a million for the industrial. Thus we get five and a half millions, the products of whose labour supply themselves with food and necessaries, and the rest of the community with every thing it uses, beyond the absolute food on which it subsists.

Assuming that the necessary supplies for the wants of the non-productive population (including most of the women and all the children) will absorb the labour of two and a half millions more, we shall have left some three millions for the production of luxuries or superfluities and the accumulation of wealth, nearly one third of the total workers.

These calculations may be tabulated in round numbers thus:—

Census return of industrial and commercial		7,500,000
Add ¼ of agricultural class who do not produce food		750,000
Deduct:		8,250,000
Producers of foreign food	1,500,000	2,000,000
„ necessaries for producers	500,000	
		6,250,000
„ necessaries for industrial workers		750,000
		5,500,000
Assumed to be employed in manufacturing necessaries		2,500,000
Leaving for the production of superfluities		3,000,000

The powers of the whole population will thus be expended:—

In the production of food	4,250,000
„ „ other necessaries	3,250,000
„ „ superfluities	3,000,000
	10,500,000
Consumers only	21,000,000
	31,500,000

Although resting upon a sound basis, as regards the numbers employed and the class of occupation, these calculations can only claim a presumptive accuracy as to the purposes which such employment serves. There is not much reason to question the proportion of the nation's power assigned to the production of food; but opinions may differ as to how much is required for the supply of its necessities, and the degree in which the product of the remainder is to be considered essential to comfort and happiness, or to be looked upon as unnecessary or even hurtful. It is not, however, requisite that there should be precise agreement on these points. Let it be granted that, after providing the means of subsistence (whatever that may be deemed to include), there is any surplus at all, the national welfare cannot really be imperilled by its existence. That such is the case needs no proof. The rapid growth of its wealth, the luxurious living of so many of its members, and the ability of so many to exist and spend without any labour, all prove that the means of subsistence have hitherto kept ahead of the increase of the population.

III. Another line of argument, founded also upon the Census Returns, will lead up to the same conclusion. Dividing the whole population, as ascertained in 1871, according to sex and age, we find that there were 15,301,830 males and 16,182,831 females, viz.:—

	Males.	Females.	Both sexes.
Under 15 years	5,706,589	5,383,683	11,090,272
Over 65 „	721,997	501,306	1,223,303
Wives and women performing household duties	......	5,058,298	5,058,298
	6,428,586	10,943,287	17,371,873
Between 15 and 65, excluding household women	8,873,244	5,239,544	14,112,788
	15,301,830	16,182,831	31,484,661

In making this division, it is assumed that the working period of life is between 15 and 65, whilst all under and over those ages are unable to labour for their own support or that of others. It is true that many children below 15, and aged persons beyond 65, do in part earn the means of subsistence; but there is probably an equivalent number between 15 and 65 who do not actually work, and thus one may be set against the other. Married women, too, and those engaged in household duties, although in some instances assisting as bread-winners, must, generally speaking, be excluded from the class of productive workers. These together amount in round numbers to 17½ millions, leaving 14 millions of an age and position to be profitably employed. So far, however, as being actually productive members of the community, we must except the professional class and those engaged in domestic service, together numbering 3¾ millions. Deducting these from the 14 millions at the working age, we have 10¼ millions to perform the various agricultural and industrial operations on which the nation depends for its sustenance (necessary and superfluous) and its growth in wealth. By the former separation into productive occupations, we found that 10½ millions were so classed —a number so singularly near to the 10¼ millions arrived at by the division into ages, as to confirm the accuracy of the reasoning by which we arrive at the following results, viz.:—

1. That one third of the population is capable of labouring, and actually does labour for its own support and that of the remaining two thirds which are dependent upon it.

2. That of the productive portion of the community about 40 per cent. are either directly or indirectly engaged in the production of food, from 25 to 30 per cent. in that of other necessaries, leaving 30 to 35 per cent. free for those occupations which furnish us with luxuries for consumption or wealth for accumulation.

3. That therefore the growth of population in this country has not hitherto unduly pressed upon or overtaken the means of subsistence.

IV. If then, as these two sets of figures seem conclusively to show, one worker, besides procuring food and necessaries for his own support, can and does produce the food which nourishes six or seven others (4¼ to 31½ millions), whilst there are on the average no more than one adult and one child dependent upon each producing member of the community (10¼ to 10½ over, and 11 under 15 years), there can be no doubt whatever that the power employed in raising the means of subsistence is far below what might be made available should more be required. If, again, the strength of the nation is such that, after allowing for the employment of nearly one half of its producing power (5 out of 10½ millions) in labour for their own necessities and the food of others, it has more than the other half (5½ millions) left to supply the remaining wants of the other 21 millions and the further desires of the whole 31½ millions, there can be no true reason why the growth of the population needs to be restrained. Neither is there any room to fear that such a ratio of increase as the present progress furnishes can do no other than add to the productive power of the nation. If such restriction be advocated, let it be honestly done with the object of confining the use of the nation's wealth in undue proportion to a part of the community, or of substituting luxurious self-indulgence for the natural use of our powers and privileges.

The numbers and the conditions of existence with which we are now dealing are those of the present time, when it is admitted that much room exists for sanitary, hygienic, and moral improvement, the beginnings of, or rather some advance in which we already witness. From such improvement there would certainly result a strengthening of our position. Disease lessens the power of those who live, and premature death destroys the power which has cost much to rear. The children under fifteen years of age are rather more in number than the productive workers; and reckoning the average consumption of each as equal to half that of an adult, they must absorb one sixth of the food and necessaries produced by the workers. This they more than repay during mature years. If, however, life is cut short before maturity, every year that it has lasted has been a tax upon the means of subsistence, for which there is no recompense. Infant mortality is confessedly higher than it ought to be. Every life which knowledge or care can rescue is an addition to future producing power, and so to the surplus which makes the nation's wealth. Still more is this the case with improved health amongst producers, because to the extent which disease exists it not only destroys power in the sufferer himself, but draws upon the resources of those whose own power is thus directed to unproductive uses. It is not too much to hope that an improvement in this respect is taking place, by which a considerable gain may ensue, the whole of which will be that of surplus power.

Beyond this, the constant increase of mechanical power, and of economy in its uses, largely adds to the producing capacity of those who call it to their aid. Whatever is thus applied to the actual forcing of a greater yield from the soil, or to the manufacture of the necessaries for home use, must be a clear gain; but so much as increases the product of manufactures for exchange with other nations may not really be any gain, if thereby, through competition or other causes, the value of the articles produced sustains an equivalent diminution. To make this plain, the reaping-machine will set free so many reapers to reclaim and plant other land; but an improved steam-engine may only increase the produce of the loom without ensuring its value in exchange for food being any greater. The whole tendency, however, of growing intelligence, knowledge, and wealth is to render the employment of power more productive, and thus to increase the available surplus. If, therefore, there be any surplus at all at present, and we have seen that there is a considerable one, increase of population should cause it to become still greater.

V. Two objections, however, may arise, which it is important to meet. It may be asserted that there must be a limit to the numbers which our country can hold and maintain, and that the time when this limitation makes itself felt has arrived, or is soon to come. Again, many will maintain that we have even now no true surplus of productive power, because the producers and their dependents are both straightened in their consumption, and overstraightened by the amount of labour which is necessary to procure even that they have, whilst a proper supply of necessaries and a just limitation of labour would consume or lessen the surplus now produced.

To deal first with this latter argument in both its branches. If we look at the so-called working classes, it is impossible not to see that in both the quality and quantity of the food they consume, in the sufficiency and finery of the clothes they wear, and in the comfort and size of the houses they inhabit, they are better off at this time than at any previous period. There may be much of squalid poverty, many ill-filled stomachs and ill-clad backs, uncomfortable houses and miserable homes, but there is still more of lavish expenditure in drink and tobacco, of wasted food and unsuitable clothing, of ill-kept habitations and mismanaged homes. The relief from want is to be obtained by the repression of extravagances, and comfort is to be procured by the economic use of time and money; for there can be little doubt that the wages earned, if properly employed and fairly distributed, are amply sufficient to purchase food and necessaries for a larger population than they now support. With the middle class the strain and privation, not perhaps of the absolute necessaries, but in those which habit and education have made such, is probably much greater than in the lower strata. There is more difficulty in finding profitable employment for sons and fitting homes for daughters; but here, too, the cause is to be found in the improvident expenditure of money and time, ill-regulated desires, and undue aspirations—not, indeed, here or in the lower classes always on the part of those who suffer; for the misery-maker is too often not the one who endures the suffering. With the higher classes there can be no question as to the actual means of subsistence or of comfortable existence; it is one of maintaining their present position, or of failure in attaining a higher one, should the numbers amongst whom existing or prospective means are to be divided greatly increase. Looking to the rapid growth and concentration of wealth on the one hand, and the equally rapid increase of luxurious expenditure on the other, it cannot be for a moment maintained that, even supposing this accession of means not to keep pace as it has hitherto done with the growth of population, there is not ample for division amongst greater numbers. Besides this there seems to be some natural cause or effect whereby the accretion, possession, or expenditure of wealth is generally attended with a stationary or decreasing family.

As regards the supposed undue amount of labour exacted from those who produce for themselves or work for others, almost the same course of reasoning may be pursued. It is not that the aggregate amount of exertion is more than the whole body can well put forth, it is the unequal distribution among its various members. There is scarcely a family or neighbourhood—certainly not a town or county—in which we do not see quite sufficient available power for the relief of those who are unduly pressed. The time which is devoted to pleasure, or spent in frivolity and idleness, and the strength which is wasted unnecessarily or exhausted by dissipation, is amply sufficient for lessening the strain put upon the overworked members of the community; nay more, it needs no argument, for it is self-evident to the most ordinary observer, that a just appropriation of time and a wise administration of power would produce far more than at present without at all limiting the hours which may rightly be devoted to rest, improvement, and enjoyment. Excepting for our follies and our pleasures, it cannot be said as a nation we are on the whole overworked, or that we need to restrict the total time devoted to labour.

But granting, for argument's sake, that these evils do exist, are they to be removed or lessened by restraint upon marriage or increase? Is the disease one which may be cured by the prescriptions of either Malthus or Bradlaugh? Do we find that deferred matrimony or life-long celibacy really add to the productive power which the abstainers put forth? Is it not a fact that, as a rule, the larger families thrive the best, and that a large number of those who have none dependent upon them, themselves become dependent upon others? Let a young man feel that he has no home to make or keep, and he too often loses the stimulus to putting forth his productive power, and fails to preserve it by healthy exercise. He is tempted to expend his earnings in unprofitable or hurtful enjoyments, if even he does not exhaust his energies by dissipation and self-indulgence. Let a young woman feel that she is debarred from having a home of her own with those for whom she may expend her powers and cultivate the best feelings of her nature, and let her know that instead of being provided for by the husband or sons, on whom she may lavish her affections and her cares, she must earn her own livelihood, and she is too often forced into uncongenial pursuits and exhausting labours, which go far to repress her vital powers, and ultimately extinguish her capacity, not so much for being herself a producer as a real helper to those who are such. When, on the contrary, the young of both sexes feel that they may possess a united home, in which the obligations of parental love may be an incentive to the preservation and development of their powers, they are supplied with the strongest inducement to the right use of the health and strength which makes them an addition to the nation's productiveness. There is nothing in this to enforce matrimony and its consequent multiplication of life upon those who are unfitted or unwilling to enter upon it, nor yet to encourage premature, imprudent, or ill-assorted unions; on the contrary, the steady contemplation of the married state as a legitimate object to be attained will be the best encouragement to prudent preparation. A knowledge of the duties it entails, and the noble self-sacrifice it requires, will be the most effectual restraint upon those to whom it has no attractions; whilst those who realize the fulfilment of their desires will be far more likely to have healthy offspring, and in adding to the numbers of the population to give those who will be an increase of its productive powers.

VI. Thus far it has been assumed that an increase of productive power is a source of strength and prosperity; but here the former of the two objections which were suggested requires to be met, and we need to be satisfied that with possession of increased power we have a sufficient field for its employment.

Malthus thought that the prudential limits of population for our island was nearly reached, and trembled for the time when the world might have more inhabitants than it could possibly feed. The only possible justification for Bradlaugh's philosophy is, that we are already full enough, and that an addition to our numbers can but add to our misery.

Political economists, social reformers, and practical philanthropists of the highest stamp have thought that the growth of population is unduly pressing upon the nation's means, and there can be no doubt that the problem is one of somewhat difficult solution. For a series of years the national expenditure for food has gone on increasing simultaneously with a diminishing receipt from the sale of the manufactures which our producing power enables us to send to the countries with which we trade.

Since 1872 each year has been worse in this respect than its predecessor, and the present year promises to be the worst of all that have yet passed. Every succeeding year the home resources afford a less amount of food per head of its population, and every year the money value of our exports is also less per head. There are those amongst us, whose judgment is entitled to respect, who view this state of things without anxiety, believing either that the growth of our income abroad advances at least in proportion to our draughts upon it, or that the present depression of trade is but temporary, and will soon give place to returning prosperity. There are some, too, who really believe that, despite all adverse tokens, the profits in our manufacturing and trading operations are really greater, and so compensate for the larger supply we draw from abroad. With the soundness or fallacy of these different views it is not the business of this paper to deal; but we have to consider what bearing these circumstances have upon the continued increase of the mouths we have to fill, the wants we have to supply.

Let it be granted, again, that there is a real evil to be overcome, what does it mean? that we must interfere with nature's laws or natural results? or that we must learn the lessons these results are designed to teach; that we must obey the other laws which nature enacts? Is it impossible to bring increased supplies to our people? And if it be so, is it out of our power to carry our people where they may find scope for the employment of their productive power, in making provision for their wants, and securing possession of comforts and luxuries?

When Abraham and Lot found the land too small to pasture their flocks, they agreed to extend the borders they occupied. When Solomon wanted the wood of Lebanon and the gold of Ophir, he exchanged the surplus products of his own land for those of others. We in times past have done both, and we must still do both in larger degree; for we have this advantage, that the two go hand in hand—the one helps the other, and thus lessens the strain on both. Every family which goes forth to cultivate an unoccupied space, to render the earth productive where it has never hitherto yielded fruits, or to make two blades grow where only one grew before, furnishes additional customers for our industrial class at home, and enables our land in comfort to hold increasing numbers.

It is probable that there never was a time when colonization was so easy as it might be now. We have capitalists who can prevent our emigrants going out empty-handed, and can prepare the way for them with the certainty that the investment will pay. We have ships that can carry them with speed, safety, and economy. We have broad acres under our own sovereign's sway where we may plant or consolidate our laws, our customs, our principles of justice and religion; or we have peaceful relations with other nations who will be only too glad to receive our people. We have scientific means for lessening the hardships incident to a new life, and we have still brave hearts and true to go up and possess the lands. We have, then, mechanical skill, industrious workers, rich capitalists and manufacturers at home to receive the products of industry abroad, to cheaply convert them into articles of utility and luxury, to speedily return them in their useful forms to those who have raised the raw materials; and we have facility of intercourse to prevent the entire rupture of family ties, to cement old friendships, and to create new tastes and inclinations in those who are in reality less separated in time and distance than were our forefathers when actually within the borders of our own little island.

Again, colonization in the present day may be different in its character from that of previous times. We then went forth to conquer, rob, oppress, and exterminate the aboriginal inhabitants of the settlements we chose. We now go, or ought to go, to them with the open hand of friendship, teach them our laws, instruct their ignorance, help their weakness, carry to them the blessings of civilization and christianity, and thus make them at once our friends and our customers.

In all these several ways a small exodus from home may serve to restore the balance and to furnish the means of subsistence for the many who remain behind. By so doing a redundancy of population will become the means of producing redundant food, health, happiness, and wealth.

VII. Away, then ,with the false economy and cold expediency which would stifle all the finer feelings of our nature, cramp all the expansive powers of our minds, rob us of all the warmer desires of our hearts, which would check the progress of the world in all that can constitute real greatness, by selfishly refusing to convey to the dark regions of the earth the light which art, science, and religion have permitted us to enjoy. Away still more with the impure philosophy which would degrade us to mere machines for the gratification of the inclinations given us for wise and noble ends—creatures of the flesh rather than of the mind and spirit, wallowers in the filth of this world rather than aspirants for the purity of heaven.

Whether, therefore, we examine into the present resources and demands of the population, or whether we look to the economy of the vegetable or the animal world, the experience of human history, the record of human progress, the constitution of the human frame, the objects of human existence, or the prospects of our race in the future of this world and the eternity of the next, we shall find that the law of increase is of natural and divine enactment. Let us honestly strive to discover wherein lies the secret of our strength, the security for our happiness, and we shall realize the conviction that it is to be found in fulfilling the terms of the charter whereby we hold possession of the earth and dominance over the lower creatures: "Be fruitful, and multiply, and replenish the earth."

On the Water Supply of London. *By* J. F. Bramwell, *F.R.S.*

In the year 1874 the population of London supplied with water was 3,655,000, dwelling in 511,000 houses, and the daily average quantity throughout the year was 116,250,000 gallons. The quantity per head, therefore, for all purposes was a little under 32 gallons. This water supply was in the hands of eight companies, and the aggregate capital employed in 1874, including share and loan capital, was £11,196,000. The gross income from the water was £1,137,000, and, in addition to this, there was £16,000 from land rents, making a total of £1,153,000. The expenses were £447,000, so that the nett income was £705,700, giving a rate of interest upon all capital employed of proximately 6·3 per cent. The last report, made in June, showed that the population supplied was 3,796,000, dwelling in 533,000 houses, and the average daily quantity was 132½ million gallons, equal to a little less than 35 gallons per head. The water supply of London for purposes of cleanliness (personal and domestic), manufacturing, and road-watering was generally satisfactory; but, except in rare cases, this could not be said of the water for drinking and culinary purposes, nor in any case could it be said of the water for the purpose of extinguishing fire. And yet the importance of these two objects it was difficult to exaggerate, as on the quality of the potable water depended to a large extent the health of a vast population, and on an adequate provision for the extinction of fire depended the preservation of the largest aggregation of wealth in the world. There were many who supposed that the defects complained of arose from the fact of the supply being in the hands of private trading companies, and who urged that if the undertakings of those companies were acquired by the governing body of the metropolis, so as to put the whole water supply under one management, every complaint would disappear; but this could not be the case if, after the acquisition of the property by the governing authority, the present system was continued. That system was the obtaining of water for all purposes either from the Thames, the sea, or from wells. With the exception of the well-supply the water so obtained was put into depositing reservoirs, was filtered, and was thus treated whether it be used to flush a sewer or whether it was drunk and delivered at one and the same pressure, whether it be required at the basement of a house or for the extinction of a fire. If the governing authority pursued the same system, obviously, though there might be some economy in management, there would be no radical change, either in the quality of the water for drinking, or in the quantity and pressure for the extinction of fire. It would be no advantage for the Corporation to buy up the present companies unless they went to a different source for a supply;

and his proposal was that the water should be got from deep wells within a distance of about twelve miles from London, and pumping that water to reservoirs 400 feet above the ordnance datum, these reservoirs to be connected or coupled with large mains, and arterial pipes to be laid in every street, and hydrants fixed on the pipes. These pipes for the supply of potable water should be laid to every house, with a closed cistern attached, so that from three to ten gallons could be drawn off at a time. But all water for washing-purposes was to be taken from the companies as before. The object of this proposed change was to give to the metropolis good water for drinking and culinary purposes, as well as to secure a sufficient quantity for the extinction of fire.

On the Tea-consumption of the United Kingdom. By R. BURRELL.

On the Debts and Liabilities of Sovereign and Quasi-Sovereign States due to Foreign Creditors. By HYDE CLARKE, *F.S.S.*

The author showed how the number of these States had increased in this century, and that for all were claimed the prerogatives of sovereign States of the highest civilization. The U.S. of Columbia and the Argentine Confederation had imitated the United States of America in endowing their provinces with a sovereign title. In consequence of the war of secession, the States of the American Union had ceased to be really sovereign, although retainingthe title and privileges. Thus they could not be sued in the United States Supreme Court, nor in foreign courts, while no diplomatic agents were accredited to them, and the United States Federal Government declined to interfere with them. At the same time the English Foreign Office had adopted a policy of non-interference with sovereign and semi-sovereign States for claims of English merchants and creditors. The author traced the progress of the issue of foreign loans in its legitimate relations, and in its recent illegitimate expansion for fraudulent purposes. He showed that at present although States can sue in English courts for claims against English citizens, they are not allowed to be sued. He expressed a doubt whether, as a question of international law, any State had the prerogative of suing. He held it to be only a matter of comity, but subject to submission to the procedure of the courts of England, France, &c. Having pointed out the hardship to merchants and others of the present one-sided jurisdiction, he proposed that it should be made a rule of the procedure of courts in Europe and America, that on a State presenting itself as plaintiff, it should be acquired to accept services as a defendant. Service should be made, not on an ambassador or minister, but on the commercial agents, the consul, or fiscal agent.

On some Doctrines of Population. By DR. FARR, *F.R.S.*

The author said the unity of the human family was an accepted scientific truth. Although there were infinite diversities in men, differences not only in rank, but in character, never such equality between man and man as was passionately asserted at the French revolution, and no single nationality in the same stage of civilization as the rest, yet there was a unity of plan, of structure, faculty, passion, sense, and intellect in individuals and in nations. The population of the world was estimated by McCulloch in 1841 at 800,000,000; others raised the numbers to a thousand millions; but the more recent estimates of Behm and Wagner made the population of the world 1,424 millions. The population of Europe and of America was known by the censuses to be increasing, and it was probable that there was some, though not a corresponding increase in Asia and Africa; but the chief difference was due to the recent estimate being based on a better knowledge of Africa and Asia acquired by geographical exploration. There had been censuses of the greater part of European States, and it was announced at the St. Petersburg Conference that the Russian Government proposed to take a census, by name, of its subjects in 1878. In a few years we might hope that the population of Turkey—the only un-statistical State in Europe—would be enumerated. What degree of reliance was to be placed on the census of China he did not know. The most remarkable recent statistical operation, and one which did infinite credit to the Government, the Civil Service, and the people, was the census of British India, which was found to contain more subjects than had ever been conjectured. In the last century some thinkers called in question the account of the origin of mankind in the first chapters of Genesis. They contended that it was impossible to admit that the millions of people then living on the earth could have descended from two ancestors—Adam and Eve. But Euler undertook to meet the objectors, and he showed that by a process of doubling the population from one pair, it might be increased to any conceivable number. The subject had been prosecuted still further by Malthus and others, and in the abstract nothing was simpler than the exponential equation by which the number of years in which a sum of money, increasing at compound interest, or a population increasing at any rate in geometrical progression would double itself. It had been laid down that a population could double itself in twenty-five years, but it had not yet been proved. It was true that the population of the United States, during a period of seventy years, was doubled every $23\frac{1}{3}$ years, but it did not double itself at that rate, for the increase was largely due to immigration.

The author next pointed out that the natural increase of population was due to the excess of births over deaths; and he also showed by a series of statistics that the reduction of the death-rate did not imply a more rapid increase of population. He argued further that a diminution of the mortality of England by sanitary improvement was in no danger of multiplying men beyond the means of subsistence. Experience proved the contrary: the birth-rate and the death-rate by the providence of the people rose and fell together. The birth-rate was depressed below its standard in England and France; it varied with the prosperity of the country, with the demand for people, and it could be reduced to as low a figure as the lowest attainable death-rate; and he contended that to keep a population stationary, or to retard national growth, there was need of neither of the destroying angels—war, pestilence, or famine. While he did not decry the existence of armies and navies, he utterly denied that wars were necessary to check the growth of population. Although it had been shown that the birth-rate could be reduced, he asked whether it would be wise in this country to accept that policy which had been advocated by Malthus, Mill, Drysdale, and others. He shared in the admiration which had been expressed of Mill, and appreciated much that Malthus had written; but against nothing was it more clearly their duty to protest than the errors of authorities in philosophy. Admirable as were the industry and thrift of the French peasant, he could no more hold that England was called upon to practice his social philosophy, than to revolutionize our agriculture by either cutting up the land into infinitesimal parcels, or ceasing to employ in its culture the several capitals of the landlord in acres, the farmer in stock, or the labourer in thews, sinews, and inherited skill.

On the Cost of adopting the System of Public Prosecutors in England, as illustrated by the results of the Scotch and Irish Systems. By W. Neilson Hancock, *LL.D.*

The author showed that the extension to England of the system of public prosecution, which had long existed in Scotland and Ireland, was apparently only a question of time. In 1872 Mr. Walpole had said, "it was really a disgrace, and he used the word advisedly, that England was the only country in the world where prosecutions for crime were left at the mercy of private individuals, who might or not proceed with them as they thought fit." That the delay in adopting so essential a reform is connected with fears of the cost, appears from the observation of the Home Secretary, who, while announcing that a bill was prepared, said, a "public prosecutor was an expensive luxury." The Scotch system of a local Crown Solicitor, called a Procurator Fiscal, in 60 districts in Scotland, taking charge under the direction of the Lord Advocate (who corresponds to the English and Irish

Attorney-General) of all prosecutions from the very commencement to the final stage, cost only £27,960 a year, viz.:—£23,332 for salaries, £3,708 for other emoluments, and £920 for office expenses. The effect of this public local officer taking charge of prosecutions arising out of sudden deaths was to dispense altogether with coroners' inquests, the inquiry by the Crown Solicitor into every sudden death that might possibly have resulted from crime being accepted as a complete substitute for coroners' inquests, which do not exist in Scotland. In England the direct cost of coroners' inquests was £84,285. From this it may be estimated that the dispensing with coroners' inquests in Scotland is a direct saving of about £14,000 a year, or half the whole cost of the Crown Solicitors. There is a further saving in having only a single instead of a double preliminary inquiry: this diminishes the time and expenses of witnesses, and saves double information, with all risk of complication and failure of justice the double informations before coroners and justices give rise to. The Scotch system leads to a further saving at the trial. With them the case goes before only one jury, composed partly of special and partly of common jurors. Their proceeding is like information in England, and, except in cases of treason, bills of indictment are not sent to a Grand Jury. This saves time of witnesses, of judges, and jurors when trials actually take place. The witnesses especially are saved, because the public prosecutor can regulate the whole course of the business, and witnesses need not as at present necessarily attend from the commencement of the assizes, but only when the trial is fixed. The single jury system leads to another saving, prosecutions in Scotland being stopped at an early stage, which in England and Ireland are stopped by Grand Juries, involving cost of attendance, of witnesses, and of court proceedings. In Ireland (if the cost of inquests, £8,094, which the Scotch precedent would indicate to be unnecessary, be deducted) the true cost of the public prosecutor system, £69,025, very slightly exceeded the cost of the English system, £62,015, in a portion of the population equal to that of Ireland. The slightly greater cost of the public prosecutor system in Ireland was far more than counterbalanced by having only 9½ in each 10,000 of the population, instead of 14, as in England and Wales, confined at the cost of the State in goals, convict prisons, and reformatories. These institutions cost only £187,155 in the year in Ireland, as compared with a cost of £239,926 in an equal population in England and Wales, or £52,771 less. The Irish system does not, like the Scotch, meet frauds connected with public companies, and embezzlement on private people: these are left to the private prosecutor, as to which there is a strong demand for a public prosecutor intervening. This arises in part, no doubt, from the idea that crimes of this class seldom occur without some great carelessness or neglect of checking on the part of the person injured making it proper for them to bear the cost of prosecution. This view could, however, be met without entrusting the conduct of the cases to them, with the strong temptation to abandon a prosecution that must disclose their own neglect and want of caution. The true plan would appear to be, not only in those cases of fraud and embezzlement, but in all cases where crimes arose to any considerable extent from culpable carelessness or neglect, or from provocation of the person against whom the crime was committed, to give the court power, while punishing the crime on the one hand, to award, on application of the public prosecutor, the whole or any portion of the costs to be paid by the person whose neglect or provocation led to the crime being committed.

On the Law of Succession to Property. *By* W. Neilson Hancock, *LL.D.*

The author said that few people who discuss laws of succession seem to be aware that there are in England three laws of succession as to property in land, and were, till 1856, three laws of succession as to personal property. They rest, however, upon no general or scientific principle. The differences in the succession of real property depend on the accidents of tenure; those in personal property arose from the customs which prevail in the Province of York, including a large portion of the North of England and in the City of London, and which were recognized as modifying the Statute of Distributions; the differences as to land prevailed for many centuries; those as to personal property for two centuries. In succession to fee-simple all goes to the eldest son and widow, the widow getting a third for her life only. In freehold succession (estates for a life or lives, whether renewable or not) all goes to the eldest son, and the widow gets nothing. In succession to yearly tenancies or leases for years, however many, it goes to the widow and all the children, the widow getting a third (not for life, but absolutely), and all the children taking the other two thirds in equal shares, and the eldest son comes in for this share, no matter how much of fee-simple or freehold he may inherit from the same intestate from whom the personal property comes. As to succession to personal property in the Province of York, land, as well as money, before 1856, constituted an advancement; and, however small the value of the land inherited by the eldest son, it was an absolute bar to his sharing with the other children in the personality under the custom. According to the custom of London, in the matter of advancement, no regard was paid to a freehold estate, but chattel interests were deemed an advancement. As to the succession of widows, the customs of London and York both gave widows their apparel and the furniture of their own room; in York they had, besides, their coffer-box including all jewels, &c. In addition to these privileges, if there be children, they got four ninths of the residue; or, if there be no children, three fourths. In all other parts of England and in Ireland widows had no privilege as to apparel, furniture, or coffer-box, and get only three ninths, or a third if there be children, and a half if there be not. When these various laws of succession are tested by the usages of settlement and devise, they are found not to correspond with the usual dispositions of any class as to landed property. As the disposal of property in England and Ireland rests upon freedom of bequests and settlement, it follows, as a scientific consequence, that when there is, amongst large classes that can be easily marked out by well-ascertained differences, the usual disposal of property at death, the true and scientific solution of the law of succession is to make the law for each such class correspond to the usage. It is upon this principle of recognizing usage that the customs of London and York have prevailed for two centuries. The effect of this would be to leave primogeniture amongst peers and landed proprietors undisturbed. The eldest son should, however, take the property, charged with portions at the usual rate for younger children, and jointure at the usual rate in lieu of dower. Amongst manufacturers and other capitalists the mansion and furniture, and an income to maintain it, would go to the widow, subject to condition of not marrying again, and providing home for her unmarried children. Property, whether real or personal, would be divided so as to give each son twice the portion of each daughter, the sons' shares to go equally, the daughters' shares to form a common fund, subject to mother's appointment amongst daughters and their issue,—with farmers (whether tenants or proprietors), unless there be a son of age, and designated by the father by having been joined with him in the management of the farm, to go to the widow until the youngest son attains 21, then to the son that she shall select; or if there be not any son, in like event to daughters that she shall select. The widow, thus displaced by child in succession, to have her room, furniture thereof, and maintenance; the children who do not succeed to have house-room till 21, and then portions. In the case of professional men and all classes living by salary and wages, the statute of distributions, as modified by the custom of the Province of York, to prevail.

On the importance of Increasing the Punishment of Habitual Drunkards, and of Punishing those who Seriously Injure their Children by what they Spend in Drink. By W. NEILSON HANCOCK, *LL.D.*

The author quoted some Irish statistics, with which he was officially connected, showing that out of 14,416 commitments of men of ascertained bad character proceeded against on indictment and summarily, no less than 5,602, or 39 per cent., were commitments of habitual drunkards. Taking the corresponding classes among women—out of 4,477 commitments the commitments of habitual drunkards were 1,053, or 32 per cent. In the case of men the commitments of habitual drunkards were five times the number of known thieves, and in the case of women three times.

This indicates one of two conclusions—either that the habitual drunkards are a very numerous class as compared with the thieves, or else that owing to the shortness of the punishments for drunkenness the same habitual drunkards are committed over and over again. The statistics do not enable the author to analyze exactly which is the true solution; but it is obvious that if the habitual drunkards are more numerous than the known thieves, something like the punishment of thieves should be applied to such a formidable class. If, on the other hand, it is the same persons being repeatedly committed within the year that swells the number, it indicates how ineffectual the petty imprisonments inflicted are to reform and check the habitual drunkards so punished. The calamitous effects upon the victims themselves of allowing habitual drunkards to proceed in their career unchecked is shown by some other figures. The deaths from excessive drinking in a year in Ireland (128) are more numerous than the manslaughters, murders, and deaths aggravated by neglect (126). In a portion of the population of England and Wales equal to that of Ireland the proportion is still more marked, 115 deaths from excessive drinking, as compared with 93 from manslaughter, murders, and deaths aggravated by neglect. In comparing the serious crime of Ireland with that of England and Wales, it has been for many years from 30 to 40 per cent. less in Ireland than in a corresponding population in England. One marked exception occurs to this rule; in crimes against human life taken together the proportion is the other way. Taking a recent year for example, the Irish figures are greater than the English by about eight per cent. Taking a selection of these carefully examined, it appears that 46 per cent. belong to the less serious class, and 54 per cent. to the most serious class. Of the most serious cases, 57 in number, 27, or nearly one half, were connected with drunkenness or drink—a very large proportion, compared with 6 from party or faction disputes, 6 from malicious ill-feeling, 5 from agrarian crimes between landlord and tenant, 4 from immorality, 3 from protection of game, and 2 from robbery. Of the 243,145 offences determined summarily in a single year in Ireland, no less than 102,394, or 42 per cent., were for drunkenness, or drunk and disorderly. Of the 192,857 classed punishments, 170,056, or 86 per cent., were fines, and only 47 per cent. other punishments. In England and Wales 24 per cent. were other vices punished, and only 79 per cent. fined. From the aspect of these figures there can be little doubt that the habitual drunkards figured largely in these respective cases of fines, which occupied so much of the attention of the courts and police. One other aspect of the statistics should be noticed. Notwithstanding the general and continuous decrease in serious crime in Ireland, when there is an increase in convictions for drunkenness, the author has generally had to notice an increase in offences indicating a low moral tone, such as aggravated assaults on women and children, cruelty to animals, and assaults on peace officers. The State has commenced in England and Scotland protection from one species of parental neglect, that of not supplying education. The necessity of this protection, so far as England is concerned, was shown by the fact that in 1875 there were in England and Wales 21,334 convictions for offences against the Elementary School Act. In Ireland we have no similar protection, as there is no provision for compulsory education in Ireland. The analogy of protecting children by these provisions as to compulsory education suggests protection of them in other respects against the results of undue expenditure in drink, connected as it so frequently is with habitual drunkenness.

The remedies suggested were:—

1. That punishment for drunkenness should take the form of more lengthened detentions, with a view towards reformation; in other words, that punishment should be of a reformatory character.

2. That when reformation became hopeless, the drink-craving should be treated as a physical disease to be treated like any other form of insanity.

3. That the protection of children and wives of men repeatedly convicted of drunkenness should commence at an earlier stage than at present, by the men being, after imprisonment, at first let out on license like younger persons released from reformatories, with a certain supervision and watchfulness over their conduct to their wives and children, to see that they were adequately cared for according to the means of the parent.

On the Assimilation of the Laws of the United Kingdom, with especial reference to the Town Laws of Scotland as to Ruinous Buildings. By W. NEILSON HANCOCK, *LL.D.*

In Scotland in one hundred of the principal towns called Royal Burgs, unber an Act of the Scotch Parliament two centuries old, in all cases of doubtful or insecure title, certain Burg magistrates can, after certain public notice, give a valid charge for the execution of repairs and buildings sanctioned by them. In England and Ireland the corresponding power only dates so recently as 1868, and, instead of extending to all town-buildings, is limited to the single case of artisans' and labourers' dwellings in a state dangerous to health so as to be unfit for human habitation. The Scotch Law further deals with the case of waste and uninhabited houses when the owners are not known, or are unwilling to build or repair in a decent way. The Burg magistrates may, after due notice, have the property valued and sold, preserving the price for the owner. These Scotch Laws are reported by Mr. MacNeel Caird as in successful operation, and their extension to Ireland has been approved of by the Town Councils of Dublin and Belfast. The delay in extending to the whole United Kingdom this simple and wise embodiment of the sound economic principle of promoting improvements by giving security for capital and guarding against the impediments to improvement which defects of title create, shows the backward state of the whole system of the assimilation of the laws of the three parts of the United Kingdom. While the Ante-Union statutes of England have been all revised and expurgated, and a revised edition published some time since, for Ireland and Scotland the similar work has been neglected, the revision of the Irish statutes being thus several hundred years behind the English and Imperial statutes. Thus the very basis of a scientific assimilation of the laws is wanting. If a state provision for carrying out assimilation as far as possible existed, the distinct law of Scotland and Ireland would be studied, and the elements of good in them, as in the present case, preserved, by being generalized and extended to the whole United Kingdom. The defects and shortcomings in them would, on the other hand, be remedied. The past Session of Parliament has been marked by some very wise and successful assimilations, the three Prison Acts for England, Scotland, and Ireland on substantially the same lines, the Irish Judicature Act and the Irish County Courts Acts on the lines of the corresponding English Acts. These legislative achievements only show what wonderful results would be attained if there was a really large and systematic effort at assimilation of the laws of the three portions of the United Kingdom. If the Lord Chancellor, the Home Secretary, the Chief Secretary for Ireland, the Irish Attorney-General, and the Lord Advocate of Scotland were constituted a standing committee charged with this duty, their first step would be to have the expurgations of the Ante-Union statutes of Ireland and Scotland brought to the same state as that of the Ante-Union statutes of England, and to have an expurgated edition of these statutes published. Their second step would be to have the able and succinct account given by Paterson of the differences in the laws of England and Scotland revised and brought up to date. Thirdly, to have a similar account of the differences of the Irish and English law prepared. Fourthly, to have steps taken for the prompt extinction of all non-essential differences in the laws, where the assimilation was easy, obvious, and not strongly opposed. Fifthly, in cases where assimilation was found difficult or was strongly opposed, a careful historical account might be prepared of the origin of the differences of the laws and of the practical working of each form of legislation. The publication of such accounts would have a tendency to diminish opposition, and to lead to suggestions for removing difficulties. Such a work would by its breadth and scientific character simplify the business of legislation, save the time of Parliament, and prevent delay in the adoption of useful reforms, the principles of which are conceded. It would, too, lay the lasting and sure foundation of good government and the contentment of all Her Majesty's subjects in whatever part of the United Kingdom it was their lot to live.

On Rates of Interest and Banks of Issue. By AKIN KÀROLY.

On the Health of Plymouth. By THOMAS LITTLETON, *M.B., F.R.C.S.*

The estimated population of Plymouth, in 1877, was 72,911, that of Devonport 49,449, and that of Stonehouse 14,585; total of the Three Towns, 136,945. The health of Plymouth represented that of a large extent of country—the banks of the Tamar and Plym. The late Rev. J. Wallis (Cornwall Register, 1847), speaking of this district, said:—“ The twelve parishes, &c., form one of the most interesting and beautiful districts in the world, &c.” The health of Plymouth in fortim times had been fully illustrated by Drs. Huxham, Mudge, Yonge, Woolcombe, and Blackmore, Sir S. Hammick, Dr. Butter, and others. Plymouth had been also the subject of a great number of reports in connexion with sanitary matters by Odgers, Rawlinson, Hawksley, A. Rooker, Dr. A. Smith, and Dr. Letheby, and they were now awaiting a report by Dr. Ballard, of the Local Government Board. But it was to the elaborate and exact statistics set fourth by Dr. Farr, in his Supplement to the Thirty-fifth Annual Report of the Registrar-General, that he must chiefly direct attention. The average annual rainfall of Plymouth, as observed by Dr. Huxham, was 30·35 inches. Sir John Forbes stated it at 31, and during the last 12 years Dr. Merrifield had found the average to be 37 inches. Mr. G. J. Symons's statement that it was 44·81 inches represented Ham, Plympton, Dartmoor, &c., and not the town of Plymouth proper. The same is to be understood of Mr. Bellamy's remarks. The chemical examination of Plymouth rain showed its healthfulness in a favourable light. The planting of trees had been spoken of, and a decision given in its favour; but if such were to any great extent indulged in, Plymouth would be injured by so doing. Dr. Huxham's work proved the prevalence of ague, and changes by recovery of marsh lands and drainage had been the agents in its removal. Large tracts of land were recovered in the reign of William and Mary—Chelson Meadow (175 acres) by Lord Morley, and other large tracts at Maristowe, Landulph, Ernesettle, &c. The last of these marshes, between Plymouth and Devonport, had been removed in the time of those still living. As intimately associated with this part of his subject attention must be particularly directed to the excellent water supplied to Plymouth by Sir Francis Drake. As supplied in its unfiltered state it was found to be as follows:—Free ammonia, 0·02 part per million; albuminoid ammonia, 0·09. After filtration through a silicated carbon filter:—Free ammonia, 0·05; albuminoid ditto, 0·03; solids in grains per gallon, equal 4 grains. This water was unequalled, and not surpassed even in the town supply of Glasgow. While speaking thus highly of the town water, he would advise the local wells of Plymouth to be carefully kept, as these supplied a goodly proportion of lime salts, and would prevent by their use very much of the rickets which prevailed amongst children, and leucorrhœa in women. The insufficient supply and bad quality of the milk, as well as overcrowding, had very much to do with the prevalence of rickets. A registration of disease was much required to make known the extent of this and other diseases, which did not affect the death-rate, but diminished very materially the efficiency of the population—a point so judiciously remarked on by Earl Fortescue in his presidential address. By a comparison of the death-rates of this town at different periods they would at once be able to notice the value of sanitary improvements. The death-rate of Plymouth in 1829 was 35·7 per 1,000; 1811, 35·7; 1841–1850, 25; 1851–1860, 24; 1861–1870, 23; 1871–1876, 21·75; and during the past six months ending June, 1877, 21. Zymotic death-rate in last six months, 1·5. The density of population in Plymouth had been doubled in the period between 1841 and 1870. From 1841–50 the acres to a person were 0·4; in 1851–60, 0·3; and in 1861–70, 0·2. The periods of doubling of the population had been sixty years before 1800, and thirty years since that date. If the paper read by Sir James Watson received that attention to which it was justly due they shall see the death-rate in Plymouth still further reduced. The great advantage of increased cubic space in military barracks showed how much of consumption was removable by the increase of cubic space. This evil of overcrowding, the density of population, and the large number of emigrants (10,000 annually) passing through Plymouth were amongst the chief causes of epidemic diseases and the severity which they at times manifested.

On the Amendment of the Patent Laws, referring to several points not hitherto discussed. By Thomas Morgan.

The author said that inventions were of two classes—major and minor. The major referred to those embracing principles of processes or constructions, such as Giffard's injector, Bessemer's steel process, &c.; the minor referred to mere improvements in detail, or to small matters too numerous to particularize. The minor inventions were proposed to be, in the majority of cases, provided for by improvements in the utility of Designs Act: that was by lengthening its term of protection, decreasing its cost, and increasing its legal scope, provision being made that provisional registration under the Designs Act should allow of proceeding to a patent instead of complete registration under the said Act. Mr. Morgan advocated various amendments with regard to the practical operation of the present patent laws, such as could be effected without fresh legislation, and which would avoid the necessity of instituting a body of technical examiners, the objection to which had been fully shown by Mr. Bramwell. This should be coupled, however, with new legislation on one point only, namely, a large reduction of cost—at least one half reduction in all the stages of the cost in the life of a patent; also the addition of a proper permanent commissioner (or commissioners) to the present Commissioners of Patents, the idea being that codification and other necessary improvements would hereafter follow.

On Hospital Mortality. By Dr. Lawson Tait, *F.R.C.S.*

The author said that in order to obtain a proper estimate of the quality of the work done in any general hospital it was necessary to obtain exact information concerning three factors; and it was very much to be regretted that the method of keeping hospital records was generally so careless and inefficient that it was a very difficult matter to obtain correct data. After a great deal of trouble, however, he had been able to extract trustworthy figures from the records of 179 hospitals for a period of six years. The three factors required were the average daily population of each hospital, the actual number of admissions from the 1st of January to the 31st of December, and the total deaths occurring within the walls of the building. By dividing the admissions by the average population a figure was obtained which might be termed the "activity" of the hospital (that is, the number of cases treated per annum in each bed), and dividing 365 by the result gives the mean residence. The death-rate is to be calculated as a percentage on the admissions. Splitting the hospital up into four groups according to size, he found that the activity diminished and the mortality increased just as did the size of the hospital. Selecting amputation below the knee for injury as the best instance for contrasting results, the author produced the following remarkable results, and the figures showed conclusively that the causes of the increment of mortality are intrinsic to the large hospitals, and therefore entirely, or almost entirely, avoidable:—

Hospitals.	Activity.	Gen. mort.	Leg amput. mort.
Under 20 beds	15·20	5·17	23·52
20 to 100 beds	10·86	6·60	28·30
200 and over	12·04	7·98	42·37
Leeds Infirmary	14·21	6·78	20·75
Birmingham General Hospital .	13·08	8·07	42·33
St. Thomas's Hospital, London.	9·03	12·13	47·05

The case of the Leeds Infirmary showed that it was possible, by improved hygiene, to bring hospital mortality down nearly 2 per cent., and was done solely by allowing a larger floor area and cubic space to each patient. The state of St. Thomas's Hospital was, in the author's opinion, greatly to be regretted, and should immediately be altered.

School Banks. *By the* Rev. W. Tuckwell, *M.A.*

The writer, a master of a school, being painfully impressed with the reckless expenditure of pocket-money, adopted the system of penny banks established in the primary Belgian schools. He adopted two systems—a current account with no interest, and a deposit account with 10 per cent. interest on the money being left undisturbed throughout the school term. The bank was opened in January 1876, and, up to the present time, the result had been most satisfactory.

On Improving the Sanitary Condition of Large Towns. *By* Sir James Watson.

There are few subjects more interesting or important than those which relate to the general health of the community, and particularly to that of the sanitary condition of large and populous cities. These affect not only the physical but also the moral state of society. If our population are huddled together in wretched dwellings, so old and ill-ventilated as to be almost untenantable, or so damp and confined from want of sufficient breathing-space as to render them alike unwholesome and dismal, can it be wondered at if such population should either resort to stimulating drinks to relieve their physical depression, or seek for enjoyment beyond their own homes?

That such a state of things should exist to a considerable extent in most of our large cities is much to be deplored, and it is only of late that the public have been awakened to the importance of providing against this serious evil. The author mentioned that the city of Glasgow has been one of the first to set the example of seeking to remedy these defects. The city of Edinburgh, to a limited extent, followed, and it is satisfactory to know that other towns are about to follow their example. In the session of 1860 the author had occasion to bring under the notice of the Social Science Association, at their meeting in Glasgow, the then existing state of the lower portions of the city, showing that in these the population, which numbered from 400 to 1000 in an acre, were crowded together in pent-up lanes or closes of about three and four feet wide, with large tenements of three and four stories rising on each side and running backwards to the extent of 250, and in some cases 280 feet, into which neither the light nor air of heaven could freely penetrate. A large portion of these dwellings were dark, dismal, and unwholesome, devoid of comfort and family accommodation, and inhabited chiefly by the lower and criminal class of the population. When fever or contagious disease broke out in these places the results were appalling. As an instance of this, it has been shown that, even as late as 1871, in one district known as the Havannah and New Vennel, where the population amounted to 3200, 303 fever patients and 16 smallpox patients were in one year removed to hospital at the public expense—in all 319, or 10 per cent. of the population. The death-rate was 70 in the thousand. The moral disease in these districts was not less appalling, the houses being to a large extent receptacles of pauperism, disease, and crime. What rendered this state of things more distressing was the fact that a fresh stream of people from the country, seeking employment, were each year pouring into the city; that from the want of cheap dwellings these people were driven into those haunts, and though respectable when they entered, they very soon fell, by contact with their neighbours, to the same low level.

To remedy this state of things, measures were adopted by the Corporation, at the instigation and under the presidency of Lord Provost Blackie. The city was surveyed with the view of clearing out those objectionable districts, and plans were drawn out with the view of obtaining an Act of Parliament, showing the portions of the city necessary to be dealt with, and scheduling every tenement required for carrying out the scheme.

The plan was a bold and extensive one, seeking to sweep away whole streets of unwholesome houses in order to obtain breathing-spaces, and to form broad, spacious streets and open spaces in their stead, selling the vacant ground for this purpose. Power was asked to expend £1,250,000 in the purchase of property, and to assess by taxation 6*d.* per £ on rental for five years, and 3*d.* per £ for ten years. The scheme, as originally devised, covered an area of 88 acres of overbuilt ground, and included the formation of new streets and improvement of old thoroughfares to the number of forty-five.

In the Parliamentary Session of 1866 the Improvement Act was passed almost without opposition, and immediately thereafter a committee was appointed for carrying out its provisions, over which committee I presided for six years. A tax of 6*d.* per £ on the rental of the city, to be paid by occupiers, was imposed for the first year. Negotiations were entered into for the purchase of properties, and a bank credit was arranged for until the tax could be collected and money borrowed on the security of the trust. As many of the properties required were old and dilapidated, the owners were generally not averse to quit them; and from care and skill on the part of their manager, Mr. Lamb, the committee succeeded for a considerable time in purchasing at a very moderate rate—in many cases from ten to twelve and fourteen years' purchase of the gross rental for dwellings, and eighteen to twenty years' for shops. By the end of the first year the committee had secured, by private bargain, property to the extent of £50,512, and loans had begun to come in freely on the security of the trust at the rate of 4 per cent. per annum. These purchases have gone on from year to year, and, as will be seen from the published accounts, the sum paid for properties up till 31st May last amounted to £1,612,504, of which they have sold to the extent of £830,532. In addition to this the committee purchased and paid £40,000 for a public park for the use of the citizens. The whole of these purchases have been made by private negotiations and friendly arbitration, with the exception of two cases of trial by jury. The principle laid down by the committee, which has been adhered to amidst strenuous opposition, was to begin no improvement until the whole property in the district had been purchased, and also to take care that both sides of the streets should be secured. They consider the adherence to this principle the means by which they have been able to secure properties at a moderate rate, and so promote the success of the scheme.

The tax, which was 6*d.* per £ for the first year, was, in the second, reduced to 4*d.*, at which it was continued for four years, viz. till 1871. Afterwards it was reduced to 3*d.* for two years, and since then to 2*d.* per £, at which it now stands.

In about two years after the passing of the Act there was commenced that process of demolition which has been carried on *gradually* up to the present time, by which old and dilapidated buildings were removed, the haunts of the criminal classes broken up, breathing-spaces opened in pent-up lanes and closes, playgrounds procured for children, old streets widened, and new streets driven through the most densely crowded districts. The effects of these changes on the health of the inhabitants, and more particularly on that of the children, have been very striking, the procuring of open playground having in many cases wholly changed their sickly appearance into that of robust health. During the first four years the operations of the committee were chiefly confined to the purchase of property, to the putting into temporary repair many of the worst dwellings, and particularly in taking down and removing tenements of houses which were dens of fever and disease in the crowded districts.

As recorded in the information given to the Home Secretary:—"It was feared at one time that the dispersion of the low-class population might have a tendency to spread crime and disease, and was a dangerous experiment. None of these fears have been verified; on the contrary, the police and sanitary inspectors have repeatedly certified that the whole condition of the population displaced has been improved, and 'that although paying higher rents in other districts of the city for houses worthy of the name, they are themselves satisfied of the advantages of the change.'" The information furnished to the Government of the operations of the Trust, and a visit from the Home Secretary, led to Mr. Cross bringing in and passing the "Artisans' Dwellings Bill."

The clearances thus effected, along with the other clearances made by the Union Railway Company, have led to a diminution of crime, and have, besides, given a power and control to the police over the parties inhabiting these districts not formerly possessed. It is consequently found, that while between the years 1867 and 1873 there is a diminution in the total cases of crime *annually* reported of 3030, there is an increase in the apprehensions of 749. The criminal returns give the following:—"Total crimes reported to the police in 1867, 10,899; in 1873, 7869.

Total apprehensions in 1867, 5042; in 1873, 5791. This in the face of an increase in the population of 57,483 during that period."

In giving his report in 1871 the chief constable says:—"Through the operations of the City Improvement and the Union Railway the city has been cleared of the foulest dens of crime and profligacy, and their occupants been scattered amongst a population breathing a purer moral atmosphere, thereby affording facilities to the police for bringing the vicious to justice more easily and certainly than when the whole formed a concentrated and combined colony of ruffianism." The death-rate, which was 29 per 1000 in 1866, was 25 in 1876; should this differerence of 4 continue, it would show a saving of life (counting the population at 500,000) of 2000 annually. So many circumstances, however, affect this, that we dare not impute it wholly to these operations, or trust entirely to its continuance.

In about five years after the passing of the Act, the Committee began to dispose of the ground for carrying out the Improvement plans, care was taken not to put much in the market at one time, and the prices realized have exceeded their expectations—in some cases more than sufficient to recoup them, in others less; but the prices realized have been on the whole most satisfactory. In every case the ground has been sold by public sale.

When the operations of the Committee began to be seen, and the want of workmen's houses began to be felt (a want which had existed for some time previously), builders immediately commenced the erection of such dwellings. The rage for building these went on from year to year; new streets of houses of this description have sprung up, until the supply is now in excess of the demand.

In an able pamphlet on this subject by Mr. Morrison, the present able and active chairman of the committee, it is shown, that since the passing of the Act, now ten years, there have been provided 40,460 houses within the municipality, giving accommodation for 202,320 persons, while within a radius of half a mile of the city there has been provided a further accommodation for not less than 100,000, making accommodation for 302,300, to meet the natural increase of the population and the 28,965 persons displaced by the Improvement Act. In alluding to the accommodation thus provided, he says, "he believes it constitutes a fact unprecedented in the history of any city, not even excepting Chicago itself."

In the early stages of their displacements, some fears existed on the part of the committee as to finding accommodation for the population so displaced, and two large lots of building-ground in the immediate vicinity of the town, and costing about £74,000, were therefore purchased, so as to give ground to builders at moderate rates for erecting such houses. The plan proved eminently successful, and has resulted in a profit of about £30,000. In the displacement of so many, the Committee found that there were living in these localities certain poor persons unable to pay for more than the most miserable accommodation, viz. 1*s.* or 1*s.* 6*d.* per week. To provide for such, and as a single apartment in the new buildings could not be had under £5 or £5 5*s.* per annum, or say from 6*s.* 8*d.* to 8*s.* 3*d.* per month, the Committee erected Model Lodging Houses in six different quarters of the city, the cost of lodging, including fire, gas, and cooking utensils being 3½*d.* per night, or 1*s.* 9*d.* per week, Sunday being allowed gratis. These have been taken advantage of to a large extent, and, while self-supporting, have enabled the inmates to live with more security and in a more healthy atmosphere than that in which they were previously located. As yet there has been no case of infectious disease in any of these houses. These, with the exception of a Model Tenement in Drygate, are the only buildings which have been erected by the Committee, the others having been done by private enterprise.

Lastly, as to cost. The property sold and what is on hand, moderately valued, amounted on 31st May last to £1,647,332, while the sums paid amount to £1,612,504, showing a difference of £34,828 in favour of the improvements; so that these, properly speaking, may be said to have paid themselves. Taxes, however, have been raised to the extent of £283,462, and there is still to raise, at 2*d.* per £, for four years, £80,000, making in all £363,462. From this has to be deducted price of a public park, purchased and made over to the citizens, £40,000. If from this we deduct eighteen acres of most valuable ground thrown into streets, and open spaces valued at not less than £100,000, and a further sum for paving streets and for construction of sewers, say £65,000, you reduce the actual cost of the improvements to £178,462, arising from waste rents, interest of ground remaining for a time unbuilt upon before being sold, parliamentary expenses, and expenses of management. In this estimate the author has been anxious not to give the most favourable view of the case.

The result of the operations of the Committee has been entirely to renovate large portions of the city. Wide and handsome streets, with large spacious shops and dwellings, have taken the place of narrow streets and lanes, of old and dilapidated buildings. The narrow closes, where the criminal classes were wont to combine for all sorts of crimes, and from whence they nightly sallied out to rob and plunder, have given place to respectable dwellings. Fever-dens have been extirpated, and, by the aid of the Sanitary Committee, the death-rate has been in these districts greatly reduced. Many of the vicious who inhabited these localities being driven from them, have been forced either to labour or to emigrate. The moral effect produced it is not easy fully to ascertain, and this effect can only be gradual. It must, however, be apparent to every one that there are few things more likely to raise the tone of the working classes than clean and comfortable homes in healthy localities and respectable neighbourhoods.

The author is glad to find that the important town of Birmingham is proposing to engage in the good work; and he hopes the result of what has been done in Glasgow will be sufficient to encourage other towns throughout the kingdom, where reform of this kind is wanted, to follow the example.

On a proposed Reduction to System of the 'Modifications,' or Privileges to work Overtime, which are granted under the Factory Acts to particular Trades. By Sir George Young, *Bart.*

After a preface claiming that the Factory Acts, if rightly considered, were not out of harmony with the principles of political economy, and were even a good exemplification of the principles of legislation which are founded on political economy, the paper proceeded, "The principal enactments under which overtime can be worked are these:—1. Provisions for leave to be given to "season trades" to work overtime to the extent of $1\frac{1}{2}$ or $2\frac{1}{2}$ hours in the day, for a maximum of 72 or 96 days. This applies in some cases to women and boys over 14; in others to women and boys over 16. The list includes the makers of wearing apparel, Christmas goods, &c. 2. Exemptions of lads of 16 from the provisions of the Acts, so that they may be worked as adults. 3. Permission to work "according to the accustomed hours of the trade," which amounts, in fact, to an almost entire absence of regulation. This applies to paper-making and Turkey red dyeing. 4. Suspension of the Acts for particular emergencies, such as the danger of spontaneous combustion in Turkey red dyeing and the gutting and salting of fish immediately on their arrival in the boats. 5. Permissions for night-work in the case of boys over 13. The metal trades, blast-furnaces and foundries, and paper-making profit by these. The working of females at night has never been permitted. 6. Water-power manufactories have been allowed to make up for time lost by flood or drought; but the recent course of legislation has been adverse to the privileges. 7. Half an hour's extra time is allowed to bleach-works and glass-blowing to finish an incomplete process. There are also miscellaneous enactments, consulting the requirements of Jewish employers, of lace factories, glass foundries, &c. The complexity of these rules occasions great difficulty in ascertaining and administering the law. The commissioners recommend that they should be simplified, upon a plan of which the following are the leading principles:—1. They did not interfere with the prohibition of female labour at night. 2. The regulations permitting night-work to boys of 13 would be by their recommendations altered so as to limit the minimum age to 14. 3. They desired to limit, so far as possible, the opportunities of working overtime. 4. They recommend that these privileges should be conceded to whole trades and not to particular trades, on personal application; but as this would enormously increase the opportunities of working overtime, they propose to diminish considerably the maximum which is allowed to be worked.

5. They leave to the Secretary of State a discretionary power to extend the privilege to other trades which fall within the same principle. 6. All exercise of such discretionary power to be subject to the assent of Parliament, obtained by laying the authority for a fixed period on the table of the House. 7. Privileges of recovery of lost time to be reduced to the same rule as those of working overtime. 8. All privileges to work "according to the custom of the trade," or for the exemption of boys of 16 from the supervision of the law, are disapproved. The classes of trades which are defined by the commissioners for enjoyment of the privilege of working overtime are:—1, trades where the material is perishable, and is brought to market in large quantities at one time, as curing of fish, preserving of fruit, &c.; 2, trades where stoppage is caused by weather emergency, as open-air bleaching, brick-making, and (if that form of claim is still to be allowed) mills worked by water-power; 3, trades liable to emergency from a sudden press of orders, as dressmaking, letterpress printing, &c.; 4, trades liable to similar emergency from a press of orders which can be, to some extent, foreseen and provided against, as printers of almanacks and periodicals, Christmas goods makers, and some provision trades. In these latter cases they propose, as an additional check, that the overtime worked shall be repaid out of the ordinary time when the emergency is past." In conclusion, the author expressed a hope that this classification would find its way into the draft of the Factory Consolidation Act before it came on again for consideration in Parliament. He said:—"In legislation, as in every other Act, it is most mischievous to talk as if it proceeded, here and there, in contravention of scientific principles. Science all the while stands patiently waiting, with her hands full of gifts, which are principles. We come to her, like children, for a gift; and, having received it, we run away and put it to all manner of uses, for some of which it is unsuited, till it breaks in our hands. Those who return, time after time, to the fountain of principles to rectify their general conclusions, and learn to apply them more carefully, will not be disappointed in that exhaustless storehouse. When, therefore, in legislation an exception or group of exceptions has forced itself upon us, and broken up the symmetry of our system, it is the part of a wise legislator to set to work to discover the principles which lie behind these exceptions, and to reduce them, in their turn, to rule."

MECHANICAL SCIENCE.

Address by EDWARD WOODS, *Esq., C.E., President of the Section.*

[PLATES III. & IV.]

IN accordance with long-established usage it has been customary for the President of this as of the other Sections to open the proceedings of the Session by giving an introductory address.

Presuming on your kind indulgence, I venture on this occasion to submit to your notice some remarks on a subject which has latterly much engaged the attention of the Railway Companies and of the Government, namely, the question of the application of adequate brake-power to the control of railway trains.

In the summer of 1874 a Royal Commission was appointed to inquire into the causes of accidents on railways, and into the possibility of removing any such causes by further legislation.

One branch of this inquiry naturally led to the consideration of the causes contributory to accidents of the nature of collisions; and it appeared from the evidence taken before the Commissioners that not only was there generally an insufficiency of controlling power in trains, but also that the distance within which a train running at high speed could be stopped by the brake-power ordinarily in use was not ascertained with any approach to accuracy.

It was under these circumstances that the Commissioners applied to the Railway Companies to institute a definite series of experiments to test the amount of control given by the brake-power ordinarily applied to their trains, and the effect of various systems of continuous brakes.

Several of the railway companies at once, and willingly, responded to this suggestion, and, in conjunction with Colonel Inglis, of the Royal Engineers, I was entrusted by the Royal Commissioners with the supervision of an important series of experiments, to the satisfactory conduct of which the Railway Companies contributed in the most liberal manner, placing for the purpose all their resources at the disposal of the Commissioners.

It is mainly to the conduct of those experiments, and to the conclusions that may be legitimately drawn therefrom, that I would now desire to invite the attention of the members of this Section, although I am aware that the subject is one with which many gentlemen present are perfectly familiar.

With a few exceptions, and up to a comparatively recent period, Railway Companies appear to have remained content with the brake appliances which were common forty years ago. These no doubt were sufficient to control the trains of those early days, infrequent as they were in number, and limited both in weight and speed.

The brakes were applied separately and by hand power, always to the tender, and usually to some few of the carriages, and to the guard's van, or vans if such accompanied the train.

As long ago as 1858, and consequent upon reports from their inspecting officers, the Board of Trade had by a circular of their then secretary, Captain Douglas Galton, called the special attention of the Railway Companies to the fact that the amount of brake-power then habitually applied was insufficient to prevent the frequent occurrence of accidents from collisions, many of which might, they considered, have been modified, or averted, had the trains been more adequately supplied with brake-power. Special reference was directed to two systems which had then come into daily use on the lines of the East Lancashire, and Lancashire and Yorkshire railways, viz. the brakes of Newall and of Fay, by means of which trains of ninety tons to a hundred tons weight, at speeds of over fifty miles an hour, could be effectually controlled by driver or guard, even when running down steep inclines, and could be brought up within a moderate distance; whilst the wear and tear of rolling-stock, it was alleged, was sensibly diminished by reason of the more extensive distribution of brake-power over the vehicles of the train.

In fact Mr. Newall's brake had been patented five years before, viz. in 1853.

It seems certainly matter for surprise, in view of the advantages afforded by the application of continuous brakes, as then illustrated in the daily working of the two systems referred to, on several lines of railway, that railway companies should have continued to allow themselves to remain content with the old system, and should have been so slow to avail themselves of advantages which were obviously disclosed in the instances brought under their notice, wherein the brake-power was largely augmented, and instead of being dependent for its due action on the attention of several attendants, was effectually placed under the immediate and prompt control of one.

This lethargy prevailed, too, throughout a period when increased speed came to be demanded, when increasing traffic required heavier trains, and when consequently more ponderous and powerful engines had to be applied for their transport—circumstances, all of which would have naturally, one would think, induced the companies to effect simultaneously a corresponding readjustment and improvement of their brake appliances.

It may here be of interest to glance briefly at the appliances which have been used for controlling trains since tramways and railways have been introduced.

In the early tramways, the necessity for some means of control at once commanded attention, more especially as, in the wooden roads introduced in the North of England and in South Wales during the last century, the course of the lines was made to follow the natural inclinations of the surface of the country; the declivities being often rather steep, and the friction of the vehicles being small, accidents arising from their too rapid descent were of frequent occurrence.

On most of these earlier lines the controlling power was of the simplest kind, being produced by "spragging" the wheels, or, in other words, inserting a bar of wood between the spokes, which prevented them from turning and converted the motion from a rolling to a sliding one.

Brakes, in the proper sense of the term, appear to have come in with the introduction of edge rails; and we read of such being used on the Tyne and Wear Railways, where the wagons were controlled by pressing on the end of a bent wooden lever moving on an axis fitted to the side of the wagon, and rubbing against the opposite surfaces of the two wheels on that side of the wagon.

Here we have presented, in a rude form, the type of the ordinary lever brake now generally in use in mineral and goods wagons.

Such a form of brake, but moving on a vertical instead of a horizontal axis, is in the present day, and probably has been almost from time immemorial, applied to the ox-carts of Spain which travel on the common roads and mountain tracks of that country conveying mineral and other produce.

Such were the rude contrivances which maintained their ground until the close of the first quarter of the present century, though here and there it may have been that some thoughtful mechanic sought to introduce a more perfect mechanism.

That such was the case in one instance is clear from the description, given in 'Desagulier's Experimental Philosophy,' by Charles de Labelye, of a particular form of brake which was applied early in last century, as the writer states, to the "Carriages made use of by Ralph Allen, Esq., to carry stones from his quarry, situated on the top of a hill, to the waterside of the River Avon near the City of Bath."

Here the rails were of oak, the wheels were of cast iron with flanges, the brake a lever brake. The end of the brake-lever, or "jig-pole," as it is there termed, was pulled down by a chain wrapped round a windlass worked by an iron hand spike, whilst the brake-block could be held down to its place until released by raising the pall which had dropped into the teeth of the ratchet-wheel on the barrel.

Here we have the germ of the chain-brake, now so much used on the lines of North America. Hand-brakes of improved construction, worked by levers as applied to wagons, and by screws in the case of carriages, were devised for the rolling stock of the first passenger lines; and brakes of this description, varying in the minor mechanical details, have maintained their ground to the present day, and are generally used in the working of ordinary trains.

It is scarcely necessary to advert to the fact that since the year 1830 many attempts have been made, and patents taken out, for brakes intended to supersede those of the ordinary type—some to be self-acting and operated upon by the momentum of the train; some to act as sledges or shoes; some to nip laterally the upper tables of the rails; but none of these proved to be successful. Brakes acting through the buffer-springs and buffer-bars would stop a train when steam was shut off, and the momentum tended to compress the springs; but from the same cause the brakes could not be kept out of action when backing the trains. Sledge brakes, or shoes, pressed down before the wheels had the effect of throwing the engine or carriages off the rails, and, indeed, were often broken by the shocks which suddenly came upon them.

All these forms, therefore, came to be rejected, and if ever adopted for the regular service of trains, were speedily abandoned.

The continuous brakes of Newall and Fay, however, did not involve any new principle of this kind, but simply proposed a wider distribution of power over the different vehicles of the train, and gave the means of applying and controlling that power by one or at most by two attendants.

It is in this direction that the ingenuity of inventors has of late years been turned; and we have now presented to us several systems of continuous brakes, which are successfully working on many of our leading railways, each claiming some special advantage over its rivals, whether as more simple in construction, less expensive in application, or effecting more complete control of the trains.

The Royal Commissioners desired that our attention should be primarily directed to the following points:—

a. To test the distances within which trains running at various speeds can be controlled by the system of brakes in ordinary use on the different lines in the United Kingdom.

b. To ascertain what results can be obtained by the additional application of brake-power.

c. To determine how far the sudden application of a very large amount of brake-power can be resorted to with safety in heavy trains running at high speed.

A special Committee of the Railway Companies' Association, on which Mr. Oakley, the General Manager of the Great Northern Railway Company, sat as Chairman, was appointed to confer with us as to the course the experiments should take, the trains that should be furnished for the purpose, and the ground on which the trials should be conducted.

We selected for this latter purpose the portion of the Nottingham and Lincoln branch of the Midland Railway which extends from Newark to Thurgaton, as offering a piece of line comparatively level and free from any sharp curves; and through the admirable arrangements made by the Midland Company, we were enabled to carry on the experiments without interruption for the period of a whole week, having free use of the down line of railway, the traffic both ways being worked for the time over the up line.

Six railway companies furnished for the trials eight complete trains with engines and tenders complete. These trains represented as many systems of continuous brakes, comprising four classes, viz.—

Class 1. { Clarke and Webb's brake.
Fay's brake.
Applied by ordinary mechanical gear.

Class 2. { Smith's Vacuum brake.
Westinghouse's Vacuum brake.
Actuated by atmospheric pressure produced by exhaustion of air.

Class 3. { Westinghouse's Air brake.
Steel-McInnes's Air brake.
By air pressure.

Class 4. { Clarke's Hydraulic brake.
Barker's Hydraulic brake.
By hydraulic pressure.

The ground chosen for the trial was measured and staked out with a view to obtaining accurate records of the speed of the trains before and after the application of the brakes.

It was also levelled, and the gradients thereby carefully determined and laid down in section. The part on which the brakes were generally applied was a dead level. The War Office placed at our disposal the valuable services of Captain (then Lieutenant) R. G. Scott and Lieutenant M. H. P. R. Sankey, of the Royal Engineers, aided by twelve non-commissioned officers and men of that corps. With their aid we were enabled to record in full detail, and with great accuracy, the particulars of each train and of each experiment.

The speed of the trains was ascertained by means of stop-watches, and to ensure further correctness independent results were recorded by an electric instrument. This was arranged to record in half seconds the time the trains should take to pass over a definite number of the spaces. By clockwork arrangement a long slip of paper was unwound from a drum and passed between rollers. The time corresponding with half-second beats of the pendulum was marked upon the paper by a pecker in red ink, and when the flange of the leading wheel of a train passed one of the posts the instant was denoted by a mark in black ink made on the paper slip by another pecker actuated by a magnet. Opposite each post a circuit closer was fixed to the inside edge of the rail, and when the flange of the wheel pressed down the lever, the circuit was closed and the magnetic action induced.

The time was measured by noting the positions on the tape of the black or space dots with reference to the red or time dots, which denoted the half-second intervals.

It was arranged that each train should correspond with that of an ordinary fast passenger train, with average load consisting of engine, tender, thirteen passenger carriages, and two brake-vans, and that each carriage should be loaded with a weight corresponding with three quarters of a cwt. per seat, to represent an average load of passengers with luggage, and that each van should be loaded with a weight of 2 tons, as representing the average weight of luggage it conveys. The Companies had the option of using either 4-wheel or 6-wheel carriages.

Subject to those conditions the trains varied considerably in gross weight, which ranged from 130 tons to 195 tons in respect of the fifteen loaded vehicles, and from 200 tons to 260 tons when the weight of engine and tender was included, the heaviest trains being those of the Great Northern, and London and North-Western Railways, as being made up of 6-wheel carriages, all the other trains being furnished with 4-wheel carriages.

All the comparative trials, class by class, were made, as nearly as circumstances would permit, at the same time and under the like conditions of weather, state of rails, &c.

The trains were started from a point near Newark, about three miles from the signal-post at which the signal to put on brakes was given, in order that they might acquire the requisite speed. Owing to the differences in weights of trains, and to the different powers of the engines applied to them, it was not possible to ensure equal rates of speed at the time of signalling to stop; but by computing the *vis viva* of the train in each case and dividing this by the stopping distance, the mean retarding force is obtained in each case as a coefficient of the weight of the train.

The Royal Commissioners were desirous that, if possible, some graphic mode of presenting the results should be arranged, so that by a glance, and without the need of reference to the Tables which would of course accompany our Report, the relative efficiency of the different brakes might be seen.

We accordingly devised the means of doing this by diagrams, of which the one now before the Section is a specimen (Plate III.).

We were led to this method of exhibiting the duty done by the following considerations:—

The work done from first to last in the act of stopping a train by brake-power, or otherwise, is necessarily equal to the *vis viva* or accumulated work which the train possessed at the moment of commencing the stop *.

The *vis viva* which a train possesses at any moment is that which it would have acquired in falling vertically through the height required to produce the assigned velocity in a body falling freely from a state of rest under the action of gravity.

Thus the *vis viva destroyed* in the act of stopping is represented by the weight of the train lifted through the vertical height in question, the condition necessary being that the *vis viva* can only be exhausted by the train rising on any given gradient to the height due to its velocity.

Supposing, then, that at a given point of its course the propelling power of a train should be suddenly arrested, and that at the same point it should be made to enter upon a rising gradient, it would continue to run (setting aside for the moment the question of friction) until it reached a point on that plane the vertical elevation of which shall be equal to the height which would suffice to produce the particular velocity which the train had attained on reaching the foot of the gradient.

If the gradient be a gentle one, the distance run before the train is brought to a stop will be considerable, and in proportion to its increasing steepness so will the run be shortened.

Taking such gradient as a convenient measure of the forces applied to stop a train, its effect is represented by the inclination of that gradient, taking its height as that due to the initial velocity and its length as the distance traversed during the stoppage.

A diagram can therefore be constructed by setting off by scale, from a zero point on the base line, a gradient the length of which shall equal that of the distance of the stop and its height the vertical height through which a body falling from a state of rest would attain the observed velocity of the train at the time of the commencement of the stop.

This becomes the measure of all the forces concerned in producing the stop,

* *Vis viva* (in foot tons) $=M\frac{V^2}{64 \cdot 4}$, M being the weight of train in tons, V its velocity in feet per second.

inclusive of brake-power, friction, and gravity, which latter force comes also into operation either positively or negatively, according as the stop is effected on an ascending or descending portion of the railway.

The retarding force assumed as uniformly acting throughout the period of the stop, such as friction, or brake-power, or gravity, or all combined, can therefore be *compared with* and *measured by* the force of gravity acting on a gradient opposed to the motion of the train.

That force, as measured by the supposed gradient, admits of being expressed in various ways, but preferably for our purpose (as we considered) by referring the vertical height of the plane to its length as a *percentage* of the latter.

The figure representing that percentage will of course also represent the effect of gravity on that plane; and is therefore the coefficient of the weight of the train.

The course of our experiments, which extended over the period of a week, comprised several series: one for ascertaining the friction of the carriages and vans, apart from the application of any brake or other retarding power under the control of the attendants; another for determining the frictional resistance of the engines and tenders; and lastly one for measuring the value of break application under varied combinations.

1. Friction of Carriages.

Six trains of fifteen vehicles each, but detached from their respective engines and tenders, were propelled successively past the zero or signal post, where the propelling power was suddenly withdrawn, when the trains were allowed to run freely forward until they stopped.

The speeds at the zero post ranged from 27 to 42½ miles per hour.

The distances run during the stop ranged from 1½ to 3 miles.

The Great-Northern train, weighing 199 tons, at 42½ miles per hour, stopped in a length of 15,189 feet; the London and North-Western train, 188 tons at 42 miles per hour, in 15,054 feet—giving a mean retarding force in those particular trains of ·35 per cent. of their weight, or about 8 lbs. per ton.

The mean of the entire series gave a slightly higher figure.

2. Friction of Engine and Tender.

In like manner it was found that the friction of engine and tender coupled together, no brakes being applied, amounted to ·62 per cent. of their combined weight, being about 14 lbs. per ton.

Hence it may be assumed that the friction of a complete train (in which the weight of engine and tender constitutes, say, one fourth of the gross weight of the train), inclusive of the atmospheric resistance it encounters in its course, may be taken at ·42 per cent., being about 9½ lbs. per ton.

These results confirm what long experience would lead us to anticipate.

3. Effect of Hand-Brakes.

With the exception of a few passenger trains of some of the leading companies, the bulk of the passenger traffic of the railways in this country had been conveyed in trains possessing hand-brakes, one to the tender, and one to each van, the former worked by the stoker, the latter by the guards.

It thus became important, in the view of the Royal Commissioners, to ascertain with precision what is the controlling power which these appliances afford.

The suitable trains were those furnished by five of the Railway Companies, viz. the London and North Western, the Caledonian, the Midland, the Great Northern, and the London Brighton and South Coast, when it was found that the total mean retarding force induced by the application of hand-brakes to tender and to the two vans amounted, inclusive of ordinary friction, to 2·36 per cent. of the gross weight; equivalent to encountering a gradient of 2·36 per cent., or 1 in 42. The mean gross weight of these trains, including engine and tender, was 226 tons, and their mean speed at the time of cutting off steam was 47⅓ miles per hour.

The effect of such brakes was, in fact, such as that on a level railway a train running at 45 miles per hour would be stopped in the space of 1000 yards, or if at 60 miles per hour in the space of 1700 yards or about *one mile.*

The necessity for some greater control over fast passenger trains than that afforded by hand-brakes to engine and vans was rendered obvious by such a result, and the Royal Commissioners accordingly reported as follows:—

"It appears that the amount of hand-brake power usually provided with the trains of the respective Companies failed to bring up the London and North-Western train within 2374 feet; that of the Caledonian within 3190 feet; that of the Midland within 3250 feet; that of the Great Northern within 3576 feet; and that of the Brighton within 3690 feet—the speed of the trains varying from 45·5 miles to 48·5 miles per hour.

"These trains were in the most complete order, and the guards and drivers had notice of the exact spot at which the signal to stop would be given.

"A large addition must therefore be made to these distanees in practice, and unless much greater control is obtained over trains by additional brake-power, it is clear that to ensure safety the distance signals must, for a level line, be carried back to the distance of a mile."

It is to be observed also that from the want of a larger amount of brake-power much time is lost on the journey when the stoppages are frequent, the drivers being compelled to slacken speed at such long distances from the stopping-places.

The suburban lines have not been slow to recognize this advantage, and hence continuous brakes have been generally introduced on the North London and on the underground lines of the Metropolis.

It seems, indeed, scarcely to admit of question that a system, which may be deemed almost a necessity in such special cases, would not be advantageously applicable in all cases, and that, in fact, to render the control of a train complete brakes should be adapted to all or nearly all its wheels, and that at least the driver if not the guards should possess the power of promptly bringing the whole of them into action.

The truth of this principle seems to be now very generally admitted by all our leading Railway Companies, and it will be seen, from a return made by them recently to the Board of Trade, that they appear to be fully alive to its importance; that some of them have adopted systems of continuous brakes which in their judgment answer the ends desired; and that others are preparing to make trial of inventions which promise better results.

It was not part of our duty to the Royal Commissioners to select for commendation any one or more of the systems presented for trial. We had only to conduct the trials with all possible care, and to record faithfully the facts which those trials disclosed.

It is true that some rather startling disparities in the operation of the different systems of brakes were disclosed during the course of our experiments; but this we considered might, to a certain extent, have been fairly expected from the circumstance that many of the contrivances were of comparatively recent origin, and that from want of sufficient time some of the mechanical details had to be hastily settled, and could not therefore be properly tested and corrected beforehand.

Some of these disparities, however, appeared to be incidental to the principle upon which the action of the brake was founded, and in particular we had to notice the marked effect resulting from the differences in the intervals which elapsed between the times of applying the power and the times when the pressure on the blocks attained its full effect, as between the air pressure and vacuum breaks we noticed a loss of $6\frac{1}{4}$ seconds, which, in a train running 60 miles per hour, is equivalent to 180 yards additional space traversed in the stop.

Brief mention has already been made of the systems of continuous brakes submitted for trial. There were:—

1. Two forms of brake in which the power was transmitted by wheels, chains, rods, and levers, viz. Clarke and Webb's (London and North Western) and Fay's (Lancashire and Yorkshire).
2. Two forms in which the power applied was that of the pressure of the atmosphere induced by vacuum formed in pipe and vessels, viz. the

Westinghouse vacuum (London, Brighton, and South Coast) and Smith's vacuum (Great Northern Railway).

3. Two forms in which the power was that of compressed air forced through a continuous pipe into suitable vessels and operating upon pistons: Westinghouse's Automatic (Midland), Steel and M^c^Innes' (Caledonian).
4. Two forms in which the power was transmitted by pressure of water pumped through a continuous pipe against pistons working in cylinders: Barker's Hydraulic (Midland), Clarke's Hydraulic (Midland).

These brakes have been so frequently described in detail that it may not be needful to do more than glance at some of the points in respect of which they differ.

Of the *mechanical* brakes, Fay's is worked by hand-gear in two separate sections, actuated each from its own van. Blocks are drawn on to the wheels by means of a shaft passing under the centre of each carriage, with sliding-jointed connexions rendering it continuous throughout each section of the train, and made to rotate by a vertical shaft and hand-gear in the van.

Clarke and Webb's brake is also applied to the train in sections, but the power to work it is derived from the momentum of the train itself. This is transmitted by means of a friction-pulley fixed on to the axle of the guard's van. Another friction-pulley, with barrel and chain on the same axis, is brought into contact with the first by the guard releasing a lever in the van. The chain is thus wound up, forcing the brake-blocks on to the wheels. The driver, too, is able to put on the brakes by pulling a cord which extends from the tender to the vans.

Fay's brake, and also *Newall's*, which it closely resembles, have been generally adopted throughout the Lancashire and Yorkshire system, where they have been in use for twenty years, and it is stated that all the passenger-trains are fitted with and controlled by them.

On the North-Staffordshire line all the passenger-trains, with one exception, have been fitted with slide-brakes after the manner of Fay's, and these, the Company state, have been found to answer the requirements of the line.

No train fitted with Newall's Brake was presented to the Royal Commissioners for trial. In addition, however, to its use on the Lancashire and Yorkshire system, it has been adopted since 1863 on the Highland Railway for all their through passenger-trains.

The London and South-Western Company has applied it to 110 of their brake-vans, and the North-Eastern Railway to 55 vans, as also to some of their carriages.

Clarke and Webb's brakes have been extensively adopted on the London and North-Western system. According to a published return as many as 943 of their carriages have been fitted with the brake apparatus, and 712 with the attachments to enable them to be worked in the continuous sections. The remainder of the stock is being thus fitted. On the North-London line twenty-three trains are running with an improved brake, which is gradually displacing Clarke's original chain-brake, with which all the trains were fitted about twelve years ago. Trials of the brake have been made on the Caledonian, Great Eastern, and Great Northern and Midland lines.

In the Westinghouse Vacuum Brake and Smith's Vacuum Brake the exhaustion of air is effected by one or more air-ejectors worked by steam-jet fixed on the engine. To apply the brakes it is only necessary to exhaust the air from the pipes, which, in the case of the Westinghouse, connect with a pair of cylinders with pistons placed under each carriage; and, in the case of Smith's, with collapsing India-rubber bags or cylinders, one to each carriage, and the movable ends of which are connected with the brake-gear of their respective carriages.

In the first and rear van of the Great Northern train thus fitted with Smith's brake was an air-exhauster, worked as might be required by means of friction-wheels from the van-axle, to enable the application of brakes to be made on an emergency and independently of the Ejectors. These Exhausters are also started by the action of the Ejectors.

The *Westinghouse Vacuum Brake* is used on the London, Brighton, and South Coast line, and in the train which was made the subject of several of our experiments at Lincoln; but its application in this country has been greatly superseded by the later inventions of Mr. Westinghouse, in which compressed air is made the motive power. On the other hand, Smith's Vacuum Brake has been adopted with advantage in all the trains of the Metropolitan Railway Company; and it has been so far approved by the Great Northern Railway Company that they have already fitted fifty engines and 168 carriages, and are preparing to fit more of their stock as fast as they can procure the material. The Great Eastern, Great Western, Manchester, Sheffield and Lincolnshire, Midland, South Eastern, North Eastern, North British, and Lancashire and Yorkshire railways have applied it to a more limited extent, some of them by way of experiment.

Compressed-Air Brakes.

Of the Compressed-Air Brakes, the system most extensively introduced is the *Westinghouse,* which in its latest form has been made automatic.

In this system air is forced under a pressure of about 60 lbs. per square inch into a main reservoir of about 9 cubic feet capacity placed underneath the foot-plate, and a line of tubing extends therefrom throughout the train. Each vehicle is fitted with a small reservoir and a brake cylinder, the reservoirs and tubing throughout being filled with compressed air at a uniform pressure. By reducing the pressure in the main to a slight extent, valves are opened which permit the air to enter the cylinders and press the brakes home. The severance of the main produces the like effect.

In the Steel-McInnes system there are *two* main-pipes. Each carriage carries a vertical cylinder, with piston and rod to communicate the pressure to the brake-gear, and a small air receiver on its lower end. Receivers, cylinders, and connecting pipes throughout are kept charged with compressed air by means similar to those of the Westinghouse; and to apply the brakes a differential pressure on the pistons is established by opening a cock which allows the compressed air to escape from above the pistons. The same action follows if the pressure of air in the pipes be relieved by any accidental disconnexion of them.

The *Westinghouse Automatic Air-pressure Brake* has been rather extensively adopted on the Midland and the North British Railways; on the Midland 57 engines and 166 carriages have been fitted with them, and many more vehicles are in progress of fitting. The North British Company have fitted 15 engines and 100 carriages, and purpose increasing the number as may be required. They state that they have adopted this brake as being, in their opinion, the best that has yet been devised.

The London, Chatham, and Dover, the North-Eastern, the Caledonian, the Glasgow and South-Western, and the Lancashire and Yorkshire Railways have fitted or are fitting up engines and carriages for trial of this form of brake.

Hitherto the application of Steel and McInnes' Brake appears to be limited to the Caledonian Railway, where it has been in use for two years on the Edinburgh and Glasgow section.

The *Hydraulic Brakes of Barker and Clarke* are worked by water under pressure, conveyed through continuous tubing along the length of the train. The pressure is obtained in Barker's by a double-acting steam-accumulator on the engine; and in Clarke's by a loose piston, without a rod, resting in its normal position at the bottom of a vertical cylinder, filled with water, fixed under the foot-plate of the engine; when steam from the boiler is admitted beneath, the water is driven into the tube and thence into the carriage cylinders. In Barker's each carriage is fitted with a pair of cylinders on rams, in Clarke's each carriage carries a single cylinder. The brakes were not arranged in the experimental trains to be self-acting in case of a train parting asunder.

On the Midland Railway two engines and twenty-six carriages have been fitted with Barker's brakes and are there working; and it has also been tried on the Monmouthshire section of the Great Western Railway, as also on the Crystal Palace line of the London, Brighton, and South Coast Railway.

I am not aware that Clarke's Hydraulic Brake has been fitted to any other train than that of the experimental train of the Midland Railway, which was the subject of trial at Lincoln.

Results of Lincoln Experiments with Continuous Brakes.

The experiments to ascertain the effect of Continuous Brakes were arranged in several groups, three of which involved the application of all available power for stopping, sand being allowed to be used in two sets of trials out of the three. It was found that the application of sand, in combination with brake-power, added sensibly to the stopping-power, and on an average might be estimated as giving an addition of 1·30 per cent. to the retarding force otherwise brought into play. The trains were stopped by flag-signal, the driver and guards doing the utmost the means afforded them allowed for bringing the train to a stop in the shortest possible distance. Not using sand, the retarding forces operating were found to range in the respective trains from 4·94 to 10·04 per cent. of their weights, corresponding with the effects which would be produced by the trains encountering gradients of 1 in 20 and 1 in 10 respectively.

Barker's Hydraulic, Clarke and Webb's Mechanical, Fay's Mechanical, and Smith's Vacuum Brake produced retarding forces varying from 6·47 to 5·72 per cent. of the gross weight, forming a group giving an average of 6·04 per cent. of retarding force, from which amount no deviation greater than 0·42 per cent. occurred either way.

The diagram (Plate IV.) illustrates this group of experiments.

Three out of the four brakes last named, viz. Barker's, Clarke and Webb's, and Fay's, gave, when sand was used, an average of 7·79 per cent. of retarding force, and none of them differed from that mean by more than 0·15 per cent.

These trials served to show in a very striking manner the great advantage obtained by the application of a continuous brake; for even in the least effective form in which the system was presented to our notice, more than double stopping-power was afforded than by the usual system of hand-brakes; whilst in the most effective form the stopping-power was quadrupled, enabling, in the latter case, a train travelling at 60 miles an hour to be pulled up on an emergency within a space of 400 yards instead of the mile required in the case of hand-brakes to tender and vans.

The highest amount of retarding force obtained in any of our trials had been 10·64 per cent. of the entire weight of the train, a force which stopped a train, weighing 208 tons, from 51 miles an hour in the space of 275 yards.

In this instance the continuous breaks were applied to seventy wheels out of the seventy-two wheels on which the train ran; and 94·4 per cent. of the total weight was supported by those seventy braked wheels.

This performance is above the *average* of the several systems; but I am of opinion that no system of continuous brakes should be regarded as satisfactory or otherwise than provisional which should not afford a retarding power equal to *at least* 8 to 10 per cent. of the entire weight of a train; in other words, a power by which the stoppage of fast trains can be effected in from one third to one fourth the distance required under the ordinary brake appliances.

It may be believed that the range between 5 per cent. and 10 per cent. of retarding force, as afforded by the brakes used in our experiments, involving a corresponding range of difference in the stopping distance, will be greatly reduced now that much experience in their working has been gained.

Indeed it is satisfactory to note that already better results have been attained, especially in the case of the Smith's Vacuum Brake and the Westinghouse Automatic.

I find in No. 601 of 'Engineering,' July 6, 1877, the record of a series of twelve trials on the North-Eastern Railway of each of these two systems of brakes, said to have been conducted with great care, giving as the average result of each set of trials no less than

$9\frac{1}{2}$ per cent. of gross load in the case of Smith's Vacuum, and

$12\frac{1}{2}$ per cent. in the case of the Westinghouse Automatic, as the respective retarding forces developed where the gross weight of train was 170 tons, and the initial speeds ranged from 44 to 64 miles per hour.

It is obvious that the stopping distance is influenced by two primary conditions:—

First, by the length of the interval of time which occurs between the moment of performing the operation which has the effect of putting the brake into action, and the moment when the brake-blocks begin to place an effective grip upon the wheels, and

Secondly, by the amount of pressure brought to bear on each wheel, and by the constancy or otherwise of the action after the blocks have come to grip the wheels.

It would not appear to be a difficult task to arrange the proportions of the parts of the mechanism of any brake in such wise as to ensure that an assigned and definite pressure shall be brought to bear on each block; and it is doubtless from the want of such suitable adjustment that the pressure in some of the examples of continuous brakes is found to be too feeble for accomplishing a rapid stop.

The reduction of the interval of time elapsing before the pressure is fairly put on may not so easily be effected, being in a measure incidental, more or less, to each specific form of brake.

That much room for improvement remained in the way of effecting an equal and constant pressure on the wheels throughout the period of the brake-action was evident from the results brought out by an analysis of the time-records.

These have been translated into the form of the submitted diagram (Plate IV.), from which it will be observed that the retarding force, in its earlier stage, instead of being uniform and constant, is broken up into a series of impulses more or less violent, but becoming more uniform towards the close of the period of its action, a condition due probably to the increasing number of the wheels which had become skidded.

The diagram serves to illustrate this effect. It has been prepared from the electrically recorded time-observations.

The ordinates represent by scale the mean speeds at successive intervals of space traversed.

The curved lines connecting the extremities of the ordinates thus show approximately the variations of the retarding force.

It is this intermittent fitful action which produces undue strains on the drawbars and chains, and the unpleasant sensation frequently experienced during quick stops.

It would seem that after the brakes are first brought to bite the wheels, their hold becomes relaxed, a slip takes place, followed by successive bites and slips, the latter giving rise to sudden accelerations of speed.

The action of a perfect brake should exactly resemble that which gravity would cause if an ascending incline of uniform gradient could be suddenly presented in front of the train to stop its motion.

Under such conditions no inconvenience or danger is to be apprehended from accomplishing the stop in even shorter distances than any effected during the course of our experiments.

Practically no inconvenience was experienced in stopping one of the best appointed trains, 200 tons in weight, running at over 50 miles an hour, in a period of 18 seconds; and generally the stops were effected without unpleasant sensation, though in some instances the recoil of the buffers at the final moment of stoppage gave rise to a sensible and disagreeable jerk.

It became obvious, during the course of our experiments, that a valuable addition of brake-power, under the immediate control of the driver, was afforded by the fitting of breaks to the engines; and it is satisfactory to find that the recommendation of the Royal Commissioners in this respect has met with the prompt attention of Railway Companies.

We learn from the Board of Trade return already referred to, that about 250 engines have been so fitted, about 100 engines with the Westinghouse, 100 with Smith's Vacuum, 30 with Stroudley's Steam Brake, and the rest with the brakes of Saunders, Barker, and the Steel-McInnes, showing how fully the importance of utilizing the heavy weight of the engine is becoming appreciated, and affording proof at the same time that the apprehensions of injury to the engines entertained by some of the locomotive superintendents are virtually without foundation.

It is believed that far less objection attaches to the application of brakes to the engine-wheels than to the act of reversing by back steam, whilst such reversing was proved by our experiments to be less effective than brakes.

The measure of brake-power developed in the engine may be illustrated by the following experiments which we made:—

A North-Eastern Company's engine, 40 tons weight, with tender 27 tons (altogether 67 tons), and travelling at 59 miles an hour, was brought up by Smith's Vacuum Brake applied to the engine only in 617 yards, giving a retarding force of 4·22 tons or 10·50 per cent. of the weight of the engine, an important factor when it is considered how large a portion of the gross weight of a train is represented by its engine.

On several of the continental lines, on a few of our railways here, and notably on the Highland railway, the Chatelier or Counterpressure Brake has been applied to the engines with considerable advantage, and this may in cases of emergency prove a valuable auxiliary to the engine-brake.

The Locomotive Superintendent of the Highland Railway Company has favoured me with some details of its working on that line, where it has been applied to 60 out of their 67 engines. "Generally speaking, it is not used on that line every day, and never in stopping at stations if approached at the ordinary speed; nor by the majority of drivers is it used to control the trains down the banks in ordinary working, but each driver can refer to cases in which it was of great use, especially by the service it has rendered going down banks in snow, when the ordinary brakes had lost their effectiveness."

When the reversing lever is pulled back to cut off at 40 per cent., the retarding force produced by back-pressure steam appears to be just sufficient to prevent acceleration in the speed of a train of 180 tons weight, inclusive of engine and tender, on a descending gradient of 1 in 70.

The question of the best material for brake-blocks has of late received a good deal of consideration, and it would seem that cast-iron and even steel blocks are fast superseding wood. The majority of the trains sent to Lincoln for the trials were fitted with cast-iron blocks, the only important exception being the Lancashire and Yorkshire Company's train (Fay's Brake), which was furnished exclusively with wooden blocks.

We were unable to discover any clear indication of the one being superior to the other in skidding power; but doubtless the wear of iron blocks is much less rapid.

We had occasion to observe that with none of the Continuous Brakes used did the wheels become skidded until a very considerable reduction in the speed of the train had taken place.

When the rails are in a damp and greasy state it is likely that cast iron or steel blocks displace sooner than wooden blocks the film of slimy matter which forms on the tyres of the wheels, a film which may become impressed and embedded into the soft substance of the wood, preventing, until removed by prolonged pressure, a full and powerful bite on to the wheels.

It is to be remarked that the utmost brake-power obtained scarcely exceeded 10 per cent. of the weight of the braked vehicles; whereas, from the experiments of Morin, Rennie, and others, it has been shown that the coefficient of friction of iron sliding upon iron, the surfaces being clean, is from 1-5th to 1-6th, say 16 to 20 per cent. of the insistent pressure.

The discrepancy is to be accounted for by the circumstance that during the larger portion of the space traversed in effecting the stop, only few of the wheels become skidded, and for the remaining portion not all the wheels come into that condition.

Nor does it seem desirable that such should be the case; for without doubt the wear and tear of wheel-tyres and of rails is sensibly increased by skidding.

For ordinary stops, therefore, the brake-pressure should be adjusted to act just short of skidding the wheels, whilst the full skidding power should only be applied in cases of imminent danger.

A difference of opinion exists on the question of the relative effects of skidded and unskidded wheels in effecting the stop; but this we considered was set at rest by two experiments with a train of six of the Midland Railway Company's four-wheeled vans coupled together and formed into a single train, each van having its own guard to apply the brake-power by hand. All the wheels of this train had brakes.

The speed being about 40 miles an hour in each case, stops were effected with the following results :—

1st. With force applied to brakes just short of skidding, stopped in 226 yards; retarding force 7·74 per cent.

2nd. With all the force that could be applied, stopped in 192 yards; retarding force 9·28 per cent.

Thus it was found that the skidding had added about 20 per cent. to the force produced by the same brakes when they did not skid the wheels.

It is clear that the ultimate resisting force is derived from the rails; consequently the effect under the differing circumstances of skidding or not skidding is proportional to the difference of the space traversed by the train and that described (on the average) by the tyres of the several wheels. If the wheels could be taken as being all of them skidded throughout the entire period of the stoppage, that difference would be represented by the space traversed, and then the retarding force would be a maximum; whereas if the wheels continue to revolve at a rate below that due to the speed of the train, the "slip" will represent so much retarding power lost.

The superiority of Continuous Brakes over brakes of the ordinary kind appears to be practically admitted by all railway companies, seeing that a good Continuous Brake will reduce the stopping distances of fast trains to one third of the distance within which they can be stopped by ordinary means.

The general adoption of some one effective system of Continuous Brakes on carriages which have to run from one line to another would certainly be productive of much advantage; for even in breaking up and remaking a train at any junction-station they would be found fitted with the appliances requisite for working together, and for availing of the common source of power which may be afforded by the engine or by the vans. Otherwise the specially fitted trains must be arranged to run through from end to end of the line, or passengers to whom is accorded the security afforded by the continuous brakes, must change from one train to another when entering a line of railway on which some other system of brake is employed.

If the allied companies could agree to adopt the same system there is little doubt but that the conversion of ordinary into continuous brakes would proceed with far greater rapidity than would be the case on the other assumption, and that the public would at a much earlier period be found to enjoy the full benefit of the change. Nevertheless, and until sufficient time has been allowed for testing under all circumstances the merits of the different systems now on trial, it may be scarcely reasonable to expect the present adhesion of any considerable number of railway companies to one particular system.

The time, however, has arrived not only when each system should be scrutinized and tested in the most complete manner, but when the companies should clearly set before themselves the conditions which a good continuous brake should satisfy.

A study of the different systems of brakes which came under our notice, and their behaviour under the different circumstances of their application, seems to point to the following as the conditions which a perfect continuous brake for heavy fast trains should be called upon to satisfy :—

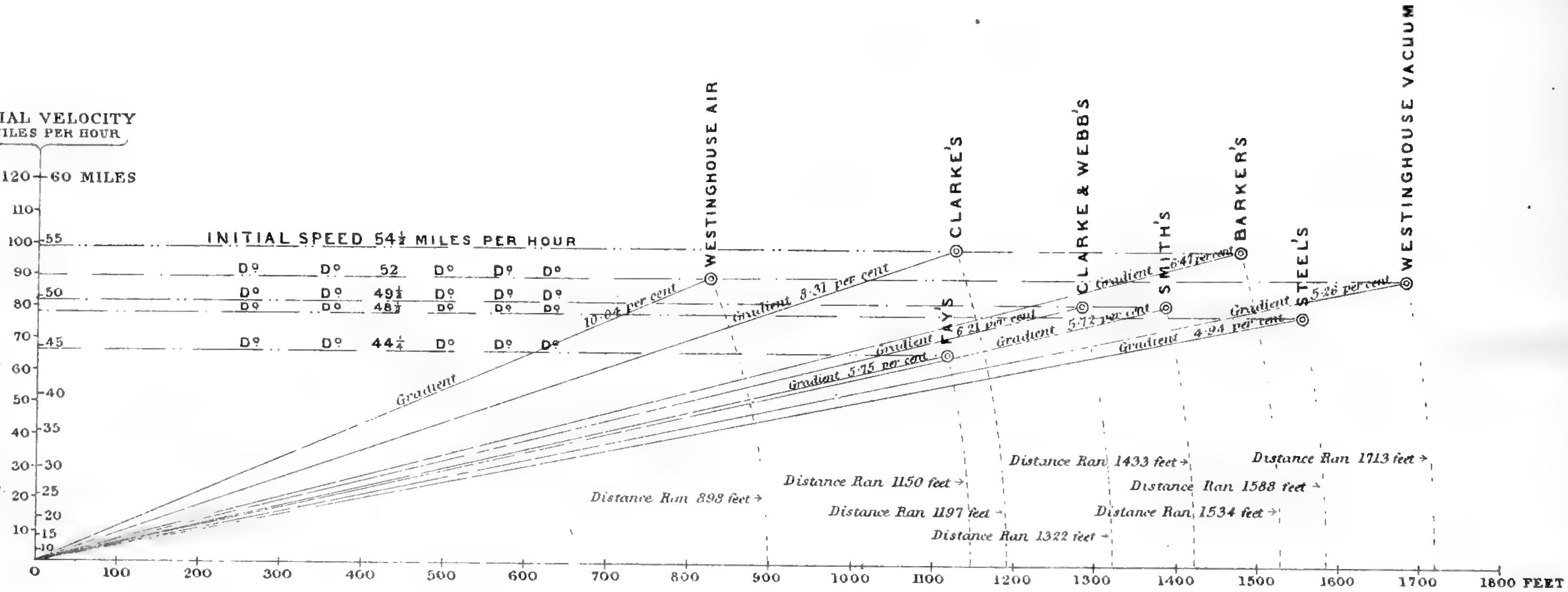
1st. The brake-power should be applied to all the wheels of all the vehicles throughout the train.

2nd. The power by which the blocks are forced upon the wheels should be adequate to skidding the wheels upon the speed becoming moderately reduced.

3rd. The Driver should have the whole of the brake-power of the train completely under his command, and be able to apply it at a moment's notice, as he is the first person likely to discover any obstruction ahead, and is primarily responsible for the regard of danger signals. He can thus stop the train at once, and no time is lost by his having to signal danger to the Guard.

4th. The Guards should individually possess the like means of applying the continuous brake, that they may be enabled to stop the train without referenc to the Driver on an emergency which may have manifested itself to the Guard, but

Diagram shewing Relative Efficiency of Brakes.

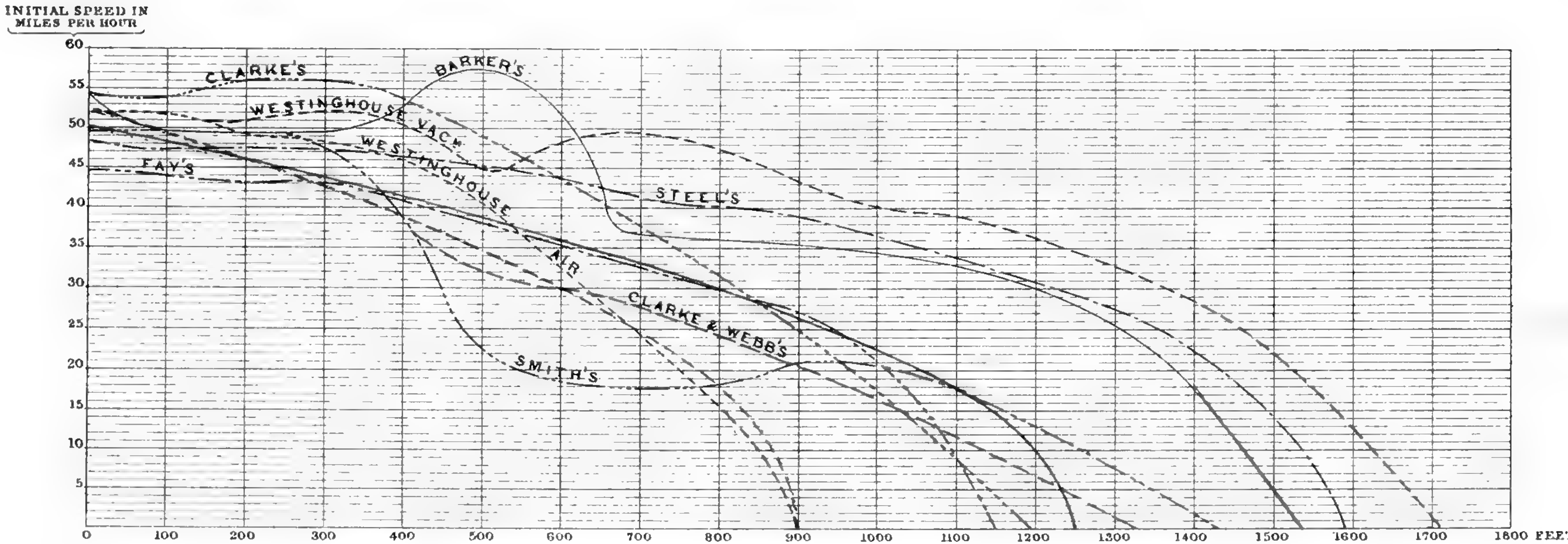


NOTE The figures on this side the Vertical Scale denote the height in feet that a body would have to fall through to gain the Velocity in miles per hour as shewn on the other side of the Scale.

NOTE The Vertical Scale is 4 times as large as the Horizontal.

Engraved by W. Faithorn.

Diagram illustrating the Irregular Action of Brakes.



NOTE The Blue full line Curve represents the action of an uniform Retarding Force assuming that with an Initial speed of 50 miles per hour a train is stopped in 1250 feet. The Blue dotted Line Curve represents what the action of the Westinghouse Air Brake would have been had the retarding force been uniform throughout the stop.
The black dotted Curves are deduced from the records of Experiments. The Red continuations of same are assumed.

Engraved by W. Faithorn

of which the Driver is unaware, such, for instance, as a broken axle, or a carriage getting off the line.

5th. The power in hand should be susceptible of easy modulation that the Driver may be able to apply a moderate amount only for effecting ordinary stops, whilst he keeps in reserve a proper excess of power to be used only on emergencies, or on the contingency of slippery rails.

6th. Full break-application should not require more than a very moderate effort on the part of Driver or Guard.

7th. The pressure should be steady and distributed as equally as possible over all the wheels, and acting upon them with the intervention of some elastic medium to prevent too sudden and violent action, which might occasion the snapping of chains or drawbars, and tend to inconvenience the passengers.

8th. The machinery should be of simple construction, not likely soon to get out of order, and admitting of being easily repaired.

9th. Indication should be constantly afforded to Driver and Guards that the brakes are in a proper condition to work or otherwise.

10th. The power of working the tender brake and the van brakes by hand, as well as by power, may be advantageously retained.

11th. The brakes to be self-acting in case of severance of the train, and when severed the Guards to have control over the severed portions.

12th. Automatic action being provided, means should be furnished to the brake-attendants for modifying that action instantaneously, according to the circumstances in which the trains may be placed after an accident has occurred.

13th. It would be dangerous, and therefore unadvisable, to give to passengers any power over the brakes.

Such seem to be the principal conditions necessary for realizing the conception of a perfect brake; and these, when carried into practice, and combined with the power of applying at will a force which, inclusive of the friction of the train, should amount to 10 per cent. of its weight, would constitute an invaluable instrument in the hands of our train-attendants for use under contingencies of almost daily occurrence at some place or another of the great network of railways which covers this country.

On the Experiments of the Boiler Committee of the Admiralty. *By* Captain Aynsley.

On the Preservation of Iron. *By* Professor Barff.

On the Upward Jets of Niagara. *By* W. H. Barlow, *V.P. Inst. C.E., F.R.S.*

When visiting Niagara last year, after acting as one of the Judges at the Centennial Exhibition at Philadelphia, I observed certain physical effects connected with the Great Falls to which I desire to draw attention.

First. It was observable that the doors and windows of our hotel, unless tightly closed, were subjected to a jarring movement, the impulses of which varied in time and degree.

The hotel in question is "Clifton House," on the Canada side, the southern face being parallel to and nearly opposite the American Falls, from which it is distant about a quarter of a mile; and its south-west corner is not far from being opposite to the mean line of face of the Canada or Horseshoe Falls, the distance being over half a mile.

The windows of the hotel opened on hinges, and if one of them was set slightly open, and the observer placed himself in such a position as to see the reflexions of distant objects in the surface of the glass, the times and varying intensity of the jarring impulses could be clearly observed.

Secondly. On looking at the Falls themselves, and especially at the Horseshoe Fall, there appeared from time to time, through the mist which always envelopes the lower part of the Falls, jets of water projected suddenly upwards. These jets frequently rose much above the level of the upper part of the Fall. Judging from the known height of the Falls, they frequently rose from 10 to 30 feet above the upper level. They occurred at varying intervals; but very few minutes elapsed without seeing one of greater or less magnitude.

It was also observable that they had a characteristic form, somewhat resembling a pine-tree—that is to say, small or pointed at the top, and widening out downwards.

They were not formed of a compact mass of water, but had that appearance, which is seen in large fountains, of being composed of lumps of water of various sizes, decreasing in the lower part, until they were lost in the general mist which surrounded the lower part of the Falls.

The continual recurrence of these jets, and the continual recurrence of the jarring action above referred to, point to the conclusion that both effects are due to one cause; and my object in drawing attention to the subject is to endeavour to suggest the nature of the cause which is producing these effects.

Proceeding to a nearer view of the waters by going beneath the Falls, and looking at and through them, it becomes apparent that the water which flows over the upper rocks in a continuous curved stream breaks up into masses of greater or less magnitude during its descent, so that air in large quantities gets in and between the falling masses of water.

In this intermixing of air and water it may frequently happen that a quantity of air is surrounded and enclosed in a heavy mass of water; and falling in this state with a velocity due to the height of 150 or 160 feet, the contained air would become suddenly and violently compressed on striking the rocks below.

The energy of the charge of compressed air thus suddenly generated would burst through the thinnest layer of its surrounding water, and so constitute a species of explosion carrying a portion of the water with it.

Assuming the weight of the water which generated the compression to be greater than that on which the energy of the compressed air operated, the effect would be to project the smaller mass of water with a greater velocity than that due to the original force.

The supposition most consistent with the observed phenomena appears, therefore, to be that the two effects, namely, the jets of water, and the jarring action shown on the doors and windows, are both due to the explosions or sudden expansions of air compressed by the falling water as above described.

There are several circumstances which appear to favour this supposition:—

First. The sudden upward blasts of air accompanied by water, felt by persons when beneath the Falls, which are probably only minor effects of a like action.

Secondly. The jarring motion imparted to the doors and windows appears to have no corresponding effect in the solid ground; from which it may be inferred that the effect is due to concussions conveyed through the air, and not to the tremor of the earth by the weight of the falling water.

Thirdly. The characteristic form of the jets, which is similar to that produced by explosions under water, when the conditions are such as to throw the water to a considerable height.

Lastly. The suddenness and energy of the operating force, as shown by the jets being frequently projected considerably above the level of the upper water.

The inquiry is one of some interest, and may serve to throw light upon those anomalous effects which have been observed from time with regard to heavy seas falling on a rocky shore, and the extreme height to which the water is occasionally projected under those conditions.

Two notable instances of this kind have been given by the engineers of the English and Scotch Lighthouses.

One at the Bishop Lighthouse, where a fog-bell weighing three hundredweight, and fixed at a height of 100 feet above the sea, was displaced and thrown down to the rocks below.

The other occurred at the North-Unst Lighthouse, which is built on a rock, whose height is 196 feet above high water, and presenting an almost perpendicular face to the sea. In this case, during a heavy north-west gale, a quantity of water was projected upwards sufficient to overthrow the boundary walls and force open the door of the house.

With regard to the form of jet produced by a subaqueous explosion near the surface, I had the opportunity, a short time since, of witnessing an experiment made by Professor Abel at the Royal Arsenal at Woolwich.

The explosive used was compressed gun-cotton. The jet on this occasion rose to a great height, reminding one of the great Crystal-Palace fountain, and it was remarkable from the complete verticality of its centre line of force, and from the resemblance in its pine-tree form to the jets of Niagara.

On Recent Experiments in Telephony. By Professor GRAHAM BELL.

On the Plymouth Waterworks. By G. D. BELLAMY.

On the Removal of Sand Bars at the Mouth of Harbours. By C. BERGERON.

On the Circulation of Hot Water in Buildings. By F. J. BRAMWELL.

Lode Mining in the West of England. By J. H. COLLINS, *F.G.S.*

The author restricted his remarks to the mining of lodes properly so called, without referring to the general geology of the district or to the mineral deposits other than lodes. He also left untouched the questions of drainage, ventilation, and ore-drainage. He defined a lode as a mineral deposit occupying a fissure in the ground or the rocks on either side in its immediate neighbourhood, and containing metallic minerals in greater or less proportion, and the *rich parts* as being those parts of a lode which are sufficiently rich to pay for working.

He stated that the same lode might be, and often was, worked at the same time by several companies, and that it might yield ores of different kinds, as tin and copper, either mingled together or at different depths; that the "bearing" of best tin- and copper-lodes was approximately east and west (magnetic), the average inclination or underlie 70°, the variations in width from a mere line to 20 or 30 feet, the average width less than 4 feet, and the average produce, even of the rich parts, taken as a whole, was less than 4 per cent. for copper-ores, and less than 2 per cent. for tin-ores; that copper-lodes in ground of moderate hardness were generally richer than those in very hard or very soft ground; that the more vertical parts of lodes were generally richer than the less vertical, the wider richer than the narrower, the lodes dipping towards granite richer than those dipping away from it; but that there were many exceptions to all these generalizations.

He then compared a lode to a steep or rearing seam of coal, and stated that it was in general subject to all the irregularities of such a seam with other irregularities superadded.

He then described in detail the modes of discovering lodes and laying out lode-workings, and the mode of sinking shafts, driving levels, &c., with the cost, under ordinary and extraordinary conditions, and the comparative advantages of downright or vertical and inclined shafts.

He then described the methods of timbering shafts and levels &c., and the different classes of workmen employed in the mines, with the nature of the different contracts under which they worked, with their advantages and disadvantages, also the arrangements for supervision.

The next topic was the use of various explosives in the mines and the recent introduction of boring machines, which he stated had proved a great success at Dolcoath and Cam-Brea Mines.

On the Eddystone Lighthouse. By J. N. Douglass.

On the Resistance of Ships, as affected by length of parallel middle Body. By William Froude, *F.R.S.*

On a new Dynamometer for large Marine Engines. By William Froude, *F.R.S.*

On the Works now in course of execution for improving the Navigation of one of the mouths of the Mississippi, under the direction of Mr. James Eads, C.E. By Captain Douglas Galton, *C.B., D.C.L., F.R.S.*

New Orleans is situated about 120 miles above the mouth of the Mississippi. The town lies in a semicircular area formed by a bend in the river, which at that part is above a mile in width and of sufficient depth to accommodate the largest vessels, as well as to allow them to lie alongside of the wharves which occupy the circumference of the semicircle. The river flows undiminished in width and breadth for about 108 miles below New Orleans, when it separates into three principal passes, which in their turn divide into many subsidiary channels, forming the delta by means of which its waters reach the Gulf of Mexico.

The point where the stream separates is called the Head of the Passes, and the three principal channels are termed the Pass à Loutre, the South Pass, and the South-west Pass respectively.

The Pass à Loutre separates into five branches of various sizes.

The South Pass gives access at about midway in its length to another channel called the Grand Bayon.

The South-west Pass runs in a continuous stream for 17 miles, but divides into separate channels at its lower end.

At the commencement of Mr. Eads's works, about 58 per cent. of the water of the Mississippi passed through the South-west Pass, 12 per cent. through the South Pass, and the remainder through the Pass à Loutre.

A shoal-bar exists at the mouth of each of these three Passes; the depth of water on each bar varies generally in proportion to the volume carried to the Gulf over it. This bar is composed entirely of sedimentary matter brought down by the river. The water issuing from the passes, no longer confined by banks, spreads out on either side. The velocity diminishes, the sediment drops, the bar forms. The central thread of the current being the strongest, and the water being the deepest there, the velocity is preserved and the sediment carried out much further than in the shoal water over the submerged new banks of the pass. The outer crest of the bar is thus thrown out $2\frac{1}{4}$ miles from the end of the land at the South Pass, and 5 miles at the South-west Pass. The depth on the bar at the former pass was $7\frac{1}{2}$ feet at mean low tide, when Mr. Eads's works were commenced.

The depth on the bar at the South-west Pass was about 15 feet; but it has been increased recently by continued dredging, under the auspices of the United-States Government, to a depth of from 16 to 17 feet.

The depth of the bar of the Pass à Loutre was somewhere between the two. The rise and fall of the tide at the mouth of the Mississippi does not exceed from one and a half to two feet.

In former years the trade of New Orleans was a large and increasing one; but the gradual introduction into commerce of a class of vessels too large to cross the bars at the mouths of the passes has for some time past tended to divert trade, and the grain-trade especially, to the Atlantic seaports.

Moreover, the war of secession interposed a sudden check to commercial intercourse between the North-western States of the Union and New Orleans. When, however, the trade between the Northern and Southern States began to revive, after the wars of secession, the merchants of St. Louis urged upon the United-States Government the necessity of improving the access from the sea to New Orleans.

The United-States Corps of Engineers, in 1873–4, were consequently called to advise; and they submitted a project for a ship-canal, which was to be protected by lock-gates, and was to be constructed from Fort St. Philip, a point in the Mississippi some 18 miles above the passes, in an easterly direction, into water of about 30 feet depth, in Isle-of-Breton Sound, whence the ships would pass out into the Gulf of Mexico.

The canal was to be entered by a lock. It would have required about 10 years for completion; its cost was estimated at $10,000,000, and it would only, when completed, have been able to accommodate a limited trade.

Mr. Eads at the same time proposed a rival scheme for improving one of the passes, by increasing and controlling the flow of water through it.

He proposed to improve the South-west Pass, which afforded the best prospect of success. The United-States Government refused this, but allowed Mr. Eads to experiment on the South Pass, provided he undertook the work at his own risk.

In addition to the bar at the mouth of the South Pass, there was also a shoal of about 12 feet deep at the head of the pass. Mr. Eads's confidence, and that of his friends, in his scheme enabled him to accept the Government offer. The following are the terms on which he has undertaken the work:—

When a depth of 20 feet for a width of 200 feet has been obtained through the channel, he was to receive a sum of $500,000; for each succeeding depth of two feet down to a depth of 30 feet he is to receive a further sum of $500,000, with several further sums of $250,000, each contingent upon the several depths being maintained for 12 months each respectively—making the total payment $4,500,000, when a depth of 30 feet has been maintained for 12 months. He is to receive two further payments of $500,000 each when the work has been effective for 10 years and 20 years, in addition to $100,000 a year for maintaining the work during 20 years.

The work was commenced on the 15th of June 1875.

The object of the works is to concentrate an increased flow of water in the South Pass as well as across the shoal-bars at each end—first, by means of lines of jetties, funnel-shaped at the head of the pass and parallel at its lower end; secondly, by closing the Grand Bayon, which diverted a portion of the water after it had entered the South Pass and prevented its reaching its lower end; and thirdly, by regulating the proportion of water to be admitted into the Pass à Loutre and the South-west Pass.

The jetties and all works in the water are constructed in a simple and comparatively inexpensive manner. Stone is not found on the lower Mississippi; that which has been used came either in ships as ballast, or has been brought down the Mississippi from the Ohio river: if stone alone had been used, the light mud of which the bottom is formed would have swallowed up an enormous quantity, and a very long time would have been occupied in the formation of the jetties.

The construction which has been adopted is as follows:—Piles are driven in the line of the proposed jetties at about 10 feet apart: against these piles mattresses of willow-branches about 2 feet thick are sunk. These mattresses vary in size from 75 feet in length and 40 feet wide to smaller widths and shorter lengths as may be desired. To make the mattress, strips of pine-wood about 3 inches by 2 inches are laid parallel to each other on inclined ways on the river-bank; they are kept in position by cross strips nailed to them at intervals: into these longitudinal strips pegs of hickory, two feet long, are fixed at six-feet intervals, the top of the peg being turned so as to correspond with a hole in a second strip of pine-wood to be eventually put on; after the pegs of hickory have been fixed into the longitudinal strips first mentioned, a layer of willow-branches is laid across and trodden down, then a second layer lengthways, and so on alternately until the thickness of two feet is attained, when the whole is kept in place by the second mentioned strip of pine-wood being fixed on to the tops of the hickory pegs; and thus sufficient solidity is obtained to permit of the mattresses being handled.

These mattresses, 75 feet long and 40 feet wide, are sunk in horizontal layers, with one edge resting against the piles on the side towards the channel. To sink them they are loaded with just sufficient stone to carry them down.

It is stated that the sediment deposited by the water would of itself suffice to sink them after its exposure in the water for a week. On these wider mattresses narrower ones are then placed, with one edge close against the piles, and so on in succession; they thus form a series of steps, till the surface of the water is reached, when a pile is driven close against the outer edge of the top mattress through the under layers to hold them all in place. The top mattress is then covered with stone to about two feet above the surface; and when the top sinks down, as it does gradually and unevenly, it is again raised by stone or by mattresses and stone.

It is intended eventually to cover the whole with stone; the sloping sides will be covered with large rough stones thrown in, and the top surface with stones laid with more regularity.

This is the method of constructing the more permanent jetties; where more temporary effects are desired to be obtained, as for the purpose of directing the flow of the current during the construction of the permanent work, the mattresses are applied sometimes vertically, sometimes at a steep incline.

The peculiarity of this mode of construction in the Mississippi is, that at first the jetty is very pervious to water; consequently a portion of the water which comes down the Pass flows through the interstices of the wickerwork in its progress through the jetties, and thus the scouring effect of the water is gradually lost.

But the water is so full of silt that by degrees the interstices become filled up, and the jetty wall is thus gradually made impervious to water: in proportion as the work is thus strengthened, the scouring power of the water on the channel will increase.

The operation of the current in the channel is therefore necessarily gradual, and its effect increases with the consolidation of the banks.

At the mouth of the Pass, the east jetty is 12,100 feet in length; and the west jetty, in consequence of the greater prolongation of the west bank of the Pass, is about 7,660 feet in length.

At the head of the Passes there is an island about mid-channel; this has been connected with the east side of the channel, so as to confine the water in one channel; and from this island, and from a point on the western shore, jetties have been carried up the stream across the shoal at the head of the Pass for a length of about 2,500 feet.

At the Grand Bayon the area of a section of the channel, at high water, contained about 24,000 square feet, whereas at the southern extremity of the Pass a corresponding section had an area of section of about 14,000, the diminished section being due to the diminished volume of water consequent upon a portion being abstracted by the Grand Bayon.

A dam has been erected across the Grand Bayon, as well as one across a small bayon lower down the Pass, so that the whole of the water which enters the head of the Pass now flows through the jetties at the mouth into the Gulf of Mexico.

Since the closing of the Grand Bayon, the advance in width and depth of the channel below that point has been steady and regular; and the increased volume of water issuing from the mouth of the Pass is gradually producing its effect, by tending to make the section of the lower part of the Pass equivalent to the normal section above.

The third object to be attained by the works, viz. to control the flow of water through the South-west Pass and the Pass à Loutre, is in progress, but not yet complete. A sill has been placed across the head of the South-west Pass to prevent scour. It consists of an apron of mattresses. It runs from a point on the west shore of the South-west Pass to a point near the head of the western jetty. A line of piles were driven and mattresses were sunk against the upperside. These mattresses are 70 feet wide, and are sunk side by side so as to make the apron 70 feet wide and 2 feet high. After the mattresses were sunk, the piles were pulled up to give a passage-way to vessels.

The soft nature of the bottom is shown by the fact that in places where the water was 30 feet deep, it was necessary to use piles 70 feet long, to make them stand.

The idea is that this sill will prevent scour in these channels. When I visited the works last spring this apron had stood the test of one flood, and no movement of the mattresses had occurred.

A similar apron is in course of being laid across the head of the Pass à Loutre.

The results of the whole works so far are, that a deep-water contour-line, of from about 22 feet to 23 feet, has been carried through the shoal at the head of the Pass; at the lower end on the outer bar the depth, which in June 1875 was 9 feet 2 inches, had increased in March of this year to 20 feet 10 inches.

The general result of the works to the last date at which I have obtained reports is shown in the following table, which gives the depth of water that could be carried through each 2000 feet below East-Point station at different dates:—

Distances in feet.

	0·2000.	2000–4000.	4000–6000.	6000–8000.	8000–10,000.	10,000–12,000.
June 1875	22·5	18·7	16·7	10·2	9·7	9·2
May 1876	23·3	20·3	22·0	21·0	17·1	15·0
August 1876	23·5	19·6	21·0	23·5	23·0	19·8
November 14, 1876	22·0	20·3	21·0	21·2	21·1	20·3

The principal effect takes place when the river is in flood. These periods of flood occur about three times a year.

It will be seen that the principle upon which the works are designed is to allow nature gradually to excavate the channel in the line laid out for it.

The work of excavation carried on by the river has been irregular, in consequence of the varying conditions of the river and of the amount of sediment which is carried in suspension; it has been, moreover, affected by the difference in the material composing the bar at various places, the state of the tides, the direction and force of the winds, the storms and resulting seas that rolled in against the current, as well as by the conditions of the works at Grand Bayon and the head of the pass and the varying conditions of the jetties.

But the general advance of the channel in width and depth has been constant and steady; and the effect of the jetty construction has shown that the volume of water issuing from the pass will eventually obtain the section which it has normally above.

A very important question, and one that cannot be definitely determined by facts until the completion of the jetties, is that of an accelerated bar-advance due to the construction of the jetties. All that can be now stated, bearing on this question, is, that there has been pushing outward of the upper part of the outer slope of the bar, due to three or more temporary causes—*first,* the impossibility of constructing the whole line of jetties instantaneously; *second,* the large amount of material excavated and carried out to sea; *third,* the closing of Grand Bayon and a new load of sediment given the water in addition to its already heavy burden; and *fourth,* the non-completion of the sea-ends of the jetties.

But yet careful surveys and calculations show a deepening instead of a shoaling immediately in front of the sea-ends of the jetties.

The volume of the bar removed during the first year of the work, without reference to amount moved in the channel as required by law, or, in other words, the total excavation, exceeds 3,000,000 cubic yards.

The following table shows the volume of the bar moved in reference to a channel 20 feet deep and 200 feet wide at that depth.

Volume in cubic yards at the bar removed in reference to a 20-feet channel.

Date of Survey.	Volume to be moved.	Volume moved.
May, 1875	1,037,635	
December 25, 1875	622,680	414,955
December 25, 1876	256,655	48,882
July 31, 1876............	4,985	8,992
August 14, 1876	75	4,915

A part of the material has fallen over the submerged jetties during their construction, or has been driven back by the waves from beyond the sea-ends of the jetties, and lodged outside on their sea-slopes; 1,000,000 cubic yards, at least, have piled themselves up against the outer or sea side of the jetties, an enduring and solid bulwark against the storms. The remainder has gone far to the westward, no doubt carried there by the prevailing westward coastwise current.

This so-called "littoral current" is a current generally existing and has a westward course. Whether it is caused principally by the prevailing north-east winds or by a more constant and stronger influence, is somewhat doubtful. There is strong evidence, from an examination of the general formation of the coast of Louisiana and Texas, from the eastward bend of the lower part of the Mississippi river toward that direction, by the excess of accumulation of sediment and consequent shore-formation westward, and from other observations, that there is a distinct, constant, and deep, moving westward, littoral or coastwise current, strong enough to remove far from the mouth of the new channel the sediment carried out by the river, and which will postpone for a century or two the re-formation of the bar.

Mr. Eads, indeed, contends that this current driven westwardly passes beneath the river-discharge, and that it thus has to excavate more room for itself as the volume of water passing through the jetties becomes stronger. However this may be, the facts are as stated; and in any case it does not appear probable that any necessity for extending the jetties, after a depth of 30 feet shall have been secured by them, will occur for a considerable period.

Mr. Eads, in discussing these works, lays especial stress on the assistance he derived from the advice of Sir Charles Hartley, C.E., whose experience at the mouth of the Danube is so well known in England.

Up to March in this year Mr. Eads had expended about 1,500,000 dollars, and had received the instalment due to a depth of 20 feet, viz. 500,000 dollars.

Vessels of 22-feet draught have, I understand, passed through the South Pass to New Orleans during the month of April; and it may safely be concluded that ere long New Orleans will be a port open to vessels of the larger sizes now used in commerce.

It would occupy too much space to show what will be the effect of these works on the trade of adjacent portions of the United States. The distance from St. Louis to New Orleans by railroad is 658 miles, as against 914 to Baltimore, 974 to Philadelphia, and between 1,100 and 1,200 to New York. Thus New Orleans will be the nearest port of importance for the rich districts of Illinois, as well as for Missouri, Arkansas, and Texas: there can thus be little doubt that, with the introduction of fresh capital which a settled government would attract, a great future is in store for this city.

On the Jetties of the Mississippi. By Captain D. Galton, *C.B., D.C.L., F.R.S.*

Interception of Rainfall from Sewers. By Baldwin Latham, *C.E., M. Inst. C.E., F.G.S., F.M.S., &c.*

The author observed that the admission of large and uncertain volumes of rainfall into sewers at uncertain periods was attended with considerable difficulties in many districts in which purification of the sewage had to be effected. In the majority of towns the rainfall was admitted into the sewers, the excess of rainfall and sewage being discharged by storm-water overflows, to the great detriment of the streams which received the discharge from such overflows. The complete separation of rainfall from sewers had been advocated; but considerable difficulties arose from such separation in crowded towns, as in times of rainfall the water flowing from the streets to the sewers was found to be quite as impure as the sewage proper. Moreover, the admittance of rainfall into the sewers necessitated an increase of capacity in the sewers—as, for example, London, where two thirds of the total capacity of the sewers was required for carrying away the moderate quantity of a quarter of an inch of rainfall in twenty-four hours. The author had carried out a complete system of sewerage in the Borough of Longton and in the contiguous district of the East Vale Local Board, the combined districts containing a population of about 25,000. The sewage was taken under an arrangement with His Grace the Duke of Sutherland, the adjoining landed proprietor, and used for irrigating land. A duplicate system of sewers had been carried out, a connexion being made between the rainfall-sewers and the sewers proper, and what was termed an "interceptor" was provided at the point of junction between the two systems of sewers. The interceptors consisted of a leaping weir so arranged that when there was a small quantity of water flowing down the rainfall-sewers, and the liquid as a natural consequence was very polluted, it passed through an adjustable opening into the sewer proper; but in time of rainfall, when the volume and velocity of the stream in the rainfall-sewers was increased and the water was comparatively pure, it leaped over the opening into the sewer and passed to the natural streams of the district. The cost of such interceptors was about £31 each, twenty-two of them being used in the district of Longton and East Vale, and their employment gave the most perfect satisfaction to the authorities.

Indications of the Movement of Subterranean Water in the Chalk Formation. By Baldwin Latham, *C.E., M. Inst.C.E., F.G.S., F.M.S., &c*

[Plate V.]

It is a matter of considerable importance to the engineer that he should be able to determine with accuracy the direction of the flow of underground water, as both the volume and quality of the water to be procured at a particular spot in well-sinking depend upon knowing the extent of the contributing area and the direction of the flow of the water.

A very large number of observations have been made by different persons on the relative height at which the water stands in wells in the Chalk formation. The Rev. James Clutterbuck, Mr. John Evans, F.R.S., Mr. J. Lucas, F.G.S., the author, and others have shown by direct measurement that the water in the chalk and other geological formations does not stand at what is termed a "water-level;" and what is known as the "water-level" of subterranean water is usually a line having a considerable declivity. The very fact of water standing at such a declivity is clear evidence of movement; and the observed declivity is called the angle-friction, or the measurement of the resistance of the water in moving through the strata, just the same as the fall in the surface of an open stream is the measurement of the resistance the water meets with in its passage down the channel of the stream.

It was pointed out by Professor Prestwich, some years ago, that subterranean water is governed in its movement by the same laws as regulate surface-streams. The more the question of movement of subterranean water is investigated this is found to be the case. The greatest elevation of the subterranean water is usually found under the highest lands, and the least elevation under the lands having the lowest level. The flow of water laterally is from the hills to the valleys, and longitudinally down the valley-lines; therefore, as a general rule, the flow of subterranean water conforms to the surface-falls of the country. There are, however, exceptions to this rule, as the author has found in several instances.

An examination of a district having a number of contributing valleys shows very clearly that the subterranean water moves down the subsidiary valleys into the main valley; and the confluence of the streams produces identically the same effect in the underground channels as is observed by the junction of two streams or the water flowing in two pipes. The increase of the volume of water brought into a main subterranean channel from a subsidiary valley elevates the surface of the water at the point of junction. This is clearly indicated by the longitudinal sections of a main valley joined by contributory valleys at various points. Taking any one of these examples, it is found that if a line is drawn from the surface of the water at a point above where a junction is known to take place with the surface of the water at another point below where the junction is effected, the result shows that at every period of the year, and whether the water is rising or falling, there is a considerable convexity in the longitudinal section of the water at the point at which water is received. A number of examples of this character are shown in making careful sections of the chalk valleys south of Croydon, particularly in a valley about eight miles long, extending from Caterham to the river Wandle at Croydon. Not unfrequently we find one valley runs across another, and such continuity of the surface may be observed which might lead to the supposition that the flow of subterranean water is continuous down the valleys. This, however, is not always the case, as is clearly shown by a section made above Croydon, in the neighbourhood of Smitham Bottom, in the valley-line between Merstham and Croydon. It might be supposed that the water flows from Merstham to Croydon; but this is not so, for the cross valley at Smitham Bottom intercepts the water and conveys it away in another direction. This abstraction of the water is clearly indicated by the depression in the water-line at the point where the water leaves. A line drawn from a point in the water-line above the point of abstraction to a point in the water-line below this point shows, during all periods, a concavity in the water-surface at the point of abstraction. Where such a depression is observed it is evidence of the abstraction of water. Just the same is observed by pumping from a well; the water is generally lowered all round the point of abstraction. The amplitude of the depression is greatest near the point of abstraction, and diminishes as we leave that point. It thus becomes quite feasible to determine, by careful survey, the exact direction in which subterranean water is flowing in such a district as that which has recently been under the examination of the author, and also to pretty accurately determine both the extent of the contributing area and the probable quantity of water such an area will yield.

A point of interest in reference to the rise of the water in the Chalk is that, taking a long valley, as, for example, the Caterham valley, observation clearly shows that the water begins to rise in the wells located at the top of the valley before it rises in the wells situated in the lower part of the same valley; in fact the water in the upper wells began to rise while the water in some of the lower wells was still falling.

Here, again, there is a parallelism of what is observed with regard to surface-streams—that the floods descend from the higher to the lower parts of the country.

It appears singular that the wells in the upper part of the basin should begin to rise first; and the only solution that the author can offer for this circumstance is that the rainfall is greater upon the higher lands than in the lower parts of the valley; for it is quite clear that on the 25th November 1876 the water in the well began to rise at Cambrian House, in the upper part of the Caterham valley, but it was not until after the 3rd December that the water in the wells began to rise in the lower parts of the valley at Croydon; and the water in an intermediate well at the Rose and Crown Inn, Riddlesdown, did not rise until about the 12th December.

In this case the water rose both in the upper and lower parts of the same valley before it rose at an intermediate point. The rise in the upper part of the valley was probably due to rainfall, and the rise in the lower part was probably due to the effect of the united contributions of a number of short valleys discharging into the main valley.

Another point which is deserving of attention has reference to the temperature of the water. Well-water is usually much colder and of much more uniform temperature than ordinary surface-water. Its coldness is, in part, no doubt due to the fact that the greatest absorption of rain takes place in the winter months, and the water enters the ground at a cold period and at about the normal temperature of the air. Very careful observations on the Chalk formation south of Croydon show that the month of December is the month which appears principally to contribute to the supply of the springs, and that after a rainfall it takes some time for the springs to rise, depending mostly on the dryness or wetness of the season. A small rainfall in December is almost sure to be followed by low springs in the following year, or a dry December interferes, to a most marked extent, with the contribution of water to the springs; for although experiments with percolation-gauges show that certain quantities of water percolate at all periods of the year, the measurement of wells and gauging the volume of springs show that a large part of the rain falling never influences the quantity of water in the ground in the slightest degree.

In the year 1876, between the beginning of May and the end of November, although over twelve inches of rain had fallen at Croydon, the rainfall did not affect the quantity of water in the subsoil; but during the whole of this period both the volume of water flowing from the springs and the height of the water in the subsoil steadily diminished. During the present year, there has been a gradual subsidence in the water, both with regard to its altitude and volume, since the 25th April, although between the beginning of April and the end of July upwards of ten inches of rain had fallen. It is found, upon examination, that the water of the deep wells in the higher parts of the district, notwithstanding the greater depth of the wells, has a lower temperature than the water in the wells in the lower portion of the district that are not so deep. The water of wells which have been sunk into the Upper Greensand has relatively a lower temperature than the water of wells sunk in the chalk. At certain periods the temperature of the water at the surface of the well is somewhat warmer than at the bottom of the well. In other cases the water at the bottom of the well is equal in temperature, or exceeds that of the surface. In all probability, in the cases where the surface-temperature is greater than the bottom-temperature, it is due to the conduction of heat from the warmer air of the well to the surface of the water; and the heat being transmitted through the water very slowly downwards, tends to keep the water at the surface at a higher temperature than at the bottom of the well. This is very clearly shown in the case of the temperature of the well at the Water Works at Croydon. The upper water in the well on the 6th December 1876 had a temperature of 64°·5, while at the bottom of the well the temperature was 51°·25. The increase of the surface-temperature in this case was due to the admittance of hot water from the surface-condenser into the well. The temperature observed at the bottom of the well was about the ordinary normal temperature. In cases in which the water is excessively cold at the bottom of the well, it is probably due to the inferior motion of the water, the strata being dense, and there being less circulation. In the lower districts, especially where the water rises into the gravel and has very free movement, the temperature of the water is higher than in the chalk. The temperature of the water under the town of Croydon, which is built upon the outflow of the springs into the gravel, is higher than in the wells immediately outside the town. The movement of the water from the higher to the lower districts would, of itself, tend to raise the temperature. The descent of the water from a high to a low elevation would also tend to compress air and gases held in the interstices of the water, and thus would tend to increase the specific heat. Probably to these two circumstances may be attributed the slight increase in the temperature of the water observed in moving down such valleys as that of Caterham, which has its discharge into the River Wandle at Croydon, and also in other valleys in this neighbourhood.

Schedule of Well-Gaugings in Valley from Caterham to River Wandle at Croydon.

Referred to in Mr. Baldwin Latham's Paper.

(All levels reduced to Ordnance datum, feet. Temperatures to degrees Fahrenheit.)

Locality.		May 20, 1876.	Sept. 29, 1876.	Nov. 4, 1876.	Dec. 9, 1876.	Dec. 21, 1876.	Jan. 25, 1877.	April 9, 1877.	July 17, 1877.
Godstone Quarry, temp. of water		....	47	47	46·25	46·25	45·5	46·75	47·25
In Upper Greensand, top water level		443·12	439·30	439·06	439·30	439·06	452·89	459·56	456·41
Cambrian House.	Temp. of water midway	....	49·5	49·25	49·5	49·5			
	„ of surface of water	....	....	....	....	....	....	49·75	49·5
Well in Chalk, temp. at bottom of well		....	....	....	....	....	....	50	50
Surface-level of well .. 453·18	Level of surface of water	343·18	286·06	287·68	306·52	327·68	399·93		
Level of bottom of well 276·68	Depth of water in well ..	66·50	9·38	11·00	29·84	51·00	123·25		
Depth of well .... 176·50		May 17, 1876.							
Marden Lodge.	Temp. of water midway	....	49·5	49	49·5	49			
	„ of surface of water	....	....	....	....	....	....	49·25	49
	„ at bottom of well	....	....	....	....	....	....	48·75	49
Surface-level of well .. 354·32	Level of surface of water	323·07	286·06	257·66	259·20	270·49	349·82	....	320·40
Level of bottom of well 239·32	Depth of water in well.	83·75	46·74	18·34	19·88	31·17	110·50	....	81·08
Depth of well .... 115·00									
Well Farm.	Temp. of water midway	....	50	49·5	49·5	49·25			
	„ of surface of water	....	....	....	....	....	....	49·25	50
	„ at bottom of well	....	....	....	....	....	....	49	50
Surface-level of well .. 333·07	Level of surface of water	313·87	266·99	254·32	255·37	265·07	329·91	....	312·07
Level of bottom of well 222·07	Depth of water in well.	91·80	44·92	32·25	33·37	43·00	107·84	....	90·00
Depth of well .... 111·00									
Rose Cottage.	Temp. of water midway	....	49·75	49·5	49·5	49·25			
	„ of surface of water	....	....	....	....	....	....	49·5	50
	„ at bottom of well	....	....	....	....	....	....	49	48·5
Surface-level of well .. 303·20	Level of surface of water	290·70	255·78	246·58	238·20	247·04	297·87	....	287·70
Level of bottom of well 211·20	Depth of water in well.	79·50	44·58	35·38	27·20	35·84	86·67	....	76·50
Depth of well .... 92·00									

			May 16, 1876.			Dec. 8, 1876.				
Opposite "Rose and Crown."		Temp. of water midway	....	49·75	49·5	49·5	49·25			
		" of surface of water	....	....	....	....	....	....	46·75	50·5
		" at bottom of well	....	....	....	....	....	....	46·5	48
Surface-level of well	300·07	Level of surface of water	281·17	251·82	243·07	238·12	241·59	287·14	....	281·24
Level of bottom of well	220·07	Depth of water in well	61·10	31·75	23·00	18·05	21·52	67·07	....	61·17
Depth of well	80·00									
"Rose and Crown" Inn.		Temp. of water midway	....	49·5	49·5	49·25	49·25			
		" of surface of water	....	....	....	....	....	....	47	49·5
		" at bottom of well	....	....	....	....	....	....	47	48
Surface-level of well	288·63	Level of surface of water	281·23	251·88	242·97	233·68	241·05	286·80	....	280·97
Level of bottom of well	212·63	Depth of water in well	68·60	39·25	30·34	21·05	28·42	74·17	....	68·34
Depth of well	76·00									
Garston House.		Temp. of water midway	....	49·5	49·25	49·25	49			
		" of surface of water	....	....	....	....	....	....	46·25	50
		" at bottom of well	....	....	....	....	....	....	46·5	49·25
Surface-level of well	276·71	Level of surface of water	262·46	238·55	231·42	224·13	227·30	266·21	....	260·46
Level of bottom of well	206·71	Depth of water in well	55·75	31·84	24·71	17·42	20·59	59·50	....	53·75
Depth of well	70·00									
Kenley Water-works.		Temp. of water midway	....	49·25	49·25	49·75	49·75			
		" of surface of water	....	....	....	....	....	....	48	49·25
		" at bottom of well	....	....	....	....	....	....	48·5	49
Surface-level of well	263·32	Level of surface of water	248·42	226·57	222·41	216·92	218·32	256·74	....	248·24
Level of bottom of well	43·32	Depth of water in well	205·10	183·25	179·09	173·60	175·00	213·42	....	204·92
Depth of well	220·00		May 15, 1876.							
Roke Farm.		Temp. of water midway	....	49·75	49·5	49·5	49·25			
		" of surface of water	....	....	....	....	....	....	49·25	49·25
		" at bottom of well	....	....	....	....	....	....	49	47·75

Well-Gaugings from Caterham to River Wandle, Croydon (continued).

Locality.	May 15, 1876.	Sept. 29, 1876.	Nov. 4, 1876.	Dec. 8, 1876.	Dec. 21, 1876.	Jan. 25, 1877.	April 9, 1877.	July 17, 1877.
Surface-level of well . . 236·42 — Level of surface of water	218·17	202·26	199·67	196·17	196·09	226·26	....	220·25
Level of bottom of well 185·42 — Depth of water in well.	32·75	16·84	14·25	10·75	10·67	40·84	....	34·83
Depth of well .... 51·00								
	May 20, 1876.							
Caterham Junction. Temp. of water midway	....	49·5	49	49·5	49·25			
" of surface of water	....	....	....	....	....	....	49·75	49·25
" at bottom of well	....	....	....	....	....	....	50	50
Surface-level of well . . 243·48 — Level of surface of water	....	192·15	187·90	186·98	186·36	210·90	....	207·15
Level of bottom of well 181·48 — Depth of water in well.	....	10·67	6·42	5·50	4·88	25·42	....	25·67
Depth of well .... 62·00								
	May 12, 1876.	Sept. 26, 1876.	Nov. 2, 1876.	Dec. 8, 1876.	Dec. 19, 1876.	Jan. 25, 1877.	April 9, 1877.	July 17, 1877.
Ebenezer Cottage. Temp. of water midway	....	49·5	49	49·5	49·25			
" of surface of water	....	....	....	....	....	....	49	50
" at bottom of well	....	....	....	....	....	....	49·25	50
Surface-level of well . . 213·72 — Level of surface of water	199·22	187·03	183·87	182·97	182·52	203·22	....	200·26
Level of bottom of well 178·72 — Depth of water in well.	20·50	8·31	5·15	4·25	3·80	24·50	....	21·54
Depth of well .... 35·00								
				Dec. 6, 1876.				July 16, 1877.
Tudor Cottage. Temp. of water midway	....	49·5	49	49·5	49·25			
" of surface of water	....	....	....	....	....	....	49	50
" at bottom of well	....	....	....	....	....	....	49·25	50·25
Surface-level of well . . 213·99 — Level of surface of water	198·49	186·91	183·87	182·20	182·33	202·49	....	199·99
Level of bottom of well 177·99 — Depth of water in well.	20·50	8·92	5·88	4·21	4·34	24·50	....	22·00
Depth of well .... 36·00								
	May 11, 1876.							
Purley Oak Terrace. Temp. of water midway	....	49·5	49·5	49·5	49·5			
" of surface of water	....	....	....	....	....	....	49	50·25
" at bottom of well	....	....	....	....	....	....	48·5	50

Surface-level of well..	190·82	Level of surface of water	178·32	169·80	167·20	166·49	166·70	182·40	....	179·70
Level of bottom of well	161·82	Depth of water in well.	16·50	7·98	5·38	4·67	4·88	20·58	....	17·88
Depth of well	29·00									
Opposite Haling Lime-works.		Temp. of water midway	....	50·5	50·5	50·5	50			
		„ of surface of water	....	....	....	....	....	....	48	
		„ at bottom of well	....	....	....	....	....	....	48	
Surface-level of well..	191·70	Level of surface of water	177·6	169·29	167·08	165·58	166·08	180·53		
Level of bottom of well	162·70	Depth of water in well.	14·90	6·59	4·38	2·88	3·38	17·83		
Depth of well	29·00							Jan. 26, 1877.		
Haling Lime-works.		Temp. of water midway	....	49·75	50	49·75	50			
		„ of surface of water	....	....	....	....	....	....	48	50·75
		„ at bottom of well	....	....	....	....	....	....	47·5	50·25
Surface-level of well..	194·50	Level of surface of water	177·00	168·91	166·67	165·38	165·88	180·83	....	178·13
Level of bottom of well	159·50	Depth of water in well.	17·50	9·41	7·17	5·88	6·38	21·33	....	18·63
Depth of well	35·00		May 31, 1876.						April 8, 1877.	
Selsdon Signal-Box.		Temp. of water midway	....	50	50	50	50			
		„ of surface of water	....	....	....	....	....	....	50	50·25
		„ at bottom of well	....	....	....	....	....	....	50	50·75
Surface-level of well..	212·56	Level of surface of water	166·31	160·39	158·56	157·94	168·40	169·64	....	166·23
Level of bottom of well	151·56	Depth of water in well..	14·75	8·83	7·00	6·38	6·84	18·08	....	14·67
Depth of well	61·00									
Selsdon Road Cottage, No. 2.		Temp. of water midway	....	50·5	50	50	50	....	50·5	
		„ of surface of water	....	....	....	....	....	....	....	51·5
		„ at bottom of well	....	....	....	....	....	....	....	51·75
Surface-level of well..	214·39	Level of surface of water	164·39	160·10	159·48	158·51	159·39	169·06	....	166·56
Level of bottom of well	152·39	Depth of water in well.	12·00	7·71	7·09	6·12	7·00	16·67	....	14·17
Depth of well	62·00									

Well-Gaugings from Caterham to River Wandle, Croydon (continued).

Locality.			May 31, 1876.	Sept. 2, 1876.	Nov. 2, 1876.	Dec. 6, 1876.	Dec. 19, 1876.	Jan. 26, 1877.	April 5, 1877.	July 16, 1877.
Selsdon Road Cottage, No. 1.		Temp. of water midway	....	50·5	49·75	dry.	49·5	....	50	
		,, of surface of water	....	....	....	....	....	....	....	
		,, at bottom of well								
Surface-level of well	208·61	Level of surface of water	164·81	160·32	158·53	dry.	157·78	168·78		
Level of bottom of well	157·61	Depth of water in well.	7·20	2·71	·92	....	·17	11·17		
Depth of well	51·00									
			May 10, 1876.	Sept. 28, 1877.	Nov. 2, 1876.	Dec. 6, 1876.	Dec. 19. 1876.	Jan. 25, 1877.	April 6, 1877.	July 16, 1877.
Nalder's and Collyer's Brewery.		Temp. of water midway	....	50·5	50·5	50·5	51	....	51	
		,, of surface of water	....	....	....	....	....	....	....	52·25
		,, at bottom of well	....	....	....	....	....	....	....	51·75
Surface-level of well	171·09	Level of surface of water	....	145·47	145·89	145·26	145·43	147·42		
Level of bottom of well	141·59	Depth of water in well.	....	3·88	4·30	3·67	3·84	5·83		
Depth of well	29·50									
Croydon Water-works.		Temp. of water midway	....	51	51					
		,, of surface of water	....	....	....	64·5	59	....	50·75	52·25
		,, at bottom of well	....	....	....	51·25	52	....	51	51
Surface-level of well	142·95	Level of surface of water	127·86	125·57	125·61	126·12	126·28	128·08	....	132·31 old well.
Level of bottom of well	46·41	Depth of water in well.	81·45	79·16	79·20	79·71	79·87	81·67	....	85·90
Depth of well	96·54									
Chasemore's Flour-mill.		Temp. of water midway	....	50·5	52	52	51	....	51·5	
		,, of surface of water	....	....	....	....	....	....	....	52·25
		,, at bottom of well	....	....	....	....	....	....	....	51·75
Surface-level of well	149·16	Level of surface of water	....	137·79	136·22	136·83	136·35	139·22	....	139·08
Level of bottom of well	135·16	Depth of water in well.	....	2·63	1·06	1·67	1·19	4·06	....	3·92
Depth of well	14·00									

Schedule of Well-Gaugings in Valley from Merstham to Caterham Junction.

Referred to in Mr. Baldwin Latham's Paper.

(All levels reduced to Ordnance datum, feet. Temperatures to degrees Fahrenheit.)

Locality.	May 12, 1876.	Sept. 27, 1876.	Nov. 3, 1876.	Dec. 7, 1876.	Dec. 20, 1876.	Jan. 25, 1877.	Apr. 7, 1877.	July 16, 1877.
Harpsoak Cottage. Temp. of water midway	....	49·75	49·25	49·25	49·5			
,, of surface of water	....	....	....	....	....	....	49·75	50
,, at bottom of well	....	....	....	....	....	....	50	50
Surface-level of well .. 447·46 Level of surface of water	318·46	306·20	302·13	294·21	299·46	336·46	....	322·76
Level of bottom of well 269·96 Depth of water in well.	48·50	36·24	32·17	24·25	29·50	66·50	....	52·80
Depth of well .... 177·50	May 24, 1876.							
Star Inn. Temp. of water midway	....	49	49	49	48·75			
,, of surface of water	....	....	....	....	....	....	49·25	49·25
,, at bottom of well	....	....	....	....	....	....	49·5	49·25
Surface-level of well .. 364·07 Level of surface of water	307·32	281·00	272·32	267·16	268·32	312·49	....	307·74
Level of bottom of well 247·07 Depth of water in well.	60·25	33·93	25·25	20·09	21·25	65·42	....	60·67
Depth of well .... 117·00								
Hooley Cottage. Temp. of water midway	....	49·5	48·5	49	49			
,, of surface of water	....	....	....	....	....	....	49·5	49·5
,, at bottom of well	....	....	....	....	....	....	49·75	49·5
Surface-level of well .. 361·21 Level of surface of water	303·96	280·80	271·01	266·05	267·46	312·05	....	307·09
Level of bottom of well 232·21 Depth of water in well.	71·75	48·59	38·80	33·84	35·25	79·84	....	74·88
Depth of well .... 129·00	May 15, 1876.							
Marl-Pit Lane. Temp. of water midway	....	49·5	49·5	49	49			
,, of surface of water	....	....	....	....	....	....	49·5	50
,, at bottom of well	....	....	....	....	....	....	50	50
Surface-level of well .. 278·82 Level of surface of water	231·82	215·78	312·41	209·57	210·66	244·32	....	232·57
Level of bottom of well 201·82 Depth of water in well.	30·00	13·96	10·59	7·75	8·84	42·50	....	30·75
Depth of well .... 77·00								

Well-Gaugings from Merstham to Caterham Junction (continued).

Locality.		May 13, 1876.	Sept. 27, 1876.	Nov. 3, 1876.	Dec. 7, 1876.	Dec. 20, 1876.	Jan. 25, 1877.	April 7, 1877.	July 16, 1877.
Near Red Lion Inn.	Temp. of water midway	....	49·75	49·5	49·5	49·5			
	" of surface of water	....	....	....	....	....	....	49·75	50
	" at bottom of well	....	....	....	....	....	....	50·25	50
Surface-level of well .. 251·04	Level of surface of water	216·04	205·96	203·21	202·29	202·79	223·28	....	216·21
Level of bottom of well 198·04	Depth of water in well.	18·00	7·92	5·17	4·25	4·75	25·24	....	18·17
Depth of well .... 53·00								April 9. 1877.	
Hope Cottage.	Temp. of water midway	....	50	49·5	49·5	49·25			
	" of surface of water	....	....	....	....	....	....	50	50
	" at bottom of well	....	....	....	....	....	....	50·25	50
Surface-level of well .. 247·87	Level of surface of water	214·57	205·37	202·37	202·12	202·17	221·29	....	214·54
Level of bottom of well 197·37	Depth of water in well.	17·20	8·00	5·00	4·75	4·80	23·92	....	17·17
Depth of well .... 50·50									
Flint Cottage.	Temp. of water midway	....	49·5	49·5	49·5	49			
	" of surface of water	....	....	....	....	....	....	49·75	50·25
	" at bottom of well	....	....	....	....	....	....	50·25	51·5
Surface-level of well .. 231·33	Level of surface of water	207·58	198·37	195·58	194·69	194·58	219·50	....	208·58
Level of bottom of well 188·08	Depth of water in well.	19·50	10·29	7·50	6·61	6·50	31·42	....	20·50
Depth of well .... 43·25									

INDICATION OF THE MOVEMENT OF SUBTERRANEAN WATER IN THE CHALK FORMATION.

By Baldwin Latham, C.E., M.I.C.E., F.G.S., F.M.S., &c. &c.

On Thomas Newcomen's Steam-engine (1712). *By* Thomas Lidston.

Nothing could happen, save the crack of doom, which would parallel in its effects on mankind a general breakdown of steam-engines. This is one way of asserting that we are imminently dependent on the steam-engine for the supply of our general wants and comforts. And this consideration may form the plausible excuse for reminding the Members of the British Association that they are meeting this year in the county where this machine was invented, and cause them to listen to a word or two about the *Inventor*.

Thomas Newcomen, an ironmonger, residing at Dartmouth in Devonshire, made there the "first self-acting steam-engine," about the year 1712.

"The model of Newcomen's engine which Watt was repairing when he invented his improvements" still exists, and belongs to the Glasgow University. It was exhibited last year at the special loan collection at South Kensington, having been sent from Glasgow for that purpose.

Newcomen's engine is called by Hugo Reid "the first really efficient engine." Tredgold (in his treatise) says, "Newcomen's engine, as compared with all preceding attempts, produces all the difference between an efficient and an inefficient engine." Farey remarks, "Savory could not succeed, but Newcomen succeeded very well." Smiles calls it "the first engine made use of." Ewbank, of New York, says, "To Newcomen belongs the honour of laying the foundation of the modern engine." Sir William Fairbairn wrote, "There cannot be a doubt that Newcomen was the first to introduce the steam-engine as a working 'machine.'"

It has been the custom to speak of Newcomen as a blacksmith, and his invention of the atmospheric steam-engine as having been the result of a lucky accident. On the contrary, Newcomen conducted his experiments on scientific data. A gentlemen of culture and of means, we find him the correspondent of Dr. Hooke, of the Royal Society, on this his pet project. Convinced of their importance, as a true God-fearing man, he continued his labours as with a conscience in his work. From a paper in the possession of his descendants, to which I have been permitted to have access, it has been shown that in the latter part of his days he devoted himself to the work exclusively, and in the year 1729 proceeded to London to take out a patent. Unfortunately he was taken down in fever from over-exertion there, and died before the patent was secured.

On the Cycloscope. By Professor M'Leod.

On a new Mechanical Furnace used in the Alkali Manufacture and for Calcining-purposes generally. By James Mactear.

The author exhibited and explained the construction of a working model of the furnace which he has introduced for the calcination or so-called carbonating of soda-ash, and which is also applicable to many other operations, notably that of calcining copper-ores, especially as required in that branch of copper-manufacture called the wet process.

These furnaces are now being widely adopted by alkali manufacturers with great success, the saving in labour having been over 60 per cent., and of coal over 20 per cent., while the quality of work done is much superior to hand-work.

On the Saltash Bridge. By P. J. Margary.

On Perkins's High-pressure Engine. By Loftus Perkins.

On certain Dynamometers. By Professor O. Reynolds, *F.R.S.*

On Compound Turbines. By Professor O. Reynolds, *F.R.S.*

On the Difference of the Steering of Steamers with the Screw reversed when under full way and when moving slowly. By Professor O. REYNOLDS, *F.R.S.*

On a more extended use of the Ordnance Datum of Great Britain. By J. N. SHOOLBRED, *Mem. Inst. C.E.*

At a time when a committee of the Association presents a Report * to endeavour to dispel certain misconceptions as to the meaning and true position of the Datum-plane selected as the basis of the levels of the Ordnance Survey of Great Britain, it may not be inappropriate to ask the question, whether this Datum cannot be more fully made use of, so as to become what it ought to be, a truly national basis or connecting link between all works of a public character throughout the entire length and breadth of the country; and also by what means this can most readily be effected. It would appear, *inter alia*, that much would be done if this basis of the system of Ordnance Levels were connected:—

1. *In towns* with all surveys of Municipal and other bodies.
2. *In seaports and harbours* with dock-sills, tide-gauges, and marine surveys of the port and of the adjoining coast, thus enabling tidal observations in different parts of the kingdom to be compared with one another.
3. With existing *local datum-marks.*
4. *On Railways* and other large public works with their system of levels as given in their deposited plans before Parliament, so as to allow of the different works, or their several portions, being connected together.

As, in order to give force to this last recommendation, an addition to the Standing Orders of both Houses of Parliament would be requisite, memorials to the Chairman of Committees of each House from such bodies as the Council of the British Association, of the Institution of Civil Engineers, of the Institution of Surveyors, of the Society of Arts, of the Geographical and of the Geological Societies, and of others having kindred objects, might be productive of the desired effect.

The whole of the foregoing remarks, it need hardly be said, apply with equal force to the Datum of the Ordnance Survey of Ireland.

It may also here be noted that the Ordnance Department is itself doing much, in the direction indicated by the foregoing remarks, by the issue, now being made, of the Parish maps (25 inches to the mile). They supply similar information to that contained in the several Tithe-Commutation Parish maps; and besides they are studded with levels of the country they represent. Thus they afford ample requisites for a good estate-map, and as such they promise to become both valuable and duly appreciated.

On a Suspended Railway. By G. STEVENSON.

On the Importance of giving a Distinctive Character to the Needles Light. By Sir WILLIAM THOMSON, *F.R.S.*

On an Improved Method of Recording the Depth in Flying Soundings. By Sir WILLIAM THOMSON, *F.R.S.*

On a Navigation Sounding Machine for use at Full Speed. By Sir WILLIAM THOMSON, *F.R.S.*

On the Mariner's Compass, with Correctors for Iron Ships. By Sir WILLIAM THOMSON, *F.R.S.*

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* See p. 200 of the present volume (Reports).

On the Plymouth Breakwater. *By* R. C. Townsend, *Superintendent.*

The author offered a few remarks on the damage done during the storm of 7th and 8th January 1867 to the western arm of the Breakwater, the most vulnerable part of the whole structure—first observing that during a South or S.W. gale, and about an hour and a half before or after low-water spring tides, the heaviest seas culminate and strike the foot of the south or sea slope with destructive force, very much exceeding that on any other portion of the work.

It would seem that each wave increases in volume from the Draystone Buoy, off Penlee Point, running in line with the Knap Buoy and Panther Shoal, finally impinging on the slope of the west arm of the Breakwater, where, especially in the winter months, it invariably dislodges from the fore shore rough limestone blocks varying in weight from 5 to 10 tons, carrying them over the work and depositing them on the inner slope. But in the case of the storm referred to (1867), not only were large rough blocks swept over, but the masonry forming the granite band protecting the foot of the slope was upheaved and carried away for a considerable length, leaving the rough hearting of the work exposed to future assault. The primary cause of weakness I traced to the subsidence of the foundation below the granite band, leaving cavities of considerable length and depth open to hydrostatic influences. The author thinks that had the granite band been seated a few feet lower in the work, and the stones of greater weight, the damage done, amounting to over £20,000, might not have been so extensive. The experience thus gained induced him to recommend the Director of Works (now Sir Alexander Clerk, R.E.) to adopt for this especial arm of the breakwater a repair of a more massive character,—that is to say, to carry the new buttress from 3 feet below low-water mark up the slope in a solid mass to a level of about half-tide, the face of this work being of large dressed granite blocks, with dovetailed joints and sunk beds, banded horizontally and vertically, dowels and cramps being introduced in the two upper courses. The new work, thus repaired, stands admirably, and has so far fulfilled all his anticipations. In addition to the stability given to this arm of the Breakwater, the vertical face (in steps) forming the new buttress prevents travelling limestone boulders being lifted and carried over the works; in fact the accumulation of detained stone at the base of the new work proves to be a valuable adjunct to the strength of this arm of the Breakwater.

As an example of the heavy waves that occasionally strike the work during a S.S.W. gale, the author mentioned the displacement of two experimental concrete blocks, weighing 24 tons each, and one limestone block weighing 35 tons, deposited 60 feet from the toe of the Breakwater and spaced about 30 feet apart. In a storm some eight years ago the two concrete blocks were capsized and in one tide swept completely over the Breakwater and deposited on an inner slope. The limestone block was driven home to the granite band and joined fast amidst other stones.

As an experiment, the author's predecessor, 13 years ago, deposited on the sea-slope of the Breakwater, not far from the return angle of west arm, a small concrete block (Portland cement), with a view to test its powers of resistance to oceanic influence. During this time the concrete cube has been dislodged more than once by travelling stones in a gale, but the author has again restored it to its original position, halfway down the slope. As it stands now, it appears but little reduced by abrasion, and forms an interesting sample of what good concrete will withstand.

The whole of the Breakwater is now in excellent condition and may not require heavy repairs for years to come.

On Electric Block Telegraphs. *By* F. H. Varley

The Government Establishments of Plymouth and Neighbourhood.
By R. N. Worth.

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MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

[*An asterisk (*) signifies that no abstract of the communication is given.*]

PRINTED BY TAYLOR AND FRANCIS,
RED LION COURT, FLEET STREET.

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 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, Professor 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 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 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 of inquiry into 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 Coast 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 5s.*

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 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

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Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

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Associates for the Meeting in 1877 may obtain the Volume for the Year at two thirds of the Publication Price.

PROCEEDINGS OF THE FIRST AND SECOND MEETINGS, at York and Oxford, 1831 and 1832, *Published at* 13*s.* 6*d.*

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PROCEEDINGS OF THE THIRD MEETING, at Cambridge, 1833, *Published at* 12*s.* (Out of Print.)

CONTENTS:—Proceedings of the Meeting;—John Taylor, on Mineral Veins;—Dr. Lindley, on the Philosophy of Botany;—Dr. Henry, on the Physiology of the Nervous System;—P. Barlow, on the Strength of Materials;—S. H. Christie, on the Magnetism of the Earth;—Rev. J. Challis, on the Analytical Theory of Hydrostatics and Hydrodynamics;—G. Rennie, on Hydraulics as a Branch of Engineering, Part I.;—Rev. G. Peacock, on certain Branches of Analysis.

Together with papers on Mathematics and Physics, Philosophical Instruments and Mechanical Arts, Natural History, Anatomy, Physiology, and History of Science.

PROCEEDINGS OF THE FOURTH MEETING, at Edinburgh, 1834, *Published at* 15*s.*

CONTENTS:—H. G. Rogers, on the Geology of North America;—Dr. C. Henry, on the Laws of Contagion;—Prof. Clark, on Animal Physiology;—Rev. L. Jenyns, on Zoology;—

Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at* 13*s*. 6*d*.

Contents:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat;—A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phenomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at* 12*s*.

Contents:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis, on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c.;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s*. 6*d*.

Contents:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thomson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lt.-Col. Sykes, on the Statistics of the Four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robison and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface;—J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s*.

Contents:—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands;—D. Lardner, LL.D., on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINTH MEETING, at Birmingham, 1839, *Published at* 13*s*. 6*d*. (Out of Print.)

CONTENTS:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media;—Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a Letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles;—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s*. (Out of Print.)

CONTENTS:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839-40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s*. 6*d*.

CONTENTS:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the FOURTEENTH MEETING, at York, 1844, *Published at* £1.

Contents:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes; —Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines; —Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves; —L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

Contents:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-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;—J. Percy, M.D., 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 Arian 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* 9*s.*

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 Lt.-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* 10*s.*

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* 15*s*. (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; —John P. Bell, M.D., 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 I.;—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 15s.*

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 $\Sigma_0^{-\alpha} \frac{t\, \alpha^{t|+1} \beta^{t|+1} \delta^{t|+1}}{1^{t+1} \gamma^{t+1} \epsilon^{t+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\,(\alpha+1)\,(\alpha+2)$ &c....$(\alpha+t-1)$;—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;—John P. Hodges, M.D., 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, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., 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, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor 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, M.A., 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, 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 20s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—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 Connal 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's 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, Esq., of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, 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 Breaks 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;—Prof. 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;—Professor 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;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Professor 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 connexion 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 N. and E. 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;—Professor 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;—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;—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;—Professor A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Professor 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 Iron-clad 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 5*s.*

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 2*s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Sea-going 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 Sea-going 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 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 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 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 5s.

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 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 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, Professor 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

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* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
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 Assistant General Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *ABEL, FREDERICK AUGUSTUS, C.B., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1873. ‡*Abercrombie, William. 5 Fairmount, Bradford, Yorkshire.*
1863. *Abernethy, James. 4 Delahay-street, Westminster, London, 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. 3 St. Alban's-road, Kensington, London, W.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1877. §Ace, Rev. Daniel, D.D. Laughton, near Gainsborough, Lincolnshire.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. Oxford.
1873. *Acland, Rev. H. D. Loughton, Essex.
ACLAND, HENRY W. D., 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. 13 Vincent-square, Westminster, S.W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.

Year of Election.

Adair, John. 13 Merrion-square North, Dublin.
1872. ‡ADAMS, A. LEITH, M.A., M.B., F.R.S., F.G.S., Professor of Zoology, Royal College of Science for Ireland. 18 Clarendon-gardens, Maida Hill, W.; and Junior United Service Club, Charles-street, St. James's, London, S.W.
1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.
*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndsean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1871. §Adams, John R. 3 College-gardens, Dulwich, Surrey, S.E.
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.
ADDERLEY, The Right Hon. Sir CHARLES BOWYER, M.P. Hams-hall Coleshill, Warwickshire.
Adelaide, The Right Rev. Augustus Short, D.D., Bishop of. South Australia.
1860. **Adie, Patrick. Grove Cottage, Barnes, London, S.W.*
1865. *Adkins, Henry. Ley Hill, Oakfield, near Birmingham.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. The Flosh, Cleator, Carnforth.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Carnforth.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1859. ‡AIRLIE, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich, S.E.
1871. §Aitken, John. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
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. Side Brook, Salemoor, Manchester.
1872. *Alcock, Thomas, M.D. Oakfield, Ashton-on-Mersey, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1859. ‡ALEXANDER, General Sir JAMES EDWARD, K.C.B., K.C.L.S., F.R.A.S., F.R.G.S., F.R.S.E. Westerton, Bridge of Allan, N.B.
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.
1867. ‡Alison, George L. C. Dundee.
1863. ‡*Allan, Miss.*
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.
1871. §ALLEN, ALFRED H., F.C.S. 1 Surrey-street, Sheffield.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.

Year of Election.

1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allman, George J., M.D., F.R.S.L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Athenæum Club, London, S.W.; and Parkstone, Dorset.
1875. §Alston, Edward R., F.Z.S. 22a Dorset-street, Portman-square, London, W.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
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.
1875. ‡Anderson, Captain S., R.E. Junior United Service Club, Charles-street, St. James's, London, S.W.
1870. ‡*Anderson, Thomas Darnley. West Dingle, Liverpool.*
1853. **Anderson, William (Yr.). 2 Lennox-street, Edinburgh.*
*Andrews, Thomas, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S., Vice-President and Professor of Chemistry, Queen's College, Belfast. Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1877. §Angell, John. 81 Ducie-grove, Oxford-street, Manchester.
1859. ‡Angus, John. Town House, Aberdeen.
*Ansted, David Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 1 Prince's-street, Storey's-gate, Westminster, S.W.; and Melton, Suffolk.
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 Mineralogy at Dublin University. South Hill, Blackrock, Co. Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
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. West Newington House, Edinburgh.
1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.
1851. ‡Argyll, His Grace the Duke of, K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inveraray, Argyleshire.
1865. ‡*Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.*
1861. ‡Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1873. §Armstrong, Henry E., Ph.D., F.R.S., F.C.S. London Institution, Finsbury-circus, London, E.C.
1876. ‡Armstrong, James. 28a Renfield-street, Glasgow.
1874. ‡Armstrong, James T., F.C.S. Plym Villa, Clifton-road, Tuebrook, Liverpool.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *Armstrong, Sir William George, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Jesmond Dene, Newcastle-upon-Tyne.
1871. ‡Arnot, William, F.C.S. St. Margaret's, Kirkintilloch, N.B.
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. District Asylum, Londonderry.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.

Year of Election.

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. Kilrea, Co. Derry, Ireland.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1872. §Atchison, Arthur T. Rosehill, Dorking.
1873. ‡*Atchison, D.G. Tyersall Hall, Yorkshire.*
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡Atherton, J. H., F.C.S. Long-row, Nottingham.
1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
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.
1858. Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1867. ‡Avison, Thomas, F.S.A. Fulwood Park, Liverpool.
1877. *Ayrton, Professor W. E. The Imperial College of Engineering, Tokio, Japan. (Care of Mrs. J. C. Chaplin, 98 Palace-gardens-terrace, Kensington, London, 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.
Backhouse, Edmund. Darlington.
Backhouse, Thomas James. Sunderland.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1877. §Badock, W. F. Badminton House, Clifton Park, Bristol.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
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.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. §Bain, James. 3 Park-terrace, Glasgow.
1865. ‡BAIN, Rev. W. J. Glenlark Villa, Leamington.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, EDWARD. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
858. ‡Baines, Frederick. Burley, near Leeds.
858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.

Year of Election.

1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley Hill, Cheadle, Manchester.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Moorland House, Stoke Bishop, near Bristol.
1875. ‡Baker, W. Proctor. Brislington, Bristol.
1860. ‡Balding, James, M.R.C.S., M.A. Barkway, Royston, Hertfordshire.
1871. *Balfour, Francis Maitland, M.A. Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. §Balfour, Isaac Bayley, D.Sc. 27 Inverleith-row, Edinburgh.
*Balfour, John Hutton, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*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 Royal Astronomer. The Observatory, Dunsink, Co. Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London; and Glen Rothay, near Ambleside, Westmoreland.
1876. ‡Ballantyne, James. Southcroft, Rutherglen, Glasgow.
1870. ‡Balmain, William H., F.C.S. Spring Cottage, Great St. Helens, Lancashire.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1874. *Bangay, Frederick Arthur. Cheadle, Cheshire.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1870. ‡Banister, Rev. William, B.A. St. James's Mount, Liverpool.
1861. ‡*Bannermann, James Alexander. Limefield House, Higher Broughton, near Manchester.*
1866. ‡Barber, John. Long-row, Nottingham.
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., M.R.A.S. Bury-hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
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.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. 48 Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡Barkly, Sir Henry, K.C.B., F.R.S., F.R.G.S. 25 Queen's Gate-terrace, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.

Year of Election.

Barlow, Peter. 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., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)
Barnes, Thomas Addison. 40 Chester-street, Wrexham.
*Barnett, Richard, M.R.C.S. 2 Barbourne-terrace, Worcester.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1861. *Barr, William R., F.G.S. Fernside, Cheadle Hulme, Cheshire.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
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.
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. St. Winifred's, Lincoln.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡Barry, Rev. Canon, D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
Barstow, Thomas. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. §Bartley, George C. T. Ealing, Middlesex, W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
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. 44 St. Paul's-road, Camden-square, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
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. 20 Queen Anne-street, London, W.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
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. 9 Hyde Park-gate South, London, W.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S., F.R.G.S. 16 Great George-street, London, S.W.
1864. ‡Bates, Henry Walter, Assist.-Sec. R.G.S., F.L.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of. The Palace, Wells, Somerset.

Year of Election

1869. ‡Batten, John Winterbotham. 35 Palace-gardens-terrace, Kensington, London, S.W.
1863. §BAUERMAN, H., F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 16 London-street, Fenchurch-street, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
1854. ‡*Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.*
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
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.
1872. ‡Beanes, Edward, F.C.S. The White House, North Dulwich, Surrey, S.E.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Captain George G., F.R.G.S. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. 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.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1865. *BELAVENETZ, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. §Bell, A. P. Royal Exchange, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *BELL, ISAAC LOWTHIAN, M.P., F.R.S., F.C.S., M.I.C.E. Rounton Grange, by Northallerton.
1875. §Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Kersal Clough, Higher Broughton, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. §Bell, R. Bruce. 2 Clifton-place, Glasgow.

Year of
Election.

- BELL, THOMAS, F.R.S., F.L.S., F.G.S. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. Crosby Court, Northallerton.
1867. ‡Bell, Thomas. Belmont, Dundee.
1875. ‡Bell, William. 36 Park-road, New Wandsworth, Surrey. S.W.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡*Bellhouse, William Dawson. 1 Park-street, Leeds.*
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 75 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. 7 Belgrave-villas, Margate.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. ‡*Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.*
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 19 Tavistock-square, London, W.C.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡BENTHAM, GEORGE, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 1 Trebovir-road, South Kensington, London, S.W.
1875. ‡Beor, Henry R. Scientific Club, Savile-row, London, W.
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. ‡Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, HENRY. Denmark Hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1876. *Bettany, G. T., B.A., B.Sc. Caius College, Cambridge.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. ‡Bickerton, A. W., F.C.S. Hartley Institution, Southampton.
1868. ‡BIDDER, GEORGE PARKER, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 16 Green Park, Bath.
1855. ‡*Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.*
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1877. §Binder, W. J., B.A. Barnsley.
1842. BINNEY, EDWARD WILLIAM, F.R.S., F.G.S. Cheetham Hill, Manchester.
1873 ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
Birchall, Edwin. Douglas, Isle of Man.

Year of Election.

Birchall, Henry. College House, Bradford.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 7 Brookside, Cambridge.
1841. *Birt, William Radcliff, F.R.A.S. Hawkenbury, Palmerston-road, Buckhurst Hill.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. §Blachford, The Right Hon. Lord, K.C.M.G. Cornwood, Ivy-bridge.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. 14 Victoria-road, Kensington, London, W.
1876. ‡Blackburn, Hugh, M.A., Professor of Mathematics in the University of Glasgow.
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.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
*Blackwall, Rev. John, F.L.S. Hendre House, near Llanrwst, Denbighshire.
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.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1845. ‡*Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.*
1861. §Blakiston, Matthew, F.R.G.S. 18 Wilton-crescent, London, S.W.
*Blakiston, Peyton, M.D., F.R.S. 140 Harley-street, London, W.
1868. ‡*Blanc, Henry, M.D. 9 Bedford-street, Bedford-square, London, W.*
1869. ‡Blanford, W. T., F.R.S., F.G.S., F.R.G.S., Geological Survey of India, Calcutta.
*Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
Blore, Edward, LL.D., F.R.S., F.R.G.S., F.S.A. 4 Manchester-square, London, W.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey
Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1866. §*Bogg, Thomas Wemyss. 129 Plymouth-grove, Manchester.*
1876. §Bogue, David. 192 Piccadilly, London, W.
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
Bond, Henry John Hayes, M.D. Cambridge.

Year of Election.

1871. §Bonney, Rev. Thomas George, M.A., F.S.A., F.G.S. St. John's College, Cambridge.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1876. §Booth, William H. Trinity College, Oxford.
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.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
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.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
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. The University, Glasgow.
Bottomley, William. 14 Brunswick-gardens, Kensington, London, W.
1876. §Bottomley, William, jun. 14 Brunswick-gardens, Kensington, London, W.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen, F.S.S. Abberley Lodge, Hudstone-drive, Harrow.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdown-parade, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's Park, Liverpool.
1869. ‡*Bowring, J. C. Larkbeare, Exeter.*
1863. ‡*Bowron, James. South Stockton-on-Tees.*
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, Rev. G. D. Soho House, Handsworth, Birmingham.
1872. *BRABROOK, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, London, S.E.
1870. §Brace, Edmund. 3 Spring-gardens, Kelvinside, Glasgow.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1861. *Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1842. *BRADY, Sir ANTONIO, J.P., F.G.S. Maryland Point, Stratford, Essex, E.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡BRADY, GEORGE S. 22 Fawcett-street, Sunderland.

Year of Election.

1862. §BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. Hillfield, Gateshead.
1875. ‡Bragge, William, F.S.A., F.G.S. Shirle Hill, Sheffield.
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §BRAMWELL, FREDERICK J., M.I.C.E., F.R.S. 37 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
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.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1873. ‡Breffit, Edgar. Castleford, near Normanton.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. §Brent, Francis. 19 Clarendon-place, Plymouth.
1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. §Briant, T. Hampton Wick, Kingston-on-Thames.
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.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1866. §Briggs, Joseph. Barrow-in-Furness.
1863. *BRIGHT, Sir CHARLES TILSTON, 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, Commander LINDESAY. Army and Navy Club, Pall Mall, London, S.W.
1842. *Broadbent, Thomas. Marsden-square, Manchester.*
1859. *BRODHURST, BERNARD EDWARD. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡BRODIE, Sir BENJAMIN C., Bart., M.A., D.C.L., F.R.S., F.C.S. Brockham Warren, Reigate.
1834. ‡BRODIE, Rev. JAMES, F.G.S. Monimail, Fifeshire.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
*BROOKE, CHARLES, M.A., F.R.S., F.R.C.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1874. §Broom, William. 20 Woodlands-terrace, Glasgow.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
*BROUN, JOHN ALLAN, F.R.S. 9 Abercorn-place, St. John's Wood, London, N.W.
1864. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.

Year of
Election.

1863. *Brown, Alexander Crum, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinbugh. 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.
1858. §Brown, Henry, J.P., LL.D. Daisy Hill, Rawdon, Leeds.
1870. §Brown, Horace T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. *Brown, J. Campbell, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1876. §Brown, John. Edenderry House, Belfast.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1863. ‡*Brown, John H.*
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡Brown, Robert, M.A., Ph.D., F.L.S., F.R.G.S. 26 Guildford-road, Albert-square, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
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.
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. Northside, St. John's, Sevenoaks, Kent.
1875. ‡Browne, Walter R. Bridgwater.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. ‡Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1853. ‡*Brownlow, William B. Villa-place, Hull.*
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1871. ‡*Brunnöw, F.*
1868. ‡Brunton, T. Lauder, M.D., F.R.S. 50 Welbeck-street, London, W.
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.
Bryce, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡Buccleuch and Queensberry, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §Buchan, Alexander, M.A., F.R.S.E., Sec. Scottish Meterological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Andrew, M.D., Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.

Year of Election.

Buchanan, D. C. Poulton-cum-Seacombe, Cheshire.
1871. ‡Buchanan, John Y. 10 Moray-place, Edinburgh.
1864. §BUCKLE, Rev. GEORGE, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, Professor JAMES, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1869. ‡Bucknill, J. C., M.D., F.R.S. 39 Wimpole-street, London, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1848. *BUDD, JAMES PALMER. Ystalyfera Iron Works, Swansea.
1875. §Budgett, Samuel. Cotham House, Bristol.
1871. §Bulloch, Matthew. 11 Park-circus, Glasgow.
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.
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. Stratton-street, Piccadilly, London, W.
1874. ‡Burdon, Henry, M.D. Clandeboye, Belfast.
1872. *Burgess, Herbert. 62 High-street, Battle, Sussex.
1865. ‡*Burke, Luke. 5 Albert Terrace, Acton, London, W.*
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877. §Burns, David, C.E. Alston, Carlisle.
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.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *BUSK, GEORGE, F.R.S., V.P.L.S., F.G.S. 32 Harley-street, Cavendish-square, London, W
1857. ‡Butt, Isaac, Q.C., M.P. 64 Eccles-street, Dublin.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir T. Fowell. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. 2 Bank-street, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1875. §Byrom, W. Ascroft, F.G.S. 27 King-street, Wigan.

1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1876. §Caird, Alexander M'Neel. Genoch, Wigtownshire.
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.

Year of Election.

1877. §Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, CHARLES A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S. 13 Cornwall-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 129 Bath-street, Glasgow.
1876. ‡Campbell, James A. 3 Claremont-terrace, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. ‡CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana. (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S.W.)
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. Dr. WILLIAM M. Queen's College, Cambridge.
1868. *Cann, William. 9 Southernhay, Exeter.
1873. *Carbutt, Edward Hamer, C.E. St. Ann's, Burley, Leeds, Yorkshire.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
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.
Carmichael, H.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. *Carpenter, P. Herbert. 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., Registrar of the University of London. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. Winifred House, Pembroke-road, Clifton, Bristol.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1867. §CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Royal Dublin Society, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.

Year of Election.

1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 69 Elizabeth-street, Liverpool.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South-grove, Highgate, London, N.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William. 38 Elmfield-terrace, Saville Park, Halifax.
1842. **Cassels, Rev. Andrew, M.A.*
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1873. *Cavendish, Lord Frederick, M.P. 21 Carlton House-terrace, London, S.W.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of 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.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID, M.P. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston Court, near Leominster.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡*Chamberlin, Robert. Catton, Norwich.*
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.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. Four Oaks Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1877. §Chapman, T. Algernon. 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.
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 113A Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.

Year of
Election.

1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, 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. Lee Place, Charlbury, Oxon.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.
1876. *CHRYSTAL, G., B.A., Professor of Mathematics. The University, St. Andrews, N.B.
1870. §CHURCH, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡*Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.*
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §CLAPHAM, ROBERT CALVERT. Garsdon House, Garsdon, Newcastle-on-Tyne.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
1876. ‡*Clark, David P. Glasgow.*
1877. *Clark, F. J. 20 Bootham, York.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1876. ‡Clark, George W. Glasgow.
1846. **Clark, Henry, M.D. 2 Arundel-gardens, Kensington, London, W.*
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
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. Lark Hill House, Edgeley, Stockport.
1877. §Clarke, Professor John W. University of Chicago, Illinois.
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
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.

Year of Election.

1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1850. ‡Cleghorn, Hugh, M.D., F.L.S., late Conservator of Forests, Madras. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1873. §Cliff, John, F.G.S. Halton, Runcorn.
1869. ‡Clifford, William Kingdon, M.A., F.R.S., Professor of Applied Mathematics and Mechanics in University College, London. 26 Colville-road, Bayswater, London, W.
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.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §Close, Thomas, F.S.A. St. James's-street, Nottingham.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. 20 Park-street, Bath.
1851. *Cobbold, John Chevallier. Holywells, Ipswich; and Athenæum Club, London, S.W.
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. 129 Lower Baggot-street, Dublin.
1854. ‡*Cockey, William.*
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. *Cole, Henry Warwick, Q.C. 23 High-street, Warwick.
1876. §Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 37 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.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1861. **Collie, Alexander.* 12 *Kensington Palace-gardens, London, W.*
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. §Collins, J. H., F.G.S. 57 Lemon-street, Truro, Cornwall.
1876. §Collins, William. 3 Park-terrace East, Glasgow.
Collis, Stephen Edward. Listowel, Ireland.

Year of Election.

1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
Colthurst John. Clifton, Bristol.
1874. ‡Combe, James. Ormiston House, Belfast.
*COMPTON, The Ven. Lord ALWYN. Castle Ashby, Northamptonshire; and 145 Piccadilly, London, W.
1846. *Compton, Lord William. 145 Piccadilly, London W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1876. ‡Cook, James. 162 North-street, Glasgow.
1876. *COOKE, CONRAD W., C.E. 5 Nelson-terrace, Clapham Common, London, S.W.
1863. ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.R.G.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
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.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1875. ‡Cooper, T. T., F.R.G.S. Care of Messrs. King & Co., Cornhill, London, E.C.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1871. ‡*Copeland, Ralph, Ph.D. Parsonstown, Ireland.*
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cormack, John Rose, M.D., F.R.S.E.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., 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.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.

Year of Election.

1874. §Courtauld, John M. Bocking Bridge, Braintree, Essex.
1865. ‡Courtauld, Samuel, F.R.A.S. 76 Lancaster-gate, London, W.; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. §Cowan, J. B. 159 Bath-street, Glasgow.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Hawthorn House, Horsham.
1873. *Cowans, John. Cranford, Middlesex.
Cowie, The Very Rev. Benjamin Morgan, M.A., B.D., Dean of Manchester. The Deanery, Manchester.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. 18 Windsor-street, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1871. ‡Cox, William J. 2 Vanburgh-place, Leith.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡*Craig, S. The Wallands, Lewes, Sussex.*
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡Crampton, Rev. Josiah. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1876. ‡Crawford, Chalmond, M.P. Ridemon, Crosscar.
1871. *Crawford, William Caldwell. Eagle Foundry, Port Dundas, Glasgow.
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfarthfa Castle, Merthyr Tydvil.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
Creyke, The Venerable Archdeacon. Bolton Percy Rectory, Tadcaster.
1865. ‡*Crocker, Edwin, F.C.S. 76 Hungerford-road, Holloway, London, N.*
1858. ‡Crofts, John. Hillary-place, Leeds.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1855. ‡*Crompton, Charles, M.A.*
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §Crookes, William, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §Crosskey, Rev. H. W., F.G.S. 28 George-road, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.

Year of
Election.

1870. *Crossley, Edward, F.R.A.S. Bermerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. §Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1876. ‡Cunlif, Richard S. Carlton House, Stirling.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Elms, Handforth, Manchester.
1877. §Cunningham, D. J., M.D. University of Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S. Professor of Natural History in Queen's College, Belfast.
1855. ‡Cunningham, William A. 2 Broadwalk, Buxton.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, Professor ARTHUR HILL, LL.D. Queen's College, Galway.
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H. Great Crosby, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡DANBY, T. W. Downing College, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1873. ‡*Danehill, F. H. Vale Hall, Horwich, Bolton, Lancashire.*
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.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. and M.R.I.A. Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1872. §Davenport, John T. 64 Marine Parade, Brighton.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.

Year of Election.

1871. §Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, F.R.S., F.G.S. 3 Leopold-road, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1863. ‡*Davies, Griffith. 17 Cloudesley-street, Islington, London, N.*
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester.
1873. *Davis, Alfred. Sun Foundry, Leeds.
1870. *Davis, A. S. Mornington Villa, Leckhampton-road, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1873. *Davis, James W. Chevinedge, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1859. ‡DAVIS, J. BARNARD, M.D., F.R.S., F.S.A. Shelton, Hanley, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
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.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Llanferris, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A. Birchview, Norman-road, Rusholme, Manchester.
Dawson, John. Barley House, Exeter.
1855. ‡DAWSON, JOHN W., 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.
1871. ‡DAY, ST. JOHN VINCENT, C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. §DEACON, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. ‡*Deacon, Henry Wade.*
1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital, London, S.E.
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.
1870. ‡De Meschin, Thomas, M.A., LL.D. 3 Middle Temple-lane, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
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.

Year of Election.

1856. *DERBY, The Right Hon. the Earl of, 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.

De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.

1870. ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.

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., F.R.S.E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. Brookside, Cambridge.

1872. ‡Dewick, Rev. E. S. The College, Eastbourne, Sussex.

1873. *Dew-Smith, A. G. 7A Eaton-square, London, S.W.

1852. ‡DICKIE, GEORGE, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.

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 Glasgow. 11 Royal-circus, Edinburgh.

1876. ‡Dickson, Gavin Irving. 37 West George-street, Glasgow.

1862. *DILKE, Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.

1877. §Dillon, James, C.E. 46 Morehampton-road, Dublin.

1848. ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwern, near Swansea.

1872. §Dines, George. Woodside, Hersham, Walton-on-Thames.

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, W. Andersonian University, Glasgow.

1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.

1853. ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.

1865. ‡*Dixon, L.*

1861. ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, Regent's-park, London, N.W.

*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.

1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.

1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.

1870. *Dodd, John. 6 Thomas-street, Liverpool.

1874. ‡*Dodd, W. H., M.A. Mountjoy-street, Dublin.*

Year of Election.

1876. ‡Dodds, J. M. 15 Sandyford-place, Glasgow.
1857. ‡*Dodds, Thomas W., C.E. Rotherham.*
*Dodsworth, Benjamin. Burton House, Scarborough.
*Dodsworth, George. The Mount, York.
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.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871. ‡*Donkin, Arthur Scott, M.D. Sunderland.*
1877. *Donkin, Bryan. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 28 Upper Sackville-street, Dublin.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *Donnelly, William, C.B., Registrar-General for Ireland. Charlemont House, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1876. *Douglas, Rev. G. C. M. 10 Fitzroy-place, Glasgow.
1877. *Douglass, James N., C.E. Trinity House, London, E.C.
1855. ‡Dove, Hector. Rose Cottage, Trinity, near Edinburgh.
1870. ‡Dowie, J. M. Wetstones, West Kirby, Cheshire.
1876. §Dowie, Mrs. Muir. Wetstones, West Kirby, Cheshire.
1857. ‡Downing, S., C.E., LL.D., Professor of Civil Engineering in the University of Dublin. 4 The Hill, Monkstown, Co. Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
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.
1869. §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
1874. ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
1859. ‡*Drummond, Robert. 17 Stratton Street, London, W.*
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡*Dryden, James. South Benwell, Northumberland.*
1870. §Drysdale, J. J., M.D. 36a Rodney-street, Liverpool.
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.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *Duff, Mountstuart Ephinstone Grant-, LL.B., M.P. York House, Twickenham, Middlesex.
1852. ‡Dufferin and Claneboye, The Right Hon. the Earl of, K.P., K.C.B., F.R.S. Government House, Ottawa, Canada.
1877. §Duffey, George F., M.D. 40 Fitzwilliam-place, Dublin.
1875. §Duffin, C. L'Estrange, C.E. Rathkeale, Co. Limerick.
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.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.

Year of Election.

1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 99 Abbey-road, St. John's Wood, London, N.W.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1862. §DUNN, ROBERT, F.R.C.S. 31 Norfolk-street, Strand, London, W.C.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodbury 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.
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.
1877. §Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
*EARNSHAW, Rev. SAMUEL, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON EDWARD, C.E. 7 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John, C.E. Durie House, Abercromby-street, Helensburgh, N.B.
1870. §Eaton, Richard. Basford, Nottingham.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡*Eckersley, James.*
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Martinstown, Dorchester.
1870. *Eddison, Dr. John Edwin. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*EDGEWORTH, MICHAEL P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. ‡Edward, James. Balruddery, Dundee.
Edwards, John.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1867. ‡Edwards, William. 70 Princes-street, Dundee.
*EGERTON, Sir PHILIP DE MALPAS GREY, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. ‡Elcock, Charles. 39 Lyme-street, Shakspere-street, Ardwick, Manchester.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.

Year of
Election.

1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
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. Fair Park House, Exeter.
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.
1869. ‡Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1871. ‡*Engelson, T.* 11 *Portland-terrace, Regent's Park, London, N.W.*
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
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.
1869. *Enys, John Davis. 33 Cambridge-terrace, Hyde Park, London, W.
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.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S.L. & E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practica Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempsted.
1865. *EVANS, Rev. CHARLES, M.A. The Rectory, Solihull, Birmingham
1872. *Evans, Frederick J., C.E. Clayponds, Brentford, Middlesex, W.
1876. ‡EVANS, Captain FREDERICK J. O., C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 116 Victoria-street, Westminster, S.W.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, S.W.
1861. *EVANS, JOHN, D.C.L., F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempsted.

Year of Election.

1876. ‡Evans, Mortimer, C.E. 97 West Regent-street, Glasgow.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Highgate, near Birmingham.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1871. §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868. *EVERETT, J. D., D.C.L., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1874. ‡Ewart, William. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred. 22 India-street, 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 Warren's, near Lyndhurst, Hants.
1866. ‡EYRE, Major-General Sir VINCENT, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. *Fairbairn, Thomas. Manchester.*
1865. ‡Fairley, Thomas, F.R.S.E. 8 Newton-grove, Leeds.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1877. §Faraday, F. J. College Chambers, 17 Brazenose-street, Manchester.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. §FARR, WILLIAM, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Register Office, London. Southlands, Bickley, Kent.
1866. *FARRAR, Rev. FREDERIC WILLIAM, M.A., D.D., F.R.S., Canon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London, S.W.
1869. *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *FAWCETT, HENRY, M.A., M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
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, Ulverston, 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.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander 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, Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.

Year of Election.

1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *FERNIE, JOHN. Bonchurch, Isle of Wight.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, M.A., F.R.S. Caius College, 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.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *FIELD, ROGERS, B.A., C.E. 5 Cannon-row, Westminster, S.W.
1876. ‡Fielden, James. 2 Darnley-street, Pollokshields, near Glasgow.
1864. ‡Finch, Frederick George, B.A., F.G.S. 21 Croom's-hill, Greenwich, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1863. ‡*Finney, Samuel.*
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S. St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. §FITCH, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.
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.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
*FLEMING, WILLIAM, M.D. Rowton Grange, near Chester.
1867. §FLETCHER, ALFRED E. 21 Overton-street, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1853. ‡FLETCHER, ISAAC, M.P., F.R.S., F.R.A.S., F.G.S. Tarn Bank, Workington.
1869. ‡FLETCHER, LAVINGTON E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡FLOWER, WILLIAM HENRY, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1877. *Floyer, Ernest A., F.R.G.S. 7 The Terrace, Putney, S.W.

Year of Election.

1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1873. *Forbes, Professor George, M.A., F.R.S.E. Andersonian University, Glasgow.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1877. §Forbes, W. A. West Wickham, Kent.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *FORDHAM, H. GEORGE, F.G.S. Odsey, near Royston, Herts.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
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.
1871. ‡*Forsyth, William F.*
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. §FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar W., M.D. 4 Old-square, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S. Truro, Cornwall.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. The Oaks Vicarage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., F.R.S., F.L.S., F.C.S. Trinity College, and Great Shelford, near Cambridge.
1859. §FOSTER, PETER LE NEVE, M.A. Society of Arts, Adelphi, London, W.C.
1873. ‡Foster, Peter Le Neve, jun. Society of Arts, Adelphi, London, W.C.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1842. *Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London, S.W.*
1870. ‡Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866. §Fowler, George. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. §Fowler, John. 4 Gray-street, Glasgow.
1870. *Fowler, Robert Nicholas, M.A., F.R.G.S. 50 Cornhill, London, E.C.
1868. ‡Fox, Major-General A. H. LANE, F.R.S., F.G.S., F.R.G.S., F.S.A. Guildford, Surrey.
*Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1876. §Fox, G. S. Lane. 9 Sussex-place, London, S.W.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
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, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London, W.

Year of Election.

*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
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. 3 Grosvenor-street, Edinburgh.
1876. ‡Fraser, Rev. William, LL.D. Free Middle Manse, Paisley.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1877. §Freeman, Francis Ford. Blackfriars House, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡Frere, The Right Hon. Sir H. Bartle E., Bart., G.C.S.I., G.C.B., F.R.S., F.R.G.S., Governor of Cape Colony and Dependencies. Government House, Cape Town.
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 Summer-hill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse-hill, London, S.W.
1860. *Froude, William, M.A., C.E., F.R.S. Chelston Cross, Torquay.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
1872. *Fuller, Rev. A. Pallant, Chichester.
1873. ‡*Fuller, Claude S., R.N. 44 Holland-road, Kensington, London, W.*
1859. ‡Fuller, Frederick, M.A., Professor of Mathematics in the University and King's College, Aberdeen.
1869. ‡Fuller, George, C.E., Professor of Engineering in Queen's College, Belfast. 6 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

*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. Richmond Hill, Sheffield.
1876. ‡Gairdner, Charles. Mount Vernon, Shettleston, N.B.
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. 338 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., H.M. Inspector of Mines. Cardiff.
1860. *Galton, Captain Douglas, C.B., D.C.L., 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. 13 Margaret-street, Cavendish-square, London, W.

Year of Election.

1870. §Gamble, Lieut.-Col. D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. 10 Vyvyan-terrace, Clifton, Bristol; and Albion House, Rottingdean, Brighton.
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, Princes-road, Fallowfield, Manchester.
1862 §GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. ‡Garnham, John. 123 Bunhill-row, London, E.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Mayfield-road, Grassendale, 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. 21 Shrubbery Park West, Clifton, Bristol.
1875. §Gaye, Henry S. Newton Abbott, Devon.
1873. ‡Geach, R. G. Cragg Wood, Rawdon, Yorkshire.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §GEIKIE, ARCHIBALD, LL.D., F.R.S.L. & E., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Boroughfield, Edinburgh.
1871. §Geikie, James, F.R.S.L. & E., F.G.S. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1854. ‡Gerard, Henry. 8A Rumford-place, Liverpool.
1870. ‡Gerstl, R. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡Gibson, Alexander. 19 Albany-street, Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
1874. ‡Gibson, Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George A. 32 Lauder-road, Edinburgh.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James, M.A., Q.C. 35 Mountjoy-square South, Dublin.
1870. ‡*Gibson, R. E.*
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 19 Parkfield-road, Prince's Park, Liverpool.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, jun. The Observatory, Aberdeen.

Year of Election.

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.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. §Gimingham, Charles H. 45 St. Augustine's-road, Camden-square, London, N.W.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Wokingham, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. **Gladstone, Murray. 36 Wilton-crescent, London, S.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.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's-Inn, London, W.C.
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.
Glover, Thomas. Becley Old Hall, Rowsley, Bakewell.
1874. ‡Glover, Thomas. 77 Claverton-street, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. §GOFF, JAMES. The Mansion House, Dublin.
1873. §Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡Goodison, George William, C.E. Gateacre, Liverpool.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1871. *Gordon, Joseph Gordon, F.C.S. 20 King-street, St. James's, London S.W.
1840. ‡Gordon, Lewis D. B. Totteridge, Whetstone, London, N.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.

Year of Election.

1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. Rathronan House, Clonmel.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
Gould, John, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. §Gow, Robert. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Manville-crescent, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
1875. ‡Grahame, James. Auldhouse, Pollokshaws, near Glasgow.
1852. *Grainger, Rev. John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡Grant, Sir Alexander, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870. §Grant, Colonel J. A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
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., C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
*Graves, Rev. Richard Hastings, D.D. 31 Raglan-road, Dublin.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
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.
1873. ‡Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*Gray, William, F.G.S. Gray's-court, Minster Yard, York.
*Gray, Colonel William. Farley Hall, near Reading.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 32 Friar-gate, Derby.
1873. ‡Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E.C.
1869. §Greaves, William. Wellington-circus, Nottingham.
1872. §Greaves, William. 2 Raymond-buildings, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1877. §Greenwood, Holmes. 78 King-street, Accrington.
1862. *Greenwood, Henry. 32 Castle-street, and The Woodlands, Anfield-road, Anfield, Liverpool.

Year of Election.

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.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
*GRESWELL, Rev. RICHARD, M.A., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
1869. ‡GREY, Sir GEORGE, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
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. Hobart House, Dalkeith.
1870. ‡Grieve, John, M.D. 21 Lynedock-street, Glasgow.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. (ASSISTANT GENERAL SECRETARY.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡GRIFFITH, Rev. JOHN, M.A., D.C.L. Findon Rectory, Worthing, Sussex.
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1870. ‡Griffith, Rev. Henry, F.G.S. Barnet, Herts.
*GRIFFITH, Sir RICHARD JOHN, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
GRIFFITHS, Rev. JOHN, M.A. Wadham College, Oxford.
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.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY, F.G.S. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 20 Cork-street, Burlington-gardens, London, W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., Ph.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.A.S. 40 Leinster-square, Rathmines, Dublin.
1857. ‡GRUBB, THOMAS, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
1872. ‡Grüneisen, Charles Lewis, F.R.G.S. 16 Surrey-street, Strand, London, W.C.
Guest, Edwin, M.A., LL.D., F.R.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford Park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. §Gunn, William, F.G.S. Barnard Castle, Darlington.

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Year of Election.

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, London, W.C.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S.L. & E., Professor of Physics in the Royal School of Mines. 24 Stanley-crescent, Notting Hill, London, W.
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F. Owens College, Manchester.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. ‡Hackney, William. 9 Victoria Chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.
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.
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.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. Scientific Club, Savile-row, London, W.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1873. §HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
1861. ‡*Halliday, James. Whalley Cottage, Whalley Range, Manchester.*
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S.L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1875. ‡Hancock, C. F., jun., M.A. Royal Institution, Albemarle-street, London, W.

Year of Election.

1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 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.
Handyside, P. D., M.D., F.R.S.E. Fairmount, Moffat, Dumfriesshire.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. 3 Norham-gardens, Oxford.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, Kings Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1876. ‡Harker, Allen. 17 Southgate-street, Gloucester.
1853. §HARKNESS, ROBERT, F.R.S.L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. Brompton, Wykeham Station, York.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and Burton Bank, Mill Hill, Middlesex, N.W.
1861. ‡*Harman, H. W., C.E.* 16 *Booth-street, Manchester.*
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1872. §Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1873. ‡Harris, W. W. Oak-villas, Bradford, Yorkshire.
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. 14 St. James's-row, Sheffield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. Cintra Park Villa, Upper Norwood, S.E.

Year of Election.

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.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡HARROWBY, The Right Hon. DUDLEY RYDER, Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. Harborne Hall, Birmingham.
1876. *Hart, Thomas. Bank View, 33 Preston New-road, Blackburn.
1875. §Hart, W. E. Kilderry, near Londonderry.
1856. ‡*Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.*
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.C.S. King's College, London, W.C.
1854. §HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea, Douglas-road, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1875. ‡Hasting, G. W. Barnard's Green House, Malvern.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1837. ‡Hastings, W. Huddersfield.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, 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., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §HAWKSLEY, THOMAS, C.E., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. §Hay, Arthur J. Lerwick, Shetland.
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.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. William A., M.A. 3 Mountjoy-place, Dublin.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. The Park, Harrow.
1851. §HEAD, JEREMIAH, C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.

Year of Election.

1872. ‡*Healey, C. E. H. Chadwyck. 8 Albert-mansions, Victoria-street, London, S.W.*
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1877. §Hearder, Henry Pollington. Westwell-street, Plymouth.
1865. ‡Hearder, William. Rocombe, Torquay.
1877. §Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1858. *HEATON, JOHN DEAKIN, M.D., F.R.C.P. Claremont, Leeds.
1865. ‡*Heaton, Ralph. Harborne Lodge, near Birmingham.*
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. FOSTER, M.D., Professor of Chemistry in the University of St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.
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.
1866. ‡*Henderson, James, jun. Dundee.*
1874. ‡Henderson, James Alexander. Norwood Tower, Belfast.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1873. *HENDERSON, W. D. 12 Victoria-street, Belfast.
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. Mount Eagle, Sandyford, Co. Dublin.
1857. ‡Hennessy, John Pope, Governor of the Bahamas. Government House, Nassau.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Mathematics in University College, London. 21 South-villas, Camden-square, London, N.W.
Henry, Franklin. Portland-street, Manchester.
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. President, Queen's College, Belfast.
*HENRY WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. Norfolk-terrace, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡Hepburn, Thomas H. St. Mary's Cray, Kent.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. ‡*Herdman, John.*
1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.

Year of
Election.

1871. *HERSCHEL, Professor ALEXANDER S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1874. §Herschel, Major John, R.E., F.R.S. Mussoorie, N. W. P. India. (Care of Messrs. H. Robertson & Co., 5 Crosby-square, London, E.C.)
1865. ‡Heslop, Dr. Birmingham.
1863. ‡*Heslop, Joseph.*
1873. ‡Heugh, John. Gaunt's House, Wimborne, Dorset.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
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.
1875. ‡Hicks, Henry, F.G.S. Heriot House, Hendon, Middlesex, N.W.
1877. §Hicks, W. M. St. John's College, Cambridge.
1864. *HIERN, W. P., M.A. Castle House, Barnstaple.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.
1866. ‡Higginbottom, John, F.R.S., F.R.C.S. Gill-street, Nottingham.
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.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. ‡*Higginson, Alfred. 44 Upper Parliament-street, Liverpool.*
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
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.
*HILL, Sir ROWLAND, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡*Hill, William. Combe Hay, Bristol.*
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.

Year of Election.

1856. ‡*Hitch, Samuel, M.D.* *Sandywell Park, Gloucestershire.*
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
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.
1863. ‡Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡HOCKIN, CHARLES, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1877. §Hockin, Edward. Poughill, Stratton, Cornwall.
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.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1875. *Hodgson, Kirkman Daniel, M.P. 67 Brook-street, London, W.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1830. ‡Hodgson, W. B., LL.D., F.R.A.S., Professor of Commercial and Political Economy in the University of Edinburgh.
1865. *HOFMANN, AUGUST WILHELM, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.
1876. ‡Hogg, Robert. 54 Jane-street, Glasgow.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. The Gables, Osborne-road, Windsor.
*Holland, Philip H. Home Office, London, S.W.
1865. ‡Holliday, William. New-street, Birmingham.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1876. *Holms, James. Hope Park, Partick, near Glasgow.
1876. ‡Holms, Colonel William, M.P. Caldwell, Renfrewshire.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.A., M.R.I.A. Bank of Ireland, Dublin.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., K.C.B., M.D., D.C.L., LL.D., Pres. R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1877. *Hooper, Samuel F. Beechwood, Clapham Common, Surrey, S.W.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. ‡HOPE, WILLIAM, V.C. Parsloes, Barking, Essex.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *HOPKINSON, JOHN. 78 Holland-road, Kensington, London, W.
1871. §HOPKINSON, JOHN, F.G.S., F.R.M.S. Holly Bank, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.

Year of
Election.

1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
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. 16 Upper Brook-street, London, W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *HUDSON, HENRY, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennet's-hill, Doctors' Commons, London, E.C.; and St. John's College, Cambridge.
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.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, No humberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Thomas Edward. The Priory, Repton, Burton-on-Trent.
1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1837. §HULL, EDWARD, M.A., 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.
1861. ‡HUME, Rev. Canon ABRAHAM, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy 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.
1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
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.

Year of Election.

1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1875. §Hurnard, James. Lexden, Colchester, Essex.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1874. ‡Hutchinson, Thomas J., F.R.G.S. Chimoo Cottage, Mill Hill, London, N.W.
1876. ‡Hutchison, Peter. 28 Berkeley-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
1863. ‡*Hutt, The Right Hon. Sir W., K.C.B. Gibside, Gatcshead.*
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡Huxley, Thomas Henry, Ph.D., LL.D., Sec. 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.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

Ihne, William, Ph.D. Heidelberg.
1873. §Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
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.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡Ingram, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1870. *Inman, William. Upton Manor, Liverpool.
Ireland, R. S., M.D. 121 Stephen's-green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡Iselin, J. F., M.A., F.G.S. 52 Stockwell Park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. ‡Jack, William. 19 Lansdowne-road, Notting Hill, London, W.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, London, S.W.
1852. ‡Jacobs, Bethel. 40 George-street, Hull.
1874. *Jaffe, John. Cambridge Villa, Strandtown, near Belfast.

Year of Election.

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.
1875. ‡James, Rev. William. Harley Lodge, Clifton, Bristol.
1858. ‡James, William C. Woodside, Plymouth.
1863. ‡*Jameson, John Henry. 10 Catherine-terrace, Gateshead.*
1876. §Jamieson, J. L. K. The Mansion House, Govan, Glasgow.
1876. ‡Jamieson, Rev. Dr. R. 156 Randolph-terrace, 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.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡Jecks, Charles. 26 Langham-place, Northampton.
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, London, E.C.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., B.D., M.R.I.A. 64 Lower Leeson-street, Dublin.
1862. §JENKIN, H. C. FLEEMING, F.R.S., M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1864. §JENKINS, Captain GRIFFITH, C.B., F.R.G.S. Little Garth, Welshpool.
1873. §Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, near Bagshot, Surrey.
1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., LL.D., F.R.S., Professor of Political Economy in University College, London. The Chestnuts, Branch Hill, Hampstead Heath, London, N.W.
1872. *Joad, George C. Oakfield, Wimbledon, Surrey, S.W.
1871. *Johnson, David, F.C.S., F.G.S. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S. 3 Queen's-road, Southport.
1866. ‡Johnson, John. Knighton Fields, Leicester.
1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-street, Norwich.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard, 27 Dale-street, Manchester.

Year of
Election.

1870. §Johnson, Richard C., F.R.A.S. Higher Bebington Hall, Birkenhead.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡*Johnson, Thomas.*
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1871. ‡Johnston, A. Keith, F.R.G.S. 1 Savile-row, London, W.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
1864. ‡*Johnston, Edward.*
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
1876. ‡*Johnston, John, M.D. Edinburgh.*
*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 (H.M. Inspector of Schools). Inverness, N.B.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1877. §Jones, Henry C., F.C.S. 190 Blackstock-road, London, N.
1865. ‡*Jones, John. 49 Union-passage, Birmingham.*
*Jones, Robert. 2 Castle-street, Liverpool.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S., Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst. 5 College-terrace, York Town, Surrey.
1847. ‡JONES, THOMAS RYMER, F.R.S. 52 Cornwall-road, Westbourne Park, London, W.
1864. §JONES, Sir WILLOUGHBY, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
1875. *Jose, J. E. 3 Queen-square, Bristol.
*Joule, Benjamin St. John B. 28 Leicester-street, Southport, Lancashire.
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.
1872. ‡Joy, Algernon. 17 Parliament-street, Westminster, S.W.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.R.S., F.G.S. 6 Manor-view, Brixton, London, S.W.
1863. ‡*Jukes, Rev. Andrew. Spring Bank, Hull.*

1868. *Kaines, Joseph, M.A., D.Sc. 13 Finsbury-place South, London, E.C.
KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S. Principal of the Royal College of Cork. 51 Stephen's-green, 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.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.
Kay, Robert. Haugh Bank, Bolton-le-Moors.

Year of Election.

1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1872. ‡Keames, William M. 5 Lower Rock-gardens, Brighton.
1875. ‡Keeling, George William. Tuthill, Lydney.
1866. ‡*Keene, Alfred. Eastnor House, Leamington.*
1850. ‡KELLAND, Rev. PHILIP, M.A., F.R.S. L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh.
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.
1875. ‡KENNEDY, ALEXANDER B. W., C.E., Professor of Engineering in University College, London. 9 Bartholomew-road, London, N.W.
1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.
1857. ‡*Kennedy, Lieut.-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.*
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡*Kenworth, James Ryley. 7 Pembroke-place, Liverpool.*
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Dougalston, Milngavie, N.B.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
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.
1860. ‡KINAHAN, G. HENRY, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1858. ‡*Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.*
1875. *Kinch, Edward, F.C.S. Agricultural College, Home Department, Tokio, Japan. (Care of C. J. Kinch, Esq., Eaton Hasting, Lechlade, Gloucestershire.)
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §KING, KELBURNE, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 16 Vyvyan-terrace, 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.
1876. §Kingston, Thomas. Strawberry House, Chiswick, Middlesex.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. 1 Victoria-street, Westminster, S.W.

Year of Election.

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.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
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. 12 Windsor-terrace West, Hillhead, Glasgow.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
1836. Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1874. §Knowles, William James. Cullybackey, Belfast, Ireland.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 2 Portland-terrace, Regent's Park, London, N.W.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1875. *Knubley, Rev. E. P. 10 Bridge-road West, Battersea, S.W.
1870. ‡Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1877. §Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1846. *Laming, Richard. Arundel, Sussex.
1870. ‡*Lamport, Charles. Upper Norwood, Surrey, S.E.*
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877. §Landon, Frederic G. Nelson House, Devonport.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
*LARCOM, Major-General Sir THOMAS AISKEW, Bart., K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
LASSELL, WILLIAM, LL.D., F.R.S. L. & E., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. Lower King-street, Manchester.

Year of Election.

1870. *LATHAM, BALDWIN, 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, Portsmouth.
1875. ‡Lavington, William F. 107 Pembroke-road, Clifton, Bristol.
1870. *Law, Channell. 5 Champion-park, Camberwell, London, S.E.
1857. ‡Law, Hugh, Q.C. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1869. ‡*Lawson, Henry. 8 Nottingham-place, London, W.*
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1876. ‡Lawson, John. Cluny Hill, Forres, N.B.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
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.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡LEBOUR, G. A., F.G.S. Weedpark House, Dipton, Lintz Green, Co. Durham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡Lees, William. Link Vale Lodge, Viewforth, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
1872. ‡LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Spring-gardens, London, S.W.
*LEFROY, Lieut.-General Sir JOHN HENRY, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S. 82 Queen's-gate, London, S.W.
*Legh, Lieut.-Colonel George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.

Year of Election.

1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1863. *Lendy, Captain Auguste Frederic, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §Leonard, Hugh, F.G.S., M.R.I.A., F.R.G.S.I. Geological Survey of Ireland, 14 Hume-street, Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡Leslie, T. E. Cliffe, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1876. ‡Leveson, Edward John. Cluny, Sydenham Hill, S.E.
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.
1870. ‡Lewis, Alfred Lionel. 151 Church-road, De Beauvoir Town, London, N.
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., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1871. *Lindsay, The Right Hon. Lord, M.P. 47 Brook-street, London, W.
1871. ‡*Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.*
1870. ‡Lindsay, Thomas, F.C.S. 288 Renfrew-street, Glasgow.
1842. *Lingard, John R., F.G.S. 4 Westminster-chambers, London, S.W.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
Lister, James. Liverpool Union Bank, Liverpool.
1873. **Lister, Samuel Cunliffe. Farfield Hall, Addingham, Leeds.*
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Glasgow.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *Liveing, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.C.S., F.G.S. The University, Sydney. (Care of Mr. Bain, 1 Haymarket, London, W.)
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡*Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.*
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Park Glass Works, Birmingham.

Year of Election.

*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1870. ‡*Lloyd, James. 16 Welfield-place, Liverpool.*
1870. ‡*Lloyd, J. H., M.D. Anglesey, North Wales.*
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. *Lloyd, Sampson Samuel, M.P. 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.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1872. ‡LOCKE, JOHN, M.P. 63 Eaton-place, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875. *LODGE, OLIVER J., D.Sc. University College, London, W.C.; and 17 Parkhurst-road, London, N.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
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.
1866. §Longdon, Frederick. Luamdur, near Derby.
1857. ‡Longfield, Rev. George, D.D., M.R.I.A. Trinity College, Dublin.
LONGFIELD, The Right Hon. MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Reform Club, Pall Mall, London, S.W.
1875. §Lonsdale, N. Lowenthal. 1 Southernhay, Clifton, Bristol.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1876. *Love, James, F.R.A.S. Talbot Lodge, Bickerton-road, Upper Holloway, London, N.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
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.M.S. Highfield House Observatory, near Nottingham.
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.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1867. *Luis, John Henry. Cidhmore, Dundee.

Year of Election.

1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Tweed Lodge, Charles-street, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney. Harrow.
1864. *Lutley, John. Brockhampton Park, Worcester.
1866. ‡LYCETT, Sir FRANCIS. 18 Highbury-grove, London, N.
1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1874. ‡Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. §Lyte, Cecil Maxwell. Scientific Club, Savile-row, London, W.
1862. *Lyte, F. Maxwell, F.C.S. 6 Cité de Retiro, Faubourg St. Honoré, Paris.

1852. ‡MacAdam, 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. ‡M'Adam, William. 30 St. Vincent-crescent, Glasgow.
1876. *Macadam, William Ivison. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M'Allan, W. A. Norwich.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James A. M., M.D. 22 Cambridge-road, Kilburn, London, N.W.
1871. ‡M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M'CALLAN, Rev. J. F., M.A. Basford, near Nottingham.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. 18 Shaftesbury-terrace, Glasgow.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1840. M'CLELLAND, JAMES, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'CLINTOCK, Rear-Admiral Sir FRANCIS L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *McClure, J. H. 10 Esplanade, Waterloo, Liverpool.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
*M'Connel, James. Moore-place, Esher, Surrey.
1859. *M'Connell, David C., F.G.S. 44 Manor-place, Edinburgh.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1878. §McDonnell, Robert, M.D., F.R.S., M.R.I.A. Belmont-street, Dublin.
*McEwan, John. 9 Melville-terrace, Stirling, N.B.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1854. **Macfie, Robert Andrew.* 13 *Victoria-street, Westminster, S.W.*
1867. *M'Gavin, Robert. Ballumbie, Dundee.

Year of Election.

1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡McGeorge, Mungo. Nithodale, Laurie Park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.
1876. ‡M'Grigor, Alexander B. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1874. §MacIlwaine, Rev. William, D.D., M.R.I.A. Ulsterville, Belfast.
1876. §Macindoe, Patrick. 9 Somerset-place, Glasgow.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *McIntosh, W. C., M.D., F.R.S. L. & E., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1871. ‡Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡McKendrick, John G., M.D., F.R.S.E. 2 Chester-street, Edinburgh.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §Mackie, Samuel Joseph, F.G.S. 84 Kensington Park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 36 Derby-road, Higher Tranmere, Birkenhead.
1850. ‡Macknight, Alexander. 12 London-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. Shipley, near Bradford, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MacLaren, Duncan, M.P. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. ‡M'Lean, Charles. 6 Claremont-terrace, Glasgow.
1876. ‡M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.
1859. ‡Maclear, Sir Thomas, F.R.S., F.R.G.S., F.R.A.S. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §M'Leod, Herbert, 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. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. §MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
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.
MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MacNeill, Sir John, LL.D., F.R.S., F.R.A.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1859. ‡*Macpherson, Rev. W. Kilmuir Easter, Scotland.*
1852. *Macrory, Adam John. Duncairn, Belfast.
*Macrory, Edmund, M.A. 40 Leinster-square, Bayswater, London, W.
1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.

Year of Election.

1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡MACVICAR, Rev. JOHN GIBSON, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 2 Portsdown-road, London, W.
1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.
1866. §MAJOR, RICHARD HENRY, F.S.A., F.R.G.S. British Museum, London, W.C.
*MALAHIDE, The Right Hon. Lord TALBOT DE, M.A., D.C.L., F.R.S., F.G.S., F.S.A., M.R.I.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. 1 Cornwall-gardens, South Kensington, London, S.W.
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.
*MALLET, ROBERT, Ph.D., F.R.S., F.G.S., M.R.I.A. Enmore, The Grove, Clapham-road, Clapham, S.W.
1876. ‡Malloch, C. 7 Blythwood-square, Glasgow.
1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
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.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., F.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §MARRECO, A. FRIERE-. College of Physical Science, Newcastle-on-Tyne.
Marriott, John.
1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1865. ‡Marsh, J. F. Hardwick House, Chepstow.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1852. ‡Marshall, James D. Holywood, Belfast.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.
1870. ‡Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. ‡Martin, William Young. 3 Airlie-place, Dundee.
*Martindale, Nicholas. Meadow Bank, Vanbrugh-fields, Blackheath, S.E.
*Martineau, Rev. James, LL.D., D.D. 5 Gordon-street, Gordon-square, London, W.C.

Year of Election.

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.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum; and Professor of Mineralogy in the University of Oxford. 112 Gloucester-terrace, Hyde Park-gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
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.
1870. ‡*Massey, Thomas. 5 Gray's-Inn-square, London, W.C.*
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1876. §Matheson, John. Eastfield, Rutherglen, Glasgow.
1865. *Mathews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 49 Harborne-road, Birmingham.
1876. *Mathiesen, John, jun. Cordale, Renton, Glasgow.
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. St. Germains, Longniddry, East Lothian.
*MAXWELL, JAMES CLERK, M.A., LL.D., F.R.S.L. & E., Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.; and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1863. ‡Mease, George D. Bylton Villa, South Shields.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, Lieut.-General Count. 35 Queen's-gate, London, S.W.
1862. §MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Girdler's-road, Brook Green, London, W.
1877. §Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1871. ‡Merson, John. Northumberland County Asylum, Morpeth.
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. ‡*Michie, Alexander. 26 Austin Friars, London, E.C.*
1865. ‡Middlemore, William. Edgbaston, Birmingham.

Year of Election.

1876. *Middleton, Robert T. 197 West George-street, Glasgow.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
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. Highfield House, Dennistoun, Glasgow.
1876. §Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1865. ‡Miller, Rev. Canon J. C., D.D. The Vicarage, Greenwich, S.E.
1861. *Miller, Robert. Poise House, Bosden, near Stockport.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
Miller, William Hallows, M.A., LL.D., F.R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's University, Glasgow. 234 East George-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
1867. *Milne-Home, David, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1864. *Milton, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
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.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870. §Mitchell, John. York House, Clitheroe, Lancashire.
1868. §Mitchell, John, jun. Pole Park House, Dundee.
1876. ‡Mitchell-Fairlie, James. 17 St. George's-road, Glasgow.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §Moffat, Thomas, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. §Moggridge, Matthew, F.G.S. 8 Bina-gardens, South Kensington, London, S.W.
1855. ‡Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1877. *Molloy, Rev. G. 86 Stephen's-green, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §Molyneux, William, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.

Year of Election.

1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgeware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.
1874. §Moore, David, Ph.D., F.L.S., M.R.I.A. Glasnevin, Dublin.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*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.
1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1868. ‡*Morgan, Thomas H. Oakhurst, Hastings.*
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1867. ‡Morison, William R. Dundee.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. §Morris, Rev. S. S. O. The Grammar School, Dolgelly.
1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1863. ‡*Morrow, R. J. Bentick-villas, Newcastle-on-Tyne.*
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. 4 Royal Crescent, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
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.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. 78 Kenilworth-square, Rathgar, Dublin.
1873. *Mosse, George Staley. Cowley Hall, near Uxbridge.
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.)
1873. ‡Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J. Adsett Court, Westbury-on-Severn.
1865. §Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.
1872. ‡Mott, Miss Minnie. 1 De Montfort-street, 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.
1863. ‡Mounsey, Edward. Sunderland.

Year of Election.

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.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1874. §Muir, M. M. Pattison, F.R.S.E. Owens College, Manchester.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1876. §Muir, Thomas. High School, Glasgow.
1871. ‡*Muir, W. Hamilton.*
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 159 Camden-road, London, N.
1871. *Muirhead, Henry, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. ‡Muirhead, R. F. Meikle Cloak, Lochwinnoch, Renfrewshire.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, A. J., M.P., F.R.G.S. The Park, Nottingham.
1876. §Munro, Donald, F.C.S. 97 Eglinton-street, Glasgow.
1864. *Munro, Major-General William, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Sillwood Lodge, Brighton.
1872. *Munster, William Felix. 41 Brompton-square, London, W.
1864. §Murch, Jerom. Cranwells, Bath.
*Murchison, John Henry. Surbiton Hill, Kingston.
1864. *Murchison, K. R. Ashurst Lodge, East Grinstead.
1876. ‡Murdoch, James. Altony Albany, Girvan, N.B.
1855. §Murdock, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. ‡Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1871. ‡*Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.*
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven, Halifax.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡*Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.*
1859. §Mylne, Robert William, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1842. Nadin, Joseph. Manchester.
1855. *Napier, James R., F.R.S. 22 Blythwood-square, Glasgow.
1876. §Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *Napier, The Right Hon. Sir Joseph, Bart., D.C.L., LL.D. 4 Merrion-square South, Dublin.

Year of
Election.

Napper, James William L. Loughcrew, Oldcastle, Co. Meath.
1872. §Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. ‡Natal, John William Colenso, D.D., Lord Bishop of. Natal.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
1876. §Nelson, D. M. 48 Gordon-street, Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, 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.
1866. *Newdigate, Albert L. 2 The Pavement, Clapham Common, London, S.W.
1876. §Newhaus, Albert. 1 Prince's-terrace, Glasgow.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Balham, London, S.W.
1866. **Newmarch, William Thomas.*
1877. §Newth, A. H., M.D. Hayward's Heath, Sussex.
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.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Thomas, ex-Dean of Guild. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1874. §Nicholls, H. F. King's-square, Bridgewater, Somerset.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. 26 Devonshire-place, Portland-place, London, W.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Wellfield, Muswell Hill, London, N.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
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 St. Andrews, N.B.
1850. ‡NICOL, JAMES, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.
1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.
1877. *Niven, James, M.A. Queen's College, Cambridge.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
‡Nixon, Randal C. J., M.A. Green Island, Belfast.
1863. *NOBLE, Captain ANDREW, F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.

Year of Election.

1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §NORMAN, Rev. ALFRED MERLE, M.A. 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.
1866. ‡North, Thomas. Cinder-hill, Nottingham.
1869. ‡NORTHCOTE, The Right Hon. Sir STAFFORD H., Bart., C.B., M.P., F.R.S. Pynes, Exeter.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
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.

O'Callaghan, George. Tallas, Co. Clare.
Odgers, Rev. William James. Savile House, Weston-road, Bath.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. The Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. ‡O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1877. §Ogden, Joseph. 46 London-wall, London, E.C.
1876. §Ogilvie, Campbell P. Sizewell House, Lenton, Suffolk.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*OGILVIE-FORBES, GEORGE, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1874. §Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
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.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.
1874. ‡O'HAGAN, The Right Hon. Lord, M.R.I.A. 34 Rutland-square West, Dublin.
1862. ‡O'KELLY, JOSEPH, M.A. 51 Stephen's-green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §OLDHAM, JAMES, C.E. Cottingham, near Hull.
1857. *OLDHAM, THOMAS, M.A., LL.D., F.R.S., F.G.S., M.R.I.A. Eldon-place, Rugby.
1860. ‡*O'Leary, Professor Purcell, M.A. Queenstown.*
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1874. ‡O'Meara, Rev. Eugene. Newcastle Rectory, Hazlehatch, Ireland.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde Park, London, W.; and United Service Club, Pall Mall, London, S.W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.

Year of Election.

1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1876. ‡Orr, John B. Granville-terrace, Crosshill, Glasgow.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1873. ‡Osborn, George. 47 Kingcross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1877. *Osler, Miss A. F. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. 1 Pownall-gardens, Hounslow, near London.
1854. ‡Outram, Thomas. Greetland, near Halifax.
OVERSTONE, SAMUEL JONES LLOYD, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
OWEN, RICHARD, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1877. §Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1859. ‡PAGE, DAVID, LL.D., F.R.S.E., F.G.S. College of Physical Science, Newcastle-upon-Tyne.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. ‡Palmer, George. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. 376 Coldharbour-lane, Stockwell, S.W.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
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, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. 6 St. Mary's-row, Birmingham.
1864 §PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1877. §Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1875. ‡Pass, Alfred C. 16 Redland Park, Clifton, Bristol.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 Old-buildings, Lincoln's-Inn, London, W.C.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.

Year of Election.

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. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
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.
1877. §Payne, J. C. Charles. Botanic Avenue, Belfast.
1851. ‡Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.
1866. ‡Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1876. §Peace, G. H. Morton Grange, Eccles, near Manchester.
1847. ‡PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1863. §Peacock, Richard Atkinson, C.E., F.G.S. 2 Moselle-villas, St. Peter's-road, Margate.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1875. ‡Pearson, H. W. Tramore Villa, Nugent Hill, Cotham, Bristol.
1872. *Pearson, Joseph. Lern Side Works, Nottingham.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbeach, Cambridgeshire.
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
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.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1875. ‡Percival, Rev. J., M.A., LL.D. The College, Clifton, Bristol.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Royal School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnuts, Sudbury Harrow.
1861. ‡*Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.*
1877. §Perkins, Loftus. 140 Abbey-road, Kilburn, London, N.W.

Year of Election.

Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.
1861. ‡*Perring, John Shae.* 104 *King-street, Manchester.*
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1874. ‡Perry, John. 5 Falls-road, Belfast.
*Perry, Rev. S. G. F., M.A. Tottington Vicarage, near Bury.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, 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.
1867. ‡PHAYRE, Major-General Sir ARTHUR, K.C.S.I., C.B. East India United Service Club, St. James's-square, London, S.W.
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. 35 Church-street, Manchester.
*Philips, Mark. Welcombe, Stratford-on-Avon.
Philips, Robert N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville-row, Newcastle-on-Tyne.
1859. *PHILLIPS, Major-General Sir B. TRAVELL. United Service Club, Pall Mall, London, S.W.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1870. ‡PHILLIPS, J. ARTHUR. Cressington Park, Aigburth, Liverpool.
1877. §Phillips, T. Wishart. 269 West Ferry-road, London, E.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D. 4 The Cedars, Putney, Surrey, S.W.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡*Pickstone, William. Radcliff Bridge, near Manchester.*
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. ‡Pigot, Rev. E. V. Malpas, Cheshire.
1871. ‡Pigot, Thomas F., C.E., M.R.I.A. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida-vale, London, W.
1873. §Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 45 Upper Mount-street, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., M.P., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brennanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877. §Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
Pim, William H., M.R.I.A. Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1876. ‡Pirie, Rev. G. Queen's College, Cambridge.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp Hill, and 33 Union-street, Birmingham.
1842. PLAYFAIR, The Right Hon. LYON, C.B., Ph.D., LL.D., M.P., F.R.S.L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.

Year of Election.

1867. ‡PLAYFAIR, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S., M.I.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. ‡*Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.*
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
*PORTER, HENRY J. KER, M.R.I.A. Hanover Square Club, Hanover-square, London, W.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D. College Park, Belfast.
1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D., M.R.I.A. Tullyhogue, Co. Tyrone.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 26 Sandhill, Newcastle-on-Tyne.
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. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1869. *Preece, William Henry. Gothic Lodge, Wimbledon Common, London, S.W.
Prest, The Venerable Archdeacon Edward. The College, Durham.
*PRESTWICH, JOSEPH, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.
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.
Price, J. T. Neath Abbey, Glamorganshire.
1875. *Price, Rees. 54 Loftus-road, Shepherd's Bush, London, W.
1870. *Price, Captain W. E., M.P., F.G.S. Tibberton Court, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1865. ‡*Prideaux, J. Symes. 209 Piccadilly, London, W.*
1876. §Priestley, John. Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.

Year of Election.

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.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1871. ‡*Procter, James. Morton House, Clifton, Bristol.*
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
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, John. 4 St. Leonard Bank, Perth.
1867. *Pullar, Robert. 6 St. Leonard Bank, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
Punnett, 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.
1874. ‡Purser, Frederick, M.A. Rathmines, Dublin.
1866. ‡Purser, Professor John, M.A., M.R.I.A. Queen's College, Belfast.
1860. *Pusey, S. E. B. Bouverie-. Pusey House, Faringdon.
1868. §PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.
1861. *Pyne, Joseph John. St. German's Villa, St. Lawrence-road, Notting Hill, London, W.

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.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡*Rafferty, Thomas.*
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.
1845. ‡RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology. Geological Survey Office, Jermyn-street, London, S.W.
1867. ‡Ramsay, James, jun. Dundee.
1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 61 Overstone-road, Hammersmith, London, W.
1876. ‡Ramsay, William, Ph.D. 11 Ashton-terrace, Glasgow.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 62 St. Andrew's-street, Cambridge.

Year of Election.

1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Kempstone Mill, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. 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.
*Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
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. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Shrawley Wood House, near Stourport.
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. Drayton House, West Drayton, Middlesex.
1868. *Rayleigh, The Right Hon. Lord, M.A., F.R.S., F.R.G.S. 4 Carlton-gardens, Pall Mall, London, S.W.; and Terling Place, Witham, Essex.
1865. ‡Rayner, Henry. West View, Liverpool-road, Chester.
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas M., C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 37 Osborne-road, Tuebrook, Liverpool.
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, Edward J., C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1876. §Reid, James. 10 Woodside-terrace, Glasgow.
1869. ‡*Reid, J. Wyatt.*
1874. ‡Reid, Robert, M.A. 35 Dublin-road, Belfast.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.

Year of
Election.

1863. §RENALS, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡*Révy, J. J. 16 Great George-street, Westminster, S.W.*
1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. Royal Dublin Society, Kildare-street, 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.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. §Rhodes, John. Union-street, Accrington, Lancashire.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1868. §RICHARDS, Vice-Admiral Sir GEORGE H., C.B., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. §Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. Albert Park, Abingdon, Berks.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.
1863. ‡*Richardson, John W.*
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1861. ‡*Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.*
1863. ‡Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow.
1870. ‡Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. §Ricketts, James, M.D. St. Helen's, Lancashire.
*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 Akroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1873. ‡Ripley, Edward. Acacia, Apperley, near Leeds.
1873. §Ripley, H. W. 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.
1860. ‡*Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S.E.*
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, J., F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
Roberton, John. Oxford-road, Manchester.

Year of
Election.

1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. Kennessee House, Maghull, Lancashire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1868. §ROBERTS, W. CHANDLER, F.R.S., F.G.S., F.C.S. Royal Mint, London, E.
*_Roberts, William P._
1866. ‡_Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire._
1876. ‡Robertson, Andrew Carrick. Woodend House, Helensburgh, N.B.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1876. ‡_Robertson, R. A. 9 Queen's-square, Regent Park, Glasgow._
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1866. ‡_Robinson, John._
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1875. *Robinson, Robert, C.E. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
ROBINSON, Rev. THOMAS ROMNEY, D.D., F.R.S., F.R.A.S., Hon. F.R.S.E., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876. §Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
*_Robson, Rev. John, M.A., D.D. Ajmére Lodge, Cathkin-road, Langside, Glasgow._
1855. ‡Robson, Neil, C.E. 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.
1861. ‡ROFE, JOHN, F.G.S. 9 Crosbie-terrace, Leamington.
1860. ‡ROGERS, JAMES E. THOROLD, 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. 87 South-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1876. §Rollit, A. K., B.A., LL.D., F.R.A.S. The Literary and Philosophical Society, Hull.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.

Year of Election.

1876. ‡Romanes, George John. 18 Cornwall-terrace, Regent's Park, London, N.W.
1863. ‡*Romilly, Edward. 14 Hyde Park-terrace, London, W.*
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clark Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1855. *Roscoe, Henry Enfield, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1874. ‡Ross, Alex. Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
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.
1869. *Rosse, The Right Hon. the Earl of, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A., Birr Castle, Parsonstown, Ireland; and 32 Lowndes-square, London, S.W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. §Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1861. ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
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.
1876. ‡Rowan, David. 22 Woodside-place, Glasgow.
1877. §Rowe, J. Brooking, F.L.S. 16 Lockyer-street, Plymouth.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salt Hill, Galway.
*Rowntree, Joseph. 5 Ivy-terrace, Fishergate, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875. ‡Rücker, A. W., M.A., Professor of Mathematics and Physics in the Yorkshire College, Leeds.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
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. Corpus Christi College, Oxford.
1857. ‡Russell, The Very Rev. C. W., D.D., M.R.I.A. Maynooth College.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
Russell, John. 39 Mountjoy-square, Dublin.
Russell, John Scott, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster-chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster-chambers, London, S.W.
1876. §Russell, R., C.E., F.G.S. 1 Sea View, St. Bees, Carnforth.
1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.

Year of Election.

1852. *Russell, William J., Ph.D., F.R.S., F.C.S., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1875. §Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1874. §Rye, E. C., F.Z.S., Librarian R.G.S. 70 Charlewood-road, Putney, S.W.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*Sabine, General Sir Edward, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡*Sabine, Robert. Auckland House, Willesden-lane, London, N.W.*
1871. §Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
Salkeld, Joseph. Penrith, Cumberland.
1857. ‡Salmon, Rev. George, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Brookland Avenue, Cambridge.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1867. ‡*Samuelson, Edward. Roby, near Liverpool.*
1870. ‡*Samuelson, James. St. Domingo-grove, Everton, Liverpool.*
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1876. §Sandeman, David. Woodlands, Lenzie, Glasgow.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.
1872. §Sanderson, J. S. Burdon, M.D., F.R.S., Professor of Physiology in University College, London. 49 Queen Anne-street, London, W.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡*Savory, Valentine. Cleckheaton, near Leeds.*
1872. §Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡*Scallan, J. Joseph.*
1850. ‡*Scarth, Pillans. 2 James's-place, Leith.*
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.

Year of Election.

1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
*Scholes, T. Seddon. 10 Warwick-place, Leamington.
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. Sunnyside, Upper Avenue-road, Regent's Park, London, N.W.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. (GENERAL SECRETARY.) 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1876. ‡Scott, Mr. Bailie. Glasgow.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1876. ‡*Scott, D. D. Glasgow.*
1872. ‡Scott, Major-General H. Y. D., C.B., R.E., F.R.S. Sunnyside, Ealing, W.
1871. ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Secretary to the Council of the Meteorological Office. 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1859. ‡Seaton, John Love. Hull.
1870. ‡*Seaton, Joseph, M.D.*
1877. §Seaton, Robert Cooper, B.A. Dulwich College, Dulwich, Surrey, S.E.
1861. *SEELEY, HARRY GOVIER, F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 61 Adelaide-road, South Hampstead, London, N.W.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rosehill Lodge, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 92 Huskisson-street, Liverpool.
1875. §Seville, Thomas. Elm House, Royton, near Manchester.
1873. §Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds.
1868. ‡Sewell, Philip E. Catton, Norwich.
1861. *Seymour, Henry D. 209 Piccadilly, London, W.
1853. ‡*Shackles, G. L. 6 Albion-street, Hull.*
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Den Iron Works, Arbroath, N.B.
1869. *Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Great Harrowden Hall, near Wellingborough.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S. L. & E. 50 Torrington-square, London, W.C.

Year of Election.

1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
1839. Shepard, John. 41 Drewton-street, Manningham-road, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. ‡*Sherard, Rev. S. H.*
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1870. *Shoolbred, James N., C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. §Shore, Thomas W., F.C.S. Hartley Institution, Southampton.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1877. *Sidebotham, Joseph Watson. The Beeches, Bowdon, Cheshire.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
1857. ‡Sidney, Frederick John, LL.D., M.R.I.A. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1856. *Siemens, C. William, D.C.L., F.R.S., F.C.S., M.I.C.E. 12 Queen Anne's-gate, Westminster, S.W.
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., Medical Officer of the Privy Council. 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.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡Simpson, Maxwell, M.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1876. §Simpson, Robert. 14 Ibrox-terrace, Glasgow.
*Simpson, Rev. Samuel. Kingston House, Chester.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1876. ‡Sinclair, James. Titwood Bank, Pollokshields, near Glasgow.
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 Foster-lane, Cheapside, London, E.C.)

Year of Election.

1865. ‡Sissons, William. 92 Park-street, Hull.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. Exley House, near Halifax.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1870. ‡Slater, W. B. 42 Clifton Park-avenue, Belfast.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1853. ‡*Sleddon, Francis. 2 Kingston-terrace, Hull.*
1877. §Sleeman, Rev. Philip. Clifton, Bristol.
1849. ‡Sloper, George Edgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1872. ‡Smale, The Hon. Sir John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smeiton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. §Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1868. ‡Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-heath, London, N.W.
1874. *Smith, Benjamin Leigh. 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., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡Smith, George. Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1876. ‡*Smith, J. Glasgow.*
1870. ‡Smith, James. 146 Bedford-street South, Liverpool.
1873. ‡*Smith, James.*
1871. *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 173 St. Vincent-street, Glasgow.
1874. ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.
1867. *Smith, John P., C.E. Haughhead Cottage, Glasgow.
Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
*Smith, Philip, B.A. 26 South Hill Park, Hampstead, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.

Year of Election.

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. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §SMITH, WILLIAM, C.E., F.G.S., F.R.G.S. 18 Salisbury-street, Adelphi, London, W.C.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. §Smith, William. 12 Woodside-place, Glasgow.
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.
1870. ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1874. ‡Smyth, Henry, C.E. Downpatrick, Ireland.
1870. ‡Smyth, H. L. Crabwall Hall, Cheshire.
1857. *SMYTH, JOHN, jun., M.A., C.E., F.M.S. Lenaderg, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
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, Lieut.-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1878. §Snell, H. Saxon. 3 Greville-place, Maida Hill, London, N.W.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Park House, Sutton, Surrey.
*SOPWITH, THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Startforth House, Barnard Castle.
1859. ‡*Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.*
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
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.
1871. ‡Spicer, George. Broomfield, Halifax.
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.

Year of Election.

1846. *SPOTTISWOODE, WILLIAM, M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. (PRESIDENT ELECT.) 41 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND. 29 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West-parade, Hull.
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. The Observatory, Falmouth.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1865. §STANFORD, EDWARD C. C. Thornloe, Partick Hill, near Glasgow.
1837. Staniforth, Rev. Thos. Storrs, Windermere.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
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.
1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.
1870. ‡Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.
1863. ‡Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
STENHOUSE, JOHN, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. §Sterriker, John. Driffield, Yorkshire.
1872. ‡Sterry, William. Union Club, Pall Mall, London, S.W.
1876. ‡Steuart, Walter. City Bank, Pollokshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. Belmont, Devizes-road, Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. 2 Wellington-crescent, South Shields.
1850. ‡*Stevenson, David.*
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1876. *Stewart, Alexander B. Rawcliffe Lodge, Langside, Glasgow.
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.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 75 Eccles-street, Dublin.
1875. *Stewart, James, B.A. Mount Hope, Sneyd Park, near Bristol.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1876. ‡Stirling, William, M.D., D.Sc. The University, Edinburgh.
1867. *Stirrup, Mark, F.G.S. 14 Atkinson-street, Deansgate, Manchester.
1865. *Stock, Joseph S. 1 Chartham-terrace, Ramsgate.
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.

Year of Election.

*Stokes, George Gabriel, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambrdge. Lensfield Cottage, Cambridge.
1862. ‡Stone, Edward James, M.A., F.R.S., F.R.A.S., Astronomer Royal at the Cape of Good Hope. Cape Town.
1874. §Stone, J. Harris, B.A., F.L.S., F.C.S. 16 Wilmot-terrace, Belfast.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1859. ‡*Stone, Dr. William H. 13 Vigo-street, London, W.*
1857. ‡Stoney, Bindon B., C.E., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 3 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. East Hill, Colchester.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1867. ‡Storrar, John, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.
1874. §Stott, William. 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. Stowey House, Clapham Common, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1876. *Stuart, Charles Maddock. Sudbury Hill, Harrow.
1872. *Stuart, Rev. Edward A. 22 Bedford-street, Norwich.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873. §Style, George, M.A. Giggleswick School, Yorkshire.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Royal College of Science for Ireland; and 53 Upper Leeson-road, Dublin.
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.
1855. ‡*Sutton, Edwin.*
1863. ‡Sutton, Francis, F.C.S. Bank Plain, Norwich.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
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. Ardchapel, by Helensburgh, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
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.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. †Sykes, H. P. 47 Albion-street, Hyde Park, London, W.

Year of Election.

1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
Sylvester, James Joseph, M.A., LL.D., F.R.S. Athenæum Club, London, S.W.
1870. §Symes, Richard Glascott, A.B., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
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., Sec. M.S. 62 Camden-square, London, N.W.
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, M.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. Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
1874. §Talmage, C. G. Leyton Observatory, Essex, E.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Mountfield, Grove Hill, Tunbridge Wells.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George. Springfield Mount, Leeds.
1876. §Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1864. *Tawney, Edward B., F.G.S. 16 Royal York-crescent, Clifton, Bristol.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
*Taylor, John, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡Taylor, John Ellor, F.L.S., F.G.S. The Mount, Ipswich.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
*Taylor, Richard, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.

Year of Election.

*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. ‡Temperley, Ernest. Queen's College, Cambridge.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.L.S. 10 Gloucester-road, Kew, W.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
Thomas, George. Brislington, Bristol.
1875. §Thomas, Herbert. 2 Great George-street, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1875. §Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South-parade, Wakefield.
1859. §Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Fulshaw, near Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1874. §Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §Thompson, Silvanus P., B.A., B.Sc., F.R.A.S. University College, Bristol.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S. L. & E. (PRESIDENT.) 66 Palace Gardens-terrace, Kensington, London, W.
1852. ‡*Thomson, Gordon A. Bedeque House, Belfast.*
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E., F.R.S. L. & E. Oakfield House, University Avenue, Glasgow.
1855. ‡*Thomson, James. 82 West Nile-street, Glasgow.*
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
1876. ‡Thomson, James. 276 Eglinton-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876. §Thomson, James R. Dalmuir House, Dalmuir, Glasgow.
1874. ‡Thomson, John. Harbour Office, Belfast.
1871. *Thomson, John Millar, F.C.S. King's College, London, W.C.
1863. ‡*Thomson, M. 8 Meadow-place, Edinburgh.*
1872. ‡*Thomson, Peter. 34 Granville-street, Glasgow.*
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.

Year of Election.

1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., 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.
1876. ‡Thomson, William. 6 Mansfield-place, Edinburgh.
1871. §Thomson, William Burnes, F.R.S.E. 1 Ramsay-gardens, Edinburgh.
1870. ‡*Thomson, W. C., M.D.*
1850. ‡THOMSON, Sir WYVILLE T. C., LL.D., F.R.S. L. & E., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1871. ‡Thorburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel, J.P. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
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.
1868. ‡Thuillier, Colonel, R.A., C.S.I., F.R.S., Surveyor-General of India. 46 Park-street, Calcutta.
Thurnham, John, M.D. Devizes.
1870. ‡Tichborne, Charles R. C., 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.
1874. ‡Tilden, William A., D.Sc., F.C.S. Clifton College, Bristol.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1865. §Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNÉ, JOHN A., F.R.G.S. Briarley, Aigburth, Liverpool.
1876. §Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1861. *TODHUNTER, ISAAC, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
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. Victoria-street, Nottingham.
1863. ‡Torrens, Colonel Sir R. R., K.C.M.G. 2 Gloucester-place, Hyde Park, London, W.
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.
1860. ‡*Townsend, John.*
1857. ‡Townsend, Rev. Richard, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡Towson, John Thomas, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1877. §Tozer, Henry. Ashburton.
1876. *Trail, J. W. H., M.A., M.B., F.L.S. King's College, Old Aberdeen.
1870. ‡Traill, William A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. §Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡Traquair, Ramsay H., M.D., Professor of Zoology. Museum of Science and Art, Edinburgh.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
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.
*Trevelyan, Arthur, J.P. Tyneholm, Pencaitland, N.B.
Trevelyan, Sir Walter Calverley, Bart., M.A., F.R.S.E. F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.
1871. ‡Tribe, Alfred, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1871. ‡Trimen, Roland, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1877. §Trimen, Henry, M.B., F.L.S. British Museum, London, W.C.
1860. §Tristram, Rev. Henry Baker, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1864. ‡*Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.*
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
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. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
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 Edinbugh. 6 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1847. ‡Twiss, Sir Travers, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1865. §Tylor, Edward Burnett, F.R.S. Linden, Wellington, Somerset.
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.

Year of
Election.

1861. *Tysoe, John. 28 Seedley-road, Pendleton, near Manchester.

1876. *Unwin, W. C., A.I.C.E., Professor of Hydraulic Engineering. Cooper's Hill, Middlesex.
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.

*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Fleetwood House, Beckenham, Kent.
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. Hatfield, Herts.
1870. ‡Varley, Mrs. S. A. Hatfield, Herts.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. §Vaughan, Miss. Burlton Hall, Shrewsbury.
1863. ‡*Vauvert, de Mean A., Vice-Consul for France. Tynemouth.*
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
1873. *Verney, Captain Edmund H., R.N. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1854. *Vernon, George V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1864. *Vicary, William, F.G.S. The Priory, Colleton-cresent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1856. ‡Vivian, Edward, M.A. Woodfield, Torquay.
*Vivian, H. Hussey, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §Voelcker, J. Ch. Augustus, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
1875. ‡Volckman, Mrs. E. G. 43 Victoria-road, Kensington, London, W.
1875. ‡Volckman, William. 43 Victoria-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1875. ‡*Wace, Rev. A. St. Paul's, Maidstone, Kent.*
1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1870. §Wake, Charles Staniland. 70 Wright-street, Hull.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869. *Walford, Cornelius. 86 Belsize Park-gardens, London, N.W.
1849. §Walker, Charles V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.

Year of Election.

Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, Kenilworth-road, Leamington.
1866. *WALKER, J. F., M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.G.S., F.R.G.S. 3 Circus, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
1863. ‡WALLACE, ALFRED RUSSEL, F.R.G.S., F.L.S. Waldron Edge, Duppas Hill, Croydon.
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.R.G.S., F.L.S. Terrace House, St. George's-terrace, Herne Bay.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
1857. ‡Walsh, Albert Jasper, F.R.C.S.I. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred. 117 Charlotte-street, Fitzroy-square, London, W.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D. Fernleigh, Botanic-road, Belfast.
1874. §Ward, John, F.R.G.S. Lenox Vale, Belfast.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
*WATERHOUSE, JOHN, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1875. *Waterhouse, Captain J. Surveyor-General's Office, 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 Birmingham.
1875. ‡Watherston, Alexander Law, M.A., F.R.A.S. Bowdon, Cheshire.

Year of
Election.

1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
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.
1869. ‡Watt, Robert B. E., C.E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *WATTS, JOHN, B.A., D.Sc. 57 Baker-street, Portman-square, London, W.
1846. §Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*WAVENEY, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
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.
1845. ‡*Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.*
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §WELDON, WALTER, F.R.S.E. Abbey Lodge, Merton, Surrey.
1876. §Weldon, W. F. R. Abbey Lodge, Merton. Surrey.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1873. ‡*West, Samuel H. 6 College-terrace West, London, W.*
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.

Year of Election.

Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. ‡Weston, James Woods. Belmont House, Pendleton, Manchester.
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.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1874. §Whitaker, Henry, M.D. 11 Clarence-place, Belfast.
1859. *Whitaker, William, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1876. ‡White, Angus. Easdale, Argyleshire.
1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡White, James, F.G.S. 58 Gresham House, Old Broad-street, London, E.C.
1876. *White, James. Overtoun, Dumbarton.
1873. §White, John. Medina Docks, Cowes, Isle of Wight.
White, John. 80 Wilson-street, Glasgow.
1859. ‡White, John Forbes. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1877. §Whiteford, Hamilton. Tothill House, Plymouth.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
1855. **Whitehouse, Wildeman W. O. 12 Thurlow-road, Hampstead, London, N.W.*
Whitehouse, William. 10 Queen-street, Rhyl.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1866. ‡Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.
1874. ‡Whitford, William. 5 Claremont-street, Belfast.
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. 94 Baggot-street, Dublin.
1874. *Whitwell, Mark. Redland House, Bristol.
1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.
*Whitworth, Sir Joseph, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. ‡Whitworth, Rev. W. Allen, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.
1860. ‡*Wilde, Henry. 2 St. Ann's-place, Manchester.*
1855. ‡Wilkie, John. Westburn, Helensburgh, N.B.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1861. *Wilkinson, M. A. Eason-, M.D. Greenheys, Manchester.

Year of Election.

1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
1873. ‡Willcock, J. W., Q.C. Clievion, Dinas Mawddwy, Merioneth.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
1870. ‡*William, G. F. Copley Mount, Springfield, Liverpool.*
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.
1864. *WILLIAMS, Sir FREDERICK M., Bart., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
1861. *Williams, Harry Samuel, M.A. 28 John-street, Bedford-row, London, W.C.
1875. *Williams, Herbert A., B.A. 91 Pembroke-road, Clifton, Bristol.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1871. ‡*Williams, James, M.D.*
1870. §WILLIAMS, JOHN. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. North Hill, Swansea.
Williams, Robert, M.A. Bridehead, Dorset.
1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1877. §Williams, W. Carleton, F.C.S. Owens College, Manchester.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.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. 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., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred, Q.C. 12 King's Bench-walk, Inner Temple, E.C.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
1874. §WILLS, THOMAS, F.C.S. Royal Naval College, Greenwich, S.E.
WILLS, W. R. Edgbaston, Birmingham.
1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. §WILSON, Major C. W., C.B., R.E., F.R.S., F.R.G.S., Director of the Topographical and Statistical Department of the War Office. Ordnance Survey Office, Dublin.
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.
Wilson, George. 40 Ardwick-green, Manchester.
1861. ‡Wilson, George Daniel. 24 Ardwick-green, Manchester.
1875. §Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.

Year of Election.

1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron-hill, Hawick, N.B.
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