S.I.A.

REPORT

OF THE

THIRTY-NINTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

EXETER IN AUGUST 1869.

LONDON:
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LIST OF PLATES.

ERRATA IN REPORT FOR 1868.

Reports, p. 399, lines 20–22, *for* maximum still occurs.. ...November. *read* maxima have occurred on the 6th–7th of December, but of which symptoms (Greg's A_{16}) can be distinguished as early as the 23rd of November.

p. 399, lines 23, 24, *for* on... on... date. *read* in... in... month.

p. 399, line 27, *for* May *read* March or April

p. 400, last line, *for* Chapelas. *read* Chapelas-Coulvier-Gravier.

p. 403, line 4 from bottom, *for* Max. 1848–52. *read* Max. Dec. 6–7, 1798 (?), 1838, 1847, 1848–52. Perhaps connected with Biela's comet.

p. 407, line 11 from bottom, *for* 12th of December, including, perhaps, *read* beginning of December, including

p. 407, last line, *add*, and Father Secchi that of "uranoliths" to designate aërolites.

ERRATA IN THE PRESENT VOLUME.

Reports, p. 274, 20th line from bottom, *for* northward *read* southward
„ 19th „ „ *for* fifty-four *read* fifty
„ 17th „ „ *for* south *read* north
„ 16th „ „ *for* northerly *read* southerly

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 of One Pound. They are eligible to all the Offices of the Association.

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

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

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

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

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

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the 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 (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

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 at the previous Meeting; 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:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. 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.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

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 Meeting.

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., 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. DelaBeche, 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. DelaBeche, 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.
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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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, M.A., Esq. 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.
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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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. Leonards, 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., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. The Earl of Devon. The Right Hon. Sir Stafford H. Northcote, C.B., Bart., 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. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

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.

Date and Place.	Presidents.	Secretaries.
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.
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. Ma 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.

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.
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.

Date and Place.	Presidents.	Secretaries.
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.

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.

Date and Place.	Presidents.	Secretaries.
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, Professor Nicol.

SECTION C (*continued*).—GEOLOGY.

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

* At the Meeting of the General Committee held in Edinburgh, it was agreed "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 xxxi.

Date and Place.	Presidents.	Secretaries.
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.

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.

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

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

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

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.

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

Date and Place.	Presidents.	Secretaries.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool	Prof. Balfour, M.D., F.R.S.	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY*.

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. Tawson, 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. S. Cobbold, Prof. Michael Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEES OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

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

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

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.

* At the Meeting of the General Committee at Birmingham, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted."

Date and Place.	Presidents.	Secretaries.
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. 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.

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.

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. xxvii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

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

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S. ...	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.

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

† *Vide* note on preceding page.

Date and Place.	Presidents.	Secretaries.
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 R. 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.

STATISTICAL SCIENCE.

COMMITTEES OF SCIENCES, VI.—STATISTICS.

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

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir 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, F.R.S., M.P.	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.

Date and Place.	Presidents.	Secretaries.
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.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P. ...	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock 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.
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.

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.

Date and Place.	Presidents.	Secretaries.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thompson, 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. Thompson, W. Sykes Ward.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	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.

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.
	Sir R. I. Murchison, Bart.	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. 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.

Date and Place.	Lecturer.	Subject of Discourse.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S. ...	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S. ...	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S. ...	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S................	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S................	Extinct Birds of New Zealand.
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. Roy.	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 is 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. 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.

Date and Place.	Lecturer.	Subject of Discourse.
1864. Bath	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S.	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.	Insular Floras.
1867. Dundee	Archibald Geikie, F.R.S.	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S. ...	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S.	The Physical Constitution of the Stars and Nebulæ.

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.

OFFICERS AND COUNCIL, 1869-70.

TRUSTEES (PERMANENT).

Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S.
Lieut.-General Sir Edward Sabine, K.C.B., R.A., D.C.L., Pres. R.S.
Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.

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GEORGE G. STOKES, M.A., D.C.L., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge.

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The Right Hon. Sir Stafford H. Northcote, C.B., Bart., 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, M.A., LL.D., F.R.S., F.L.S.

PRESIDENT ELECT.

T. H. HUXLEY, LL.D., F.R.S., F.L.S., Pres. G.S., Professor of Natural History in the Royal School of Mines.

VICE-PRESIDENTS ELECT.

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, Esq., LL.D., D.C.L., F.R.S.
Joseph Mayer, Esq., F.S.A., F.R.G.S.

LOCAL SECRETARIES FOR THE MEETING AT LIVERPOOL.

Rev. W. Banister.
Rev. Henry H. Higgins, M.A.
Rev. A. Hume, D.C.L., F.S.A.

LOCAL TREASURER FOR THE MEETING AT LIVERPOOL.

H. Duckworth, Esq., F.R.G.S.

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Busk, George, Esq., F.R.S.
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Evans, John, Esq., F.R.S.
Galton, Capt. Douglas, C.B., R.E., F.R.S.
Galton, Francis, Esq., F.R.S.
Gassiot, J. P., Esq., F.R.S.
Godwin-Austen, R. A. C., Esq., F.R.S.
Houghton, Right Hon. Lord, D.C.L., F.R.S.
Huggins, William, Esq., F.R.S.
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Rankine, Professor W. J. M., F.R.S.
Richards, Captain, R.N., F.R.S.
Sharpey, Dr., Sec. R.S.
Smith, Professor H. J. S., F.R.S.
Strange, Lieut.-Colonel A., F.R.S.
Sykes, Colonel, M.P., F.R.S.
Sylvester, Prof. J. J., LL.D., F.R.S.
Tite, Sir W., M.P., F.R.S.
Tyndall, Professor, F.R.S.
Wheatstone, Professor Sir C., F.R.S.
Williamson, Prof. A. W., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The President and President Elect, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries, the General Treasurer, the Trustees, and the Presidents of former years, viz.:—

Rev. Professor Sedgwick.
The Duke of Devonshire.
Rev. W. V. Harcourt.
Sir John F. W. Herschel, Bart.
Sir R. I. Murchison, Bart., K.C.B.
The Rev. T. R. Robinson, D.D.
G. B. Airy, Esq., Astronomer Royal.
Lt.-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. Fairbairn, Bart., LL.D.
The Rev. Professor Willis, F.R.S.
Sir W. G. Armstrong, C.B., LL.D.
Sir Chas. Lyell, Bart., M.A., LL.D.
Professor Phillips, M.A., D.C.L.
William R. Grove, Esq., F.R.S.
The Duke of Buccleuch, K.B.
Dr. Joseph D. Hooker, F.R.S.

GENERAL SECRETARIES.

T. Archer Hirst, Esq., F.R.S., F.R.A.S., Professor of Mathematics in University College, London.
Dr. Thomas Thomson, F.R.S., Kew Green, Kew.

ASSISTANT GENERAL SECRETARY.

George Griffith, Esq., M.A., 1 Woodside, Harrow.

GENERAL TREASURER.

William Spottiswoode, Esq., M.A., F.R.S., F.R.G.S., 50 Grosvenor Place, London, S.W.

AUDITORS.

Professor W. Allen Miller, F.R.S. G. Busk, Esq., F.R.S. Professor G. C. Foster, F.R.S.

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, Pres. 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.......		

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	....	434 14 0
...	...	...	...	...	1840	....	918 14 6
...	...	...	1100*	...	2400	....	956 12 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	....	830 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1260	....	208 5 4
54	25	376	197	15	929	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	330 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 3
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	1241 7 0
184	125	1589	791	15	3139	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	

* 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 20th August 1868 (commencement of NORWICH Meeting) to 18th August 1869 (EXETER).

RECEIPTS.

				£	s.	d.
To Balance brought from last Account				177	1	7
Received for Life Compositions at Norwich Meeting and since				220	0	0
„ Annual Subscriptions, ditto ditto				624	0	0
„ Associates' Tickets, ditto ditto				720	0	0
„ Ladies' Tickets, ditto ditto				682	0	0
„ Dividends on Stock				249	3	2
„ Sale of Publications—viz.						
Reports	49	15	8			
Index, Catalogue of Stars, &c.	8	10	4			
				58	6	0
„ Sale of Consols (£500 Stock)				463	15	0
„ of Mr. Catton, being portion of Grant of £60 made at Dundee, for Researches on the Synthesis of Organic Acids, but not used (£12 less Commission on Cheque)				11	19	8
				£3206	5	5

Examined and found correct, November 16, 1869.

WM. ALLEN MILLER, M.D.,
GEO. BUSK,
G. C. FOSTER,
} *Auditors.*

PAYMENTS.

				£	s.	d.
By Expenses of Norwich Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses				346	4	3
„ Printing, Engraving, and Binding Report of 37th Meeting (Dundee)				711	0	2
„ Salaries (1 year)				350	0	0
„ Grants made at Norwich Meeting, viz.—						
Maintaining 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 Performance	30	0	0			
„ Chemical Constitution of Cast iron	80	0	0			
„ Iron and Steel Manufacture	100	0	0			
„ Methyl Series	30	0	0			
„ Organic Remains in Limestone Rocks	10	0	0			
„ Scottish Earthquakes	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
1869. Aug. 18. Balance at London and Westminster Bank	£170	13	9			
„ in hands of General Treasurer	6	7	3			
				177	1	0
				£3206	5	5

W. SPOTTISWOODE,
August 18, 1869.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE EXETER MEETING.

SECTION A.—MATHEMATICS AND PHYSICS.

President.—Professor J. J. Sylvester, M.A., LL.D., F.R.S.
Vice-Presidents.—Professor J. C. Adams, M.A., D.C.L., F.R.S.; J. P. Gassiot, V.P.R.S.; William R. Grove, M.A., F.R.S.; Rev. Professor Bartholomew Price, M.A., F.R.S.; Rev. T. R. Robinson, D.D., F.R.S.; Professor Sir Charles Wheatstone, D.C.L., F.R.S.
Secretaries.—Professor G. C. Foster, B.A., F.R.S.; R. B. Hayward, M.A.; W. K. Clifford, B.A.

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

President.—Dr. H. Debus, F.R.S., F.C.S.
Vice-Presidents.—Dr. Andrews; Dr. J. Hall Gladstone, F.R.S.; Professor W. A. Miller, M.D., F.R.S.; Dr. Voelcker, F.C.S.; Dr. Williamson, F.R.S. Pres.C.S.
Secretaries.—Professor A. Crum Brown, M.D., F.C.S.; Dr. W. J. Russell, F.C.S.; Dr. Atkinson, F.C.S.

SECTION C.—GEOLOGY.

President.—Professor R. Harkness, F.R.S., F.G.S.
Vice-Presidents.—R. A. C. Godwin-Austen, F.R.S., F.G.S.; Sir P. de M. Grey Egerton, Bart., F.R.S., F.G.S.; Professor Phillips, LL.D., P.R.S., F.G.S.; Professor Huxley, LL.D., F.R.S., P.G.S.; Edward Vivian, F.G.S.
Secretaries.—W. Pengelly, F.R.S., F.G.S.; W. Boyd Dawkins, M.A., F.R.S., F.G.S.; Rev. H. H. Winwood, M.A., F.G.S.

SECTION D.—BIOLOGY.

President.—George Busk, F.R.S., F.L.S., F.G.S.
Vice-Presidents.—Professor Balfour, F.R.S.; C. Spence Bate, F.R.S., F.L.S.; Dr. Hooker, F.R.S., F.L.S.; Sir John Lubbock, Bart., F.R.S.; Dr. W. Ransom; E. B. Tylor; A. R. Wallace, F.R.G.S.; Professor E. Perceval Wright, M.D., F.L.S.
Secretaries.—Dr. Spencer Cobbold, F.R.S.; Professor Michael Foster, M.D., F.R.S.; E. Ray Lankester; Professor Lawson; H. T. Stainton, F.R.S., F.L.S.; Rev. H. B. Tristram, M.A., LL.D., F.R.S.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

President.—Sir Bartle Frere, K.C.B., F.R.G.S., LL.D., G.C.S.I.
Vice-Presidents.—Sir G. Grey, K.C.B., F.R.G.S.; A. G. Findlay, F.R.G.S.; Major-General Sir A. Scott Waugh, R.E., F.R.S.; Captain Richards, R.N., F.R.S.; Vice-Admiral Sir E. Belcher, K.C.B., F.R.G.S.
Secretaries.—H. W. Bates, Assist. Sec. R.G.S.; Clements R. Markham, F.R.G.S.; J. H. Thomas, F.R.G.S.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.
Vice-Presidents.—T. D. Acland, M.A., D.C.L., M.P.; The Earl of Derby, F.R.S.; The Right Hon. Lord Houghton, D.C.L., F.R.S.; Sir W. Tite, M.P., F.R.S.; Dr. Wm. Farr, D.C.L., F.R.S.; Professor J. E. Thorold Rogers, M.A.
Secretaries.—Edmund Macrory, M.A.; Frederick Purdy, F.S.S.; Charles T. D. Acland, M.A.

SECTION G.—MECHANICAL SCIENCE.

President.—C. W. Siemens, C.E., F.R.S.
Vice-Presidents.—G. P. Bidder, C.E.; C. Vignoles, C.E., F.R.S., F.R.A.S.; Professor W. M. Rankine, LL.D., F.R.S.; Rev. Professor Willis, F.R.S.; C. H. Gregory, Pres.I.C.E.; Admiral Sir E. Belcher, K.C.B.; Captain Douglas Galton, C.B., R.E., F.R.S.; J. F. Bateman, F.R.S.; F. J. Bramwell; Sir Joseph Whitworth, Bart., LL.D., F.R.S.
Secretaries.—P. Le Neve Foster, M.A.; H. Bauerman, F.G.S.

Report of the Council of the British Association for the year 1868–69, *presented to the General Committee at Exeter on Wednesday, August* 18, 1869.

The Reports of the General Treasurer and of the Kew Committee for the past year have been received, and will be laid before the General Committee.

At the Meeting of the Association at Norwich, the General Committee referred two Resolutions to the Council for consideration and action, if it should be deemed desirable.

The first Resolution was:—

That the Council be instructed to prepare and cause to be presented to the Houses of Lords and Commons petitions on behalf of the Association, praying them without loss of time to pass such measures as will remedy the existing defects in Secondary Education in Schools, and that the Council be empowered to take such other steps as in their judgment may be best calculated to promote the object of these petitions.

The Council, after receiving the report of a Committee specially appointed by them to consider the question, resolved to act in accordance with this Resolution. They consequently prepared the following Petition, which was presented by the Right Hon. Lord Lyttelton to the House of Lords, by Sir W. Tite to the House of Commons.

The Humble Petition of the British Association for the Advancement of Science

Sheweth,—That one of the ends for which the Association was established was 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."

That some of the chief impediments to the progress of Science in the United Kingdom are to be found in the limited and defective state of Secondary Education, and in the condition of the Endowed Grammar Schools, which, having been founded in past times, represent for the most part the knowledge and wants of the past, rather than of the present.

That, notwithstanding the defects of the Endowed Grammar Schools, they are enabled, by their number, antiquity, and endowments, to maintain a prescriptive rank and influence, and seriously to impede the adoption of improved systems of education.

That the necessity for inquiry into the state of the Endowed Grammar Schools, and into the education given in schools generally, above the Elementary, has already been recognized in the appointment by Her Majesty of three Commissions to report on this Class of Schools in England and Scotland.

That in the year 1866 the Council of the Association appointed a Committee to consider the best means of promoting Scientific Education in Schools, and that this Committee drew up a Report on the subject, which is printed in the "Report of the Schools-Inquiry Commission," presented to Her Majesty, and laid before your Honourable House.

That the recommendations of the Schools-Inquiry Commission, in regard to the introduction of the study of Natural Science into all Secondary Schools, are in general accordance with the views of the Association.

That, in the opinion of the Association, the study of Natural Science, whether as a means of disciplining the mind, or for providing knowledge useful for the purposes of life, is of essential importance to the youth of this country; and that it ought to form a part of education in all Secondary Schools.

That the Association consider the Secondary Education of the United Kingdom, both in regard to the quality and the range of the subjects of study, to be incommensurate with the needs of a well-organized state; they therefore request your Honourable House to enact such laws as shall make Natural Science an essential part of the course of education, and to put it on a footing of equality with the most favoured subjects of study.

The Second Resolution referred to the Council by the General Committee at Norwich was:—

That the Council of the British Association be requested to urge upon Government and through the British Government upon the Governments of Foreign Nations, the importance of fixing, by permanent bench-marks, certain points of level, and also of position in reference to secular changes (1st) in the elevation of the land as referred to the sea-level, and (2nd) in relation to changes of coast-line, and to the position of ice-masses.

That the Council of this Association be requested to ask the support and cooperation in this of the Council of the Royal Society; and that the following be a Committee to assist the Council and that of the Royal Society in the definition of the works proposted to be executed:—W. Sartorius von Waltershausen, Lieut.-Colonel Sir Henry James, R.E., F.R.S., Robert A. C. Godwin-Austen, F.R.S.

The Council appointed a Committee, consisting of Sir Henry James, Sir C. Wheatstone, Mr. Godwin-Austen, Professor Tyndall, Professor Ramsay, the President, General Secretaries, and Treasurer, to consider this resolution and to report thereon.

This Report being favourable, your Council applied to the Council of the Royal Society, who at once promised their support in any application to Government, but deemed it unnecessary to augment the Committee already elected by your Council for the purpose of defining the works proposed to be executed. This Committee has not yet concluded its labours.

The following foreign men of Science, who were present at the Norwich Meeting, have been elected Corresponding Members:—

Baron von Mädler, Dorpat.
Padre Secchi, Director of the Observatory at Rome.
Professor Aug. Morren, Doyen de la Faculté de Science, Marseilles.
Professor Vogt, Geneva.
Professor Broca, Paris.
Professor L. Radlkofer, Munich.
Professor Karl Koch.
M. D'Avesac, Mem. de l'Institut de France.
Dr. H. A. Weddell, Poitiers.
M. A. Heynsius, Leyden.

The Council are able to report that the Annual Volume was this year again issued in June; a still earlier publication being desirable, however, it is proposed to publish the next volume at Christmas: but in order to do so it will be necessary to defer until the following year the publication of reports which are not ready for the press immediately after the close of this present Meeting of the Association.

The Council have been informed that Invitations for 1870 will be presented to the General Committee by Deputations from Liverpool, Edinburgh, Brighton, and Bradford.

Report of the Kew Committee of the British Association for the Advancement of Science for 1868–69.

The Committee of the Kew Observatory submit to the Council of the British Association the following statement of their proceedings during the past year:—

The nature and amount of assistance to be rendered by this Committee to the Meteorological Committee of the Royal Society have now been clearly defined, and the duties undertaken at Kew Observatory may, as in the last Report, for clearness' sake be again considered under the two following heads:—

(A) The work done under the direction of the British Association.
(B) That done at Kew as the Central Observatory of the Meteorological Committee.

This system of division will be adopted in this Report, and it has been thought desirable, for the information of the Association, in the financial statement hereto appended, to include the sums received from the Meteorological Committee as well as those received from the British Association. It will thus be clearly seen that the work done at Kew for the Meteorological Committee has been paid for from funds supplied by that Committee, and not in any way from money subscribed by the British Association.

(A) Work done by Kew Observatory under the direction of the British Association.

1. *Magnetic work.*—The Self-recording Magnetographs ordered by the Mauritius Government for Mr. Meldrum, after having been verified at Kew, have been forwarded to their destination.

A Unifilar and Dip-circle for Mr. Meldrum have likewise been verified.

A Unifilar and Dip-circle have been repaired and verified for the Rev. M. Colombel, who has gone to Nankin, where he intends making magnetical observations.

M. Colombel as well as M. Berg, of the Wilna Observatory, have received magnetical instruction at Kew.

A Dip-circle is in the course of being verified for Lieut. Elagin, of the Russian Navy.

The usual monthly absolute determinations of the magnetic elements continue to be made by Mr. Whipple, Magnetic Assistant. During the last year it has been found necessary to replace the wooden pillars of the magnetic house with pillars of Portland stone, which had been previously ascertained to be non-magnetic. It has also been found necessary slightly to repair the Unifilar and Dip-circle hitherto used in these monthly determinations.

The Self-recording Magnetographs are in constant operation as heretofore, also under the charge of Mr. Whipple, and the photographic department connected with these instruments remains under the charge of Mr. Page.

The task of tabulating and reducing the magnetic curves produced at Kew subsequent to January 1865 is in progress under the direction of Mr. Stewart. Considerable advance has been made in these reductions during the present year, and it is hoped that during the next session of the Royal Society a paper may be communicated to that body by Mr. Stewart, giving certain results of these reductions, as well as results of the absolute magnetic observations made every month.

Lieut. Elagin has communicated through Mr. Stewart to the Royal Society an account of observations made at the various European observatories, by means of a Dip-circle which had been lent to him from the Kew Observatory.

Mr. Stewart has likewise communicated to the Royal Society a short paper by Senhor Capello "On the reappearance of certain periods of Declination-disturbance during two, three, or several days;" also a joint paper by the Rev. W. Sidgreaves and himself, embodying the results of a preliminary comparison of the Kew and Stonyhurst declination-curves; also a paper embodying the magnetical results obtained by Lieut. Rokeby at the island of Ascension, reduced by Mr. Whipple, Magnetical Assistant at Kew. Finally, Mr. Stewart has communicated to the Royal Society a paper containing a preliminary discussion of the peaks and hollows of the Kew magnetic curves for the first two years during which the Magnetographs were in operation.

2. *Meteorological work.*—The meteorological work of the Observatory continues in the charge of Mr. Baker.

Since the Norwich Meeting, 157 Barometers have been verified, and 27 have been rejected; 1153 thermometers have been verified, and 24 have been rejected. Two Standard Thermometers have been constructed for the Standards' Commission*, one for Stonyhurst College, and nine for Professor Tait. 38 Hydrometers have likewise been verified.

The progressive nature of this department of the Kew work will be seen by the following statement of the numbers of Barometers and Thermometers verified during the last few years:—

	Barometers.	Thermometers.
1863–64	97	389
1864–65	88	420
1865–66	126	395
1866–67	89	608
1867–68	78	1139
1868–69	157	1153

The self-recording meteorological instruments now at work at Kew will be again mentioned in the second division of this Report. These are in the charge of Mr. Baker, the photography being superintended by Mr. Page.

A Self-recording Barograph verified at Kew for Messrs. R. & J. Beck has been disposed of by these opticians to Mr. Meldrum, of the Mauritius Observatory. A Barograph and Thermograph have been verified at Kew and dispatched to Mr. Ellery, at Melbourne, and a Barograph has recently been verified for Mr. Smalley, of Sydney.

At the request of Mr. G. J. Symons, the old Kew Thermometer frame has been lent to him for certain experiments, which are being carried on by him in conjunction with the Rev. C. H. Griffith, at Strathfield Turgis.

The attention of meteorologists is directed towards an instrument devised by Mr. Beckley, mechanical assistant at Kew, for the purpose of registering

* While this Report was being printed, an application was received from the Warden of the Standards, through Lieut.-Gen. Sir Edward Sabine, for an Air Thermometer.

the rainfall automatically. A description of this instrument will be submitted to the Association at Exeter.

Attention is likewise directed to a paper to be communicated by Mr. Balfour Stewart to the Association at the Exeter Meeting, entitled "Remarks on Meteorological Reductions, with especial reference to the Element of Vapour;" separate copies of which will be at the disposal of Members.

The following revised fees are charged for the verification of meteorological instruments at Kew:—

	s.	d.
Barometers (requiring index- and capacity-corrections) ..	10	0
Ditto (not requiring capacity-correction—inches measured)	5	0
Thermometers (ordinary)................................	1	0
Boiling-point Thermometers	2	6
Hydrometers..	1	0

3. *Photoheliograph.*—The Kew Heliograph, in charge of Mr. De La Rue, continues to be worked in a satisfactory manner. During the past year 274 negatives have been taken on 168 days: 40 pictures of the Pagoda in Kew Gardens, as a fixed terrestrial object at a known distance, have likewise been taken, with the object of determining, by measurements of these pictures, which are taken in different parts of the field of the telescope, both the optical distortion of the sun-pictures and the angular diameter of the Sun.

A paper communicated to the Royal Society by Messrs. Warren De La Rue, Stewart, and Loewy, entitled "Researches on Solar Physics.—Heliographical Positions and Areas of Sun-spots observed with the Kew Photoheliograph during the years 1862 and 1863," is the first of the series of reductions of the photographic solar records; it is in the course of publication in the 'Transactions' and will shortly be distributed.

It is hoped that, during next winter, a paper containing the heliographical positions and areas of the spots observed at Kew during the years 1864, 1865, and 1866 may be communicated to the Royal Society, as well as a paper representing, both numerically and graphically, the spotted area of the sun during three complete solar periods, the results being partly derived from Schwabe's and partly from Carrington's observations, in addition to those made with the Kew photoheliograph.

Another paper by the above authors, entitled "Account of some Recent Observations on Sun-spots made at the Kew Observatory," has likewise been ordered to be published in the 'Philosophical Transactions.'

M. Berg, of the Wilna Observatory, has during the past year received instruction at Kew in the method of taking Solar Photographs and in that of measuring the positions and areas of sun-spots, the Director of the Observatory with which he is connected being desirous of working along with Kew, and of following out the same methods of observation as well as the same researches.

The number of sun-spots recorded after the manner of Hofrath Schwabe, together with a Table exhibiting the monthly groups observed at Dessau and at Kew for the year 1868, have been communicated to the Astronomical Society, and published in their 'Monthly Notices.'

We regret to mention that Hofrath Schwabe, owing to his great age, has found it necessary to discontinue his observations; but the Committee have satisfaction in stating that arrangements have been made for continuing, at Kew, the grouping of sun-observations which has been carried on for some time according to Hofrath Schwabe's plan, and for publishing the results annually.

A minute comparison of the records of Hofrath Schwabe with the simultaneous photographic records at Kew has revealed the great trustworthiness of his drawings, which are at present in the possession of Kew Observatory. The proposed communication already alluded to as representing the spotted area of the sun during three complete solar periods is thus rendered possible; and while it is imagined that by this means a valuable record of the past will be obtained, it is hoped that the interest now displayed in solar research will secure the uninterrupted continuance of such a record for the future.

4. *Miscellaneous work.*—The Superintendent has recently received a grant of £60 from the Government-Grant Committee of the Royal Society for the purpose of continuing certain experiments by Prof. Tait and himself on the rotation of a disk *in vacuo*; and means are in progress for obtaining a nearly perfect vacuum, Mr. Beckley, Mechanical Assistant at Kew, having devised an apparatus for this purpose.

An account of preliminary observations made with Kater's pendulum by the Superintendent, in conjunction with Mr. B. Loewy, has been communicated to the Royal Society.

The instrument devised by Mr. Broun for the purpose of estimating the magnetic dip by means of soft iron, constructed at the expense of the British Association, remains at present at the Observatory awaiting Mr. Broun's return to England.

The Observatory was honoured on June 25th by a visit from the eminent French chemist, M. Dumas, permanent Secretary of the Imperial Academy of Sciences, Paris, accompanied by M. Hervé-Mangon.

(B) Work done at Kew as the Central Observatory of the Meteorological Committee.

The relation between the two Committees, the Kew and the Meteorological, has during the last year been definitely settled.

The Kew Committee have undertaken to maintain the self-recording instruments belonging to the Meteorological Committee in regular operation at Kew, to tabulate from the traces, and to forward the traces and tabulations once a month to the central office of the Meteorological Committee in London, where they will be finally reduced, under the supervision of the Director of that office. They have also sanctioned the employment of such assistance by Mr. Stewart as may be necessary to enable him to examine the records which arrive from the various outlying observatories of the Meteorological Committee in accordance with a plan which has been approved by that body. Once a week, therefore, documents from these various observatories arrive at Kew, and about the middle of each month the documents for all the observatories (including Kew) for the previous month, after having been well examined, are forwarded to the Meteorological Office with a few remarks, which are printed in the Minutes of the Meteorological Committee.

Besides these duties which they have undertaken, the Kew Committee are glad to render the Meteorological Committee any occasional assistance which it may be in their power to bestow.

1. *Work done at Kew as one of the Observatories of the Meteorological Committee.*—This consists in keeping in constant operation the Barograph, Thermograph, and Anemograph furnished by the Meteorological Committee. Mr. Baker is in charge of these instruments. From the first two of these instru-

ments traces in duplicate are obtained, one set being sent to the Meteorological Office and one retained at Kew; as regards the Anemograph, the original records are sent, while a copy by hand of these on tracing-paper is retained. The tabulations from the curves of the Kew instruments are made by Messrs. Baker, Page, and Foster.

2. *Verification of Records.*—In order to maintain uniformity in the system of observation at the various meteorological observatories, it is arranged by the Meteorological Committee that Mr. Stewart shall personally visit all the observatories once every year, in addition to which, when necessary, some one of the Kew assistants will occasionally visit particular stations with a specific object in view. At the request of the Meteorological Committee, a system of checks has been devised by the Kew Committee for testing the accuracy of the observations made at the different Observatories. This system, with slight modifications, is now in operation*. As this revision takes place at Kew, it has been found necessary to engage an additional assistant for the purpose of undertaking it. Mr. Rigby has been engaged for this duty—Mr. Baker, Meteorological Assistant, having the general superintendence of this department.

3. *Occasional Assistance.*—In addition to devising the system of checks mentioned above, the Kew Committee have also, at the request of the Meteorological Committee, examined the subject of instrumental verifications, and it has been found that, owing to improved construction, a higher standard of excellence in meteorological instruments may be insisted upon without rejecting more than a very small percentage of those furnished by good makers.

It has therefore been resolved by the Meteorological Committee that in future the following limits of error shall be allowed in the construction of their instruments:—

Marine Barometers of the pattern adopted by the Meteorological Office.—Reject all for which the index-error at the ordinary pressure is greater than ·015 inch, or the capacity-error greater than ·004 inch, or for which the mercury does not fall from $1\frac{1}{2}$ inch to $\frac{1}{2}$ inch above the present pressure in a time between 3 and 6 minutes. But for *barometers purporting to be standards,* reject all for which the index-error at the ordinary pressure is greater than ·010 inch.

Thermometers (*graduated on the stem*) *of the pattern adopted by the Meteorological Office.*—Reject all in which the largest error at any point is greater than 0°·3, or in which any space of 10° is more than 0°·3 wrong.

Hydrometers of the pattern adopted by the Meteorological Office.—Reject all in which the largest error at any point is greater than 1 division of the scale (equal to ·001 sp. gr.), or in which any space of 10 divisions is more than 0·6 division wrong.

Models of Pantagraphic Apparatus, designed by Mr. Galton, have been made and experimentally used at Kew, at the desire of the Meteorological Committee, to reduce the tracings of the self-registering instruments in any desired proportions, either in length or in breadth, with a view to the ultimate publication by that Committee of all the tracings supplied by the seven Observatories in a compact volume.

It may also be mentioned, under the head of Occasional Assistance, that at the request of the Meteorological Committee, Mr. Beckley, Mechanical

* This scheme, having been extracted, with permission, from the Report of the Meteorological Committee, will be found in the Appendix to this Report.

1869.

Accounts of the Kew Committee of the British Association from August 19, 1868, *to August* 18, 1869.

RECEIP

	£	s.	d.	£	s.	d.
Balance from Central Observatory account				4	1	10
Received from the General Treasurer				600	0	0
" for the verification of Meteorological Instruments from the Meteorological Office	34	5	0			
" " from Opticians	61	16	6			
				96	1	6
" for the verification of Magnetical Instruments				35	0	0
" for the verification of self-recording Meteorological Instruments				25	0	0
" for the construction of a Standard Thermometer				1	0	0
" from the Meteorological Office:—						
Allowance as one of the Observatories of the Meteorological Committee, from 1st October 1868 to 30th September 1869				250	0	0
Extra allowance from Meteorological Committee to Kew as Central Observatory:—						
From 1st October 1868 to 1st January 1869, at £120 per annum	30	0	0			
From 1st January to 30th September 1869, at £200 per annum	150	0	0			
For subsidiary Barograph tabulations	25	0	0			
For lamp-glasses sent to various Observatories	1	11	4			
For services of assistants	7	10	0			
				214	1	4
				£1225	4	8

PAYMENTS.

	£	s.	d.	£	s.	d.
Balance from last account				0	0	5
Salaries, &c.:—						
To B. Stewart, four quarters, ending 30th September, 1869	200	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
G. Whipple, salary to quarter ending 30th September, 1869	128	6	0			
T. Baker	100	0	0			
F. Page	70	0	0			
J. Rigby, from 4th Feb. to 30th Sept., 1869	39	3	0			
R. Beckley, to 16th August, 1869	127	0	0			
J. Foster, salary from 4th July, 1868, to 5th June, 1869, 48 weeks at 12*s.* per week	28	16	0			
A. Hill, salary from 7th Nov., 1868, to 5th June, 1869, 30 weeks at 8*s.* per week	12	0	0			
				715	5	0
Apparatus, Materials, Tools, &c.				62	8	7
Ironmonger, Carpenter, Mason				30	19	6
Printing, Stationery, Books, Postage				40	1	9
Coals and Gas				68	2	3
House Expenses, Chandlery, &c.				67	18	10
Porterage and petty expenses				61	12	0
Meteorological work done at extra hours				70	17	6
Magnetical work done at extra hours				39	12	6
Rent of Land attached to Observatory				11	0	0
Tuition of assistants				10	10	0
Balance				46	16	4
				£1225	4	8

Examined with the vouchers and found correct.

3rd August, 1869.

A. STRANGE, Lt.-Col.

Assistant, was sent to Armagh to examine the Barograph there, and to Sandwick-manse, Orkney, to superintend the erection of an anemometer. The expenses have, on both these occasions, been repaid by the Meteorological Committee.

In conclusion, the Kew Committee desire to bring under the notice of the British Association, that the system of automatic records established and in actual work at the Kew Observatory, comprehends magnetic, barometric, and thermometric observations, as well as those of the direction and velocity of the wind, to which an electric self-recording instrument will soon be added. They think that it would be very advantageous to magnetical and meteorological science if a fully illustrated work were published descriptive of these instruments, and of the method of working them, together with the method of reductions actually employed.

J. P. GASSIOT, *Chairman.*

Kew Observatory,
15th July, 1869.

APPENDIX.

A Description of the Means adopted by the Meteorological Committee for ensuring Accuracy in the Numerical Values obtained from their Self-recording Instruments.

(Extracted, with permission, from the Report of the Meteorological Committee.)

In the first Report of this Committee the principles of construction of their self-recording instruments were fully described, and enough was said to render it probable that good results would be obtained; but the final method of tabulating from the traces of these instruments was not then decided on, nor had any scheme been devised for ensuring accuracy in the tabulated numerical values.

The labours of the Committee in this department have been materially aided by suggestions from the superintending Committee of the Central (Kew) Observatory, and also from the Directors of the various outlying observatories, and as a result the Committee are now satisfied that the process of examination to which the tabulated values are subjected before reaching the central office is such as to afford a satisfactory guarantee of accuracy.

It may be a fitting sequel to the description of these instruments (already given), to give here an account of the method adopted for ensuring accuracy in the results which they afford.

In the first place, the nature of the various instrumental errors and the best method of avoiding these may with propriety be described, and in the next place it may be desirable to give in detail the code of regulations adopted by the Committee for the guidance of their various observatories.

Barograph.

The values of atmospheric pressure derived from this instrument are liable to have their accuracy affected by three causes:—

(1) By an imperfect temperature compensation.
(2) By a sluggish action of the mercury in the Barograph tube.
(3) By imperfection in the system of recording and tabulating.

Temperature compensation.—The method by which the Barographs are compensated for temperature has been described in the Report of the Meteorological Committee for the year 1867. The precise position of the fulcrum of the glass rod was determined by means of some preliminary experiments made at Kew upon the first Barograph. These experiments consisted in subjecting the instrument to a very considerable range of temperature artificially produced, while frequent comparisons of its indications with those of a Standard Barometer gave the means of determining approximately what ought to be the position of the fulcrum. It may be presumed that the determination thus arrived at cannot be wrong more than one-tenth of the whole, and assuming this to be the case, the next point is to find what is the actual daily temperature range at the various observatories.

The following Table exhibits both the mean and the maximum daily range for each month for each of the seven observatories up to the end of 1868. In all these, with the exception of Stonyhurst, a night observation is made of the temperature of the Barograph at 10 o'clock, but the result will show that in Stonyhurst such an observation is unnecessary. It ought here to be borne in mind that from the system adopted in these instruments, namely, constant reference each day to a standard, it is only the daily range of temperature that we have to consider.

Daily range of temperature, in degrees Fahrenheit, as given by the observation hours.

1868.	Aberdeen.		Armagh.		Falmouth.		Glasgow.		Kew.		Stonyhurst.		Valencia.	
	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.
January	...	...	...	...	...	...	1·9	4·9	...	...	0·2	0·8	...	...
February ...	...	...	...	...	...	...	1·4	3·0	0·9	1·7	0·2	0·6	...	...
March	...	...	...	...	...	...	1·7	4·3	0·9	1·7	0·2	1·6	...	...
April	2·1	3·7	...	...	...	...	1·6	3·4	1·1	3·1	0·1	0·6	...	...
May	1·9	5·0	...	...	1·4	3·0	1·4	3·0	1·4	3·3	0·2	0·6	...	...
June	2·1	3·7	...	...	1·7	6·7	1·9	4·1	1·5	3·7	0·4	1·8	...	...
July	3·0	4·8	...	...	1·9	3·6	2·1	4·4	2·0	5·6	0·8	3·0	...	...
August	1·9	3·2	1·7	3·9	1·7	2·8	1·9	4·8	2·7	7·0	0·5	1·3	1·4	2·5
September...	2·3	4·6	1·8	3·8	1·8	6·3	2·2	7·3	2·4	8·7	0·5	1·2	1·2	2·6
October	1·5	2·5	1·9	3·6	1·4	3·0	2·0	6·0	0·8	1·8	0·6	2·7	1·2	2·7
November ...	2·1	3·7	1·9	3·6	1·4	2·8	1·3	3·1	1·0	1·9	0·7	1·3	1·2	2·4
December ...	2·0	6·3	1·4	2·2	1·1	2·3	1·3	4·9	0·9	2·5	0·7	2·4	1·0	4·3

From the results of this Table it would appear that, assuming the temperature adjustment to be one-tenth wrong, the greatest error introduced from this cause into any of the observations during the year 1868 would be about 0·0024 in., while the mean monthly error would be inappreciable in all cases.

We may therefore with confidence presume that in these Barographs the method of tabulation exemplified in the Report for 1867 and now practised is sufficiently accurate to obviate all effects of changes of temperature, and that it is unnecessary to resort to that more complicated but perfect system of reduction alluded to in the same Report, by which the influence of temperature may be completely eliminated. The near correspondence between the simultaneous Standard and Barograph readings, as exhibited in page lvii of this Report, is another proof that the temperature correction is practically perfect.

Sluggishness of Mercury.—As the Barograph tube is always in perfect repose, and the adhesion of the mercury to the glass is not counteracted by tapping or moving the tube, it is desirable to test the results obtained in order to see if the influence of adhesion causes a perceptible sluggishness of the mercury. The Standard Barometers, to which in all cases the Barographs are referred, are, on the other hand, subject to motion, and are probably sufficiently moved in the operation of reading to counteract any sluggishness of the mercury.

Now, four or five times each day, while the light is cut off from the recording cylinder of the Barograph by the clock arrangment, the Standard Barometer is read. We can thus compare these standard readings with the simultaneous measurements of the Barograms, these latter being of course properly tabulated, converted into true inches, and the residual correction applied as described in the Report of the Meteorological Committee for 1867.

Should there be any sluggishness in the mercury of the Barograph we might expect to discover it by means of this comparison, for in such a case the Barograph would lag behind, and thus read too low with a rising and too high with a falling barometer.

If therefore we presume that the Standard Barometer is free from sluggishness, and denote its readings by S, and those of the Barograph by B, then S—B ought in the case of sluggishness of the Barograph to be *positive* for a *rising* and *negative* for a *falling* barometer.

Several months' observations have been discussed in this manner for each of the observatories, and the result is exhibited in the following Table :—

Name of Observatory.	Months used.	S—B (Barometer rising).	S—B (Barometer falling).
		in.	in.
Aberdeen	July to December	+0·00033	−0·00028
Armagh	September to December	+0·00045	−0·00032
Falmouth	August to December	+0·00006	−0·00020
Glasgow	July to December	+0·00027	−0·00025
Kew	January to June	+0·00027	−0·00019
Stonyhurst	January to June	−0·00042	+0·00058
Valencia	August to November	+0·00005	+0·00015

From this Table we see how inappreciable in all the observatories is the retardation of the Barograph Barometer as compared with the Standard, while in Stonyhurst the Standard even appears to be a trifle more retarded than the Barograph Barometer.

Errors of recording and tabulating.—Under this head we may include (A) errors of adjustment and attachment of paper, (B) errors of time and date, (C) errors in tabulating from the traces. To begin with the first of these :—

(A) *Errors of adjustment and attachment of paper.*

Want of definition arising from an improper adjustment of the lens ought to be noticed, but it is believed that the definition is good in the case of all the observatories. As the instrumental constants for all the various Barographs have now been determined, it would hardly seem expedient to alter the position of the lens, which would alter these constants, for the purpose of procuring greater perfection in definition.

The photographic sheet which is attached to the cylinder of the Barograph ought to be evenly put on without any *bagging* or *bulging*; as, if it bulged, besides giving a bad result, it might come into contact with the end of the temperature adjustment bar.

Care ought to be taken that there is no *want of light*, especially in the case of a low barometer; and finally, great precaution should be taken to avoid *finger-marks* and every species of *bad photography*.

(B) *Errors of Time and Date.*

Suppose that the sheet has been placed in an unexceptionable manner upon the Barograph cylinder, the next point is for the operator to set the instrumental clock before starting to correct Greenwich mean time, as given by his chronometer. Now the instrumental clock has an arrangement for cutting off the light for four minutes every two hours, beginning to do so two minutes before an even hour and ending two minutes after it, and the practice is for the observer to read the Standard Barometer about five times every day at periods two minutes after even hours, as ascertained by his chronometer, or when the light should be about to be restored after having been cut off by the clock-stop. If therefore the instrumental clock keeps good time and its stop acts, and if the observer reads the Standard Barometer correctly and at the proper moment as ascertained by his chronometer, and if he finally reduces his curves properly, the near coincidence between the corresponding curve and Standard readings will be a good practical test, not only that all these operations have been properly performed, but also that throughout the curve the instrumental clock keeps good time with the chronometer. A further check with regard to time is afforded by the comparison made between the chronometer and the instrumental clock at the moment when the curve is taken off the cylinder, the results of which are recorded on the curve.

The clock may sometimes possibly stop, or the clock-stop may go wrong. Without discussing minutely these possibilities, it may be sufficient to state that when any such misadventure occurs the curve ought to be inspected by the Director of the Central Observatory.

There still remains the question of *date*. The security that a curve is rightly dated depends ultimately on the strong improbability that an observer at any of the observatories should make a mistake with regard to the first day of the week. When therefore he returns the Barograph journal filled up, we may be quite certain that the observations entered on the line with Sunday were really made on that day, although he may possibly put the wrong day of the month on the form beside it.

Again, the photographic operator when he takes off a curve, should mark on the back in pencil the day of the week and month when the curve was taken off, and should also, after drying, write upon its face the hour and day of putting on and taking off as recorded by the journal. If, therefore, the accuracy of the observer in assigning the proper day of the month to Sunday be checked at Kew as each week's journals are transmitted to that establishment, and if it also be seen that the date written in pencil on the back of the curve corresponds to that written on its face, and if the times of starting and ending of the curve as described in front are found to agree with the curve itself as measured by a simple time-scale, there can hardly be any doubt that the curve has been properly dated; if there still remain any doubt it will be dispelled when the tabulations from that curve are examined and it is found that the tabulated readings agree well with the simultaneous readings of the Standard Barometer.

(C) *Errors in tabulating from the traces.*

It will, in the first place, be necessary to discuss some arrangement for ensuring the entry under the *proper date* into the tabulation forms of the measurements from each curve; for even supposing that by the method now described we can ensure the proper dating of the curve, yet the tabulations from this curve may be entered under the wrong date in the tabulation form.

The appropriate check would seem to be the independent entry from the journal of the Standard readings reduced. For if either of these two independent entries be wrongly made, this will be seen by a non-coincidence of the reduced readings when compared with the simultaneous Standard readings. Our security becomes, therefore, the security which we have that these two independent readings cannot both be erroneously entered, and this may be converted into a certainty if the assistant at the Central Observatory sees that the journal readings are entered under their proper dates into the Barograph tabulation forms.

Having thus ascertained the entry into the tabulation forms under their proper dates of the tabulations and of the reduced standard readings, we come next to inquire what check there is for *accuracy of tabulations*; and here we may consider separately the cases of large and small errors.

But before proceeding to this part of the subject it may be desirable to say a few words regarding the system of Barograph tabulation.

The progress made in tabulating the Barograms up to the date of publication of the last Report of the Committee has been described in that Report. The first operation is to measure by the aid of a simple tabulating instrument, carrying a scale with a vernier attached to it, and capable of being read to the thousandth of an inch, the whole depth of the Barogram for every hour.

This system is nevertheless laborious, implying two measurements and one subtraction for each hour, besides the application of tables of conversion, and the consequence is the liability to make an occasional mistake. But although at first it is absolutely necessary to have in the case of the Barograph a tabulating instrument measuring inches, in order by its means to determine the constants of each instrument, yet when once these instrumental constants have been accurately determined, it has been found serviceable to replace the tabulating instrument by another which gives the true pressure in one measurement, instead of requiring two measurements, one subtraction and one conversion. Instruments of this nature have been obtained by this Committee for their various observatories, by which the labour of tabulation has been greatly reduced and accuracy of result much increased.

Nevertheless there is still the liability to make an occasional blunder, and as this may take the shape of a large error, it is necessary to devise some means for detecting and obviating all such mistakes.

The best remedy appears to be the use of a simple kind of subsidiary tabulating instrument, consisting of an ivory scale having a breadth equal to one hour of the time-scale, by means of which the hourly depth of the Barogram may be read to the hundredth of an inch. If these readings be compared with the readings taken independently by the tabulating instrument, any error in the latter will be at once discovered; for the errors to which the tabulated measurements are liable are such as *five hundredths of an inch*, or *one-tenth of an inch*,—errors of a large size, which may easily be detected by the system of sudsidiary measurement.

The following is an example of a day's comparison after this method, exhibiting an error which has thus been brought to light:—

August 29th.	Tabulated reading from weekly tabulation sheet to the nearest hundredth. A.	Subsidiary tabulation with ivory scale. B.	A−B in hundredths of an inch.
1 A.M.	30·22	30·21	+1
2 "	·22	·22	0
3 "	·21	·21	0
4 "	·22	·23	−1
5 "	·22	·22	0
6 "	·23	·22	+1
7 "	·24	·24	0
8 "	·25	·25	0
9 "	·25	·25	0
10 "	·26	·26	0
11 "	·26	·27	−1
Noon	·26	·27	−1
1 P.M.	·25	·25	0
2 "	·25	·25	0
3 "	·26	·27	−1
4 "	·25	·26	−1
5 "	·25	·25	0
6 "	·24	·34	−10 Error.
7 "	·24	·24	0
8 "	·24	·25	−1
9 "	·25	·26	−1
10 "	·24	·24	0
11 "	·24	·24	0
Midnight	30·24	30·25	−1

It ought to be remarked as necessary to the completeness of the check, that the observer should first of all by means of his subsidiary ivory scale fill in column B, and then (meanwhile concealing B from his view) fill in column A from the ordinary tabulation sheets. The correctness of the column A−B should be tested at the Central Observatory.

Having by this means obtained correct tabulations, the next point is to check the accuracy with which the *residual correction* has been obtained and applied (see Report for 1867, page 46). And first, with regard to the method by which it is obtained, the latest practice has been to calculate it for each day separately, making the day begin at 11 A.M. The advantage of this arrangement is that each fresh paper, which is always put on between 10 and 11 A.M., will have its own residual correction*. The accuracy of calculation of this correction ought to be checked, and such a check may be devised out of the practice pursued at Kew, of taking the mean monthly difference between simultaneous readings of the Standard and Barograph readings corrected. If these differences are taken for each day apart, beginning the day at 11 A.M. and giving each difference its appropriate sign, then the residual correction may be presumed to be accurate, when for that day there are as many *minus* as *plus* differences. Also, when any such difference exceeds, say, ·005 of an inch, the accuracy with which the

* A special arrangement regarding the residual correction has been made for Sundays and those days on which there are few observations of the Standard Barometer.

Standard readings have been reduced to 32° ought in this case to be examined. When a Standard reading is evidently wrong it ought to be noted as such on the curve, and should not be made use of either in calculating the residual correction or the monthly mean difference between the Standard and Barograph readings. By applying both the above tests any error in the calculation of the residual correction will be detected, and ought to be remedied at once. Having by this means obtained an accurately calculated residual correction, the accuracy with which this is applied to the various hours ought to be tested by the Kew assistant, who, obscuring from his view the column which embodies the values after the residual correction has been applied, should independently apply it on a separate piece of paper, thus producing a new column of corrected pressure, which ought to be compared with the old one; any error discovered by this comparison should be corrected at once. Before leaving this subject, it ought to be stated that the tabulating instrument as well as the subsidiary ivory scale are so arranged as always to ensure reading the proper point of the curve for every odd hour.

Should any portion of the curve be too *faint* for measurement with the ordinary tabulating instrument, but not too faint for measurement with the ivory scale, it ought to be measured with this scale, applying to the measurements so obtained their own appropriate residual correction. Such readings ought to be specially noted in the tabulation forms.

Should any part of the curve be *deficient from want of light or any other cause*, it ought not to be inked in. If the deficiency be in the border of the temperature curve, it will be possible to correct it, but if it be in the barometric curve, this cannot be done.

All curves in which the *clock has stopped or the clock-stop has been out of action*, should be personally inspected by the Director of the Central Observatory, in order that he may ascertain if the tabulations have been properly made.

Finally, it is right to state that the accuracy of the method of checking the tabulated values now described, has been practically confirmed by the month of October at Kew being independently measured by two observers. The results of the two sets, when compared together, are found to differ very slightly from one another, the greatest difference being ·008 in., which may be supposed to denote a difference in each of ·004 on either side of the truth. This extreme difference only occurs three times in the course of the month, that is to say, in 744 observations.

The method of subsidiary tabulations now described is thus proved to be effective in discovering the larger errors that the observer is liable to make when he measures the curve. But to ensure an efficient standard of correctness, it is not only necessary that the larger errors should be altogether eliminated, but *smaller errors* should be reduced to a minimum. Thus an observer might be sufficiently cautious in reading his scale to make no large error, yet sufficiently incautious to read erroneously when he came to the third figure of decimals. For rough results such an observer might be reckoned a good one, but for the more delicate class of investigations his figures would be of less value.

The only way of perfectly eliminating this class of errors is for two independent observers to make separate measurements, each with a tabulating instrument, a course involving much additional labour and expense. But it is obvious that the Standard Barometer affords a ready approximate means of estimating the correctness of an observer's results. For should he be an incautious observer, the mean difference between the simultaneous readings of the Standard and the Barograph Barometer will be comparatively great, but if he both observe his Standard and measure his curves well, the mean difference will be small.

The following Table exhibits the results of monthly comparisons between simultaneous Barograph and Standard readings for the year 1868 for all the observatories.

Mean Differences between Barograph and Standard Readings.

	Aberdeen.	Armagh.	Falmouth.	Glasgow.	Kew.	Stonyhurst.	Valencia.
1868.	in.	in.	in.	in.	in.	in.	in.
January	......	......	......	0·0067	0·0027	0·0032	......
February	......	......	......	0·0045	0·0027	0·0032	......
March	......	......	......	0·0039	0·0028	0·0025	......
April	0·0035	......	......	0·0035	0·0027	0·0017	......
May	0·0032	......	0·0042	0·0036	0·0025	0·0031	......
June	0·0029	0·0049	0·0029	0·0036	0·0021	0·0021	......
July	0·0032	0·0045	......	0·0026	0·0027	0·0032	......
August	0·0031	0·0033	0·0032	0·0038	0·0025	0·0023	0·0033
September	0·0023	0·0031	0·0041	0·0031	0·0025	0·0025	0·0027
October	0·0028	0·0029	0·0024	0·0030	0·0017	0·0028	0·0031
November	0·0019	0·0024	0·0017	0·0029	0·0015	0·0019	0·0038
December	0·0022	0·0022	0·0022	0·0028	0·0018	0·0030	0·0033

It is imagined that the mean differences shown by this Table have for all the observatories by the end of the year reached a minimum value not much larger than would be obtained by two observers reading the same Standard, or by the same observer reading it twice.

But while the simultaneous readings of the Standard and Barograph Barometer afford us one means of testing the correctness of the observation measurements, they do not yet do quite enough; for, in the first place, these simultaneous differences may be caused in part by an instrumental error or by some local peculiarity, such as rapid heaving of the barometer, and in the next place, an observer may unconsciously bestow a greater amount of pains upon these measurements, which are simultaneous with Standard readings, than he does upon his other measurements, and the above differences may not therefore be a true representative of his general correctness. A certain number of remeasurements of the curves of each observatory should therefore be made at the Central Observatory, and the monthly mean difference between these and the corresponding measurements by the local observer be recorded*.

* It was not until the various observatories had been supplied with their improved tabulating instrument that the final method of making these measurements was decided on. Since the beginning of 1869 the plan has been to make for each month for each observatory forty remeasurements of the curve at Kew, obtaining also independently the residual correction. These final values are then compared with the corresponding values obtained at the outlying observatories, and the result of this comparison for the first three months of 1869 has been as follows:—

Mean Difference between 1st and 2nd Measurements.

	Aberdeen.	Armagh.	Falmouth.	Glasgow.	Kew.	Stonyhurst.	Valencia.
1869.	in.	in.	in.	in.	in.	in.	in.
January	0·0020	0·0017	0·0026	0·0022	0·0012	0·0029	0·0017
February	0·0030	0·0025	0·0023	0·0022	0·0023	0·0031	0·0026
March	0·0024	0·0021	0·0025	0·0026	0·0018	0·0030	0·0025

Thermograph.

The accuracy of the Thermograph results is liable to be deranged by three causes:—

(1) By a cause depending on the situation and exposure of the instrument.
(2) By instrumental deficiencies, and especially the arrangements connected with the wet bulb.
(3) By a deficient system of tabulation.

Situation of Instruments.

The situation of their various Thermographs was a point carefully considered by the Meteorological Committee, and there is no reason to think that the effect of local peculiarity is considerable in the case of any of their instruments.

In the Report for 1867 this subject was alluded to, and the result of simultaneous comparisons made at Kew between the readings of two sets of dry and wet bulbs was given for the month of February, one of these sets being placed in a frame detached from the main building of the observatory, and the thermometers having very small bulbs, the other set being the wet- and dry-bulb Standard Thermometers of the Thermograph frame.

The result seemed to indicate that the local peculiarity of either frame was comparatively small; indeed, taking the average of the month, there was no residual difference between the dry bulbs, while, on the whole, the Thermograph wet bulb stood 0°·12 higher than the other.

A similar comparison made for the month of July gave no residual difference either for the dry or wet bulbs.

Dr. Robinson, of Armagh, has likewise made a similar comparison between his Thermograph dry bulb and another Thermometer placed at a higher elevation, and has obtained as the result of 150 observations made during the months of April and May, a mean difference indicating that the Thermograph Thermometer read on the whole 0°·27 less than the other. While this difference is not large, Dr. Robinson is of opinion that the upper thermometer is more liable to be affected by the sun, and that the Thermograph Thermometer is in consequence the most correct. No other observations have been made on the subject.

Instrumental Deficiencies.

The *wet-bulb arrangements* are peculiarly liable to go wrong, and the following course of action is suggested in order to reduce this source of error to a minimum.

The Standard Thermometers should be read at least five times a day at those moments when the light is cut off by the clock arrangement. The light remains cut off by this arrangement for four minutes, and it is necessary to read the Standard Thermometers *at the beginning* of this interval; the exact points in the curves corresponding to certain known readings of the Standards may thus be determined. When the Standards are read, the observer ought to notice if both wet bulbs are acting properly. If both are right, the sign √ should be made after the recorded temperature of the wet Standard. If the Thermograph wet bulb is wrong, the sign *t* should be made, and if the Standard wet bulb is wrong, the sign *s*. Either wet bulb, if found wrong, ought to be put right at once. Should it happen that the wet bulbs are frozen at the moment of observation, the present temperature being also below 32°, cold water should be poured over the wet bulbs and the connecting strings. In a few minutes the wet bulbs will by this means be covered with a fresh coating of ice; this should be repeated if necessary. If this operation is performed two or three times a day during very cold weather, there is reason to believe that the wet bulb will always be covered with a sufficient coating of ice. But if the wet bulb and the water of the water-vessel be frozen from previous cold, the present temperature being above 32°, the ice of the water-vessel may be thawed by warm water, using no more than is necessary for the purpose.

If these regulations be followed during the cold months of the year, it is believed that there are comparatively few instances where we may not know the temperature of evaporation during frost.

During dry weather the wet-bulb arrangement is again liable to go wrong, although from a different cause. The thread, which in the arrangement adopted lies along a copper groove, gets dry in its passage from the water-vessel to the bulb, the capillary action ceasing. Sometimes it apparently rights itself without aid, but sometimes it continues wrong until it is put right at the next observation hour. The commencement and termination of such a wrong state of the wet bulb are generally so clearly indicated by the curve itself, that there appears to be little or no uncertainty in ascertaining what observations ought to be rejected. This action would best appear to be prevented by the use of an india-rubber tube lying along the metallic groove, and having one end dipping into the water of the water-vessel; and through this tube the thread ought to be carried in its passage from the water-vessel to the thermometer. Evaporation is thus avoided, and the arrangement will probably answer in winter. When the supply of water is too rapid, it may be easily and safely altered by turning up the tube.

Even when the action of the wet bulb is unexceptionable, water must frequently be added to the water-vessel. It is usual for this water to have the temperature of the air; but in cases of a great difference between the two bulbs, this will be much above the temperature of evaporation; the consequence is found to be, that in such cases there is a rise in the wet-bulb curve which, in extreme cases, may not completely right itself until a quarter of an hour has elapsed. This can only be remedied by each observatory doing all in its power to ensure that under such circumstances the water supplied to the water-vessel shall represent as nearly as possible the temperature of the wet bulb at that moment, and also that the supply of water from the water-vessel to the wet bulb shall be no greater than is necessary to keep the bulb thoroughly damp without dripping.

With regard to other deficiencies, it will only be necessary to remark here such as are peculiar to the Thermograph, since all those common to this instrument and the Barograph have already been stated under the head of the latter.

In the first place, it should be noticed that there is sufficient *light* to illuminate the whole range of the curve in a proper manner. In order to ensure this, and at the same time procure the best possible definition, the heights of the thermometers may, as occasion requires, and without detriment to the instrument, be altered so as to bring the mean temperature of the time into a central position with respect to the lens and light. This change ought, however, to be made as seldom as possible (perhaps twice or thrice in a year), and when made great care ought to be taken that there is no strain upon the wet-bulb Thermometer through tightness of the thread, whether arising from frost or any other cause.

Errors in Trace and Tabulation.

The arrangement proposed for ensuring the entry under the *proper date* into the tabulation forms of the measurements of the Thermograph curves, and of the Standard readings corrected, is almost precisely the same as that stated in the case of the Barograph.

Having ascertained the entry into the tabulation forms under their proper dates of the tabulations, and of the Standard readings corrected, we come in the next place to consider the check upon *accuracy of tabulation*, and here, as in the case of the Barograph, it will be necessary to consider separately large and small errors.

In the first place, with respect to *large errors*, in order to prevent entirely their occurrence, it is necessary to resort to the system of subsidiary tabulations. An instrument for this purpose has been devised at Kew. It is unnecessary here to state its principle of construction; suffice it to say, that the results furnished by it are used in the same manner as in the case of the Barograph ivory scale already mentioned. By this means correct columns of tabulated readings may be obtained. Again, with regard to the *Standard readings*, all that appears to be necessary is to examine both the accuracy of entry of the Standard reading corrected, and the accuracy of tabulation for all those cases in which the recorded Thermograph temperature is more than half a degree different from the corresponding Standard reading, and to make any correction that may be found to be necessary. When a Standard reading is evidently wrong, it ought to be noted as such on the curve, and should not be made use of in calculating the monthly mean difference between Standard and Thermograph readings. Before leaving this subject, it ought to be stated that the tabulating instrument as well as the subsidiary scale, are both so arranged as to ensure reading the proper point of the curve for every odd hour.

It ought to be noted that, in tabulating from the Thermograph curves, the tabulating instrument should be set from those observation hours where there is little thermometric fluctuation.

All the dry-bulb readings ought to be compared with the corresponding wet-bulb ones, and should the latter ever appear higher than the former, the case ought to be marked.

The *maximum* and *minimum* temperatures furnished by the outlying observatories ought to be checked.

All *large errors* may, it is hoped, be completely obviated by the means now described.

With regard to *small errors*, the plan adopted is the same as that for the Barograph, viz.:—

(1) To record the monthly mean difference between the simultaneous Standard and Thermograph readings.

(2) To make forty remeasurements from each month's curves at Kew.

The following Table exhibits the results of the method employed for testing the accuracy of the Thermograph tabulations as regards small errors:—

1868.	Aberdeen. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.	Armagh. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.	Falmouth. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.
January...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
February .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
March ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
April	·17	·16	12	·15	·15	...	...	...	...	...	...	...	...	...	...
May	·18	·18	12	·16	·12	·10	·12	12	·12	·10	·13	·12	12	·10	·12
June	·18	·17	12	·11	·12	·13	·13	12	·09	·14	·13	·09	12	·13	·07
July	·15	·26	48	·16	·13	·15	·16	48	·10	·10	·12	·15	48	·14	·10
August ...	·14	·15	48	·16	·10	·11	·16	48	·10	·09	·08	·14	48	·07	·10
September.	·11	·12	48	·08	·12	·13	·14	48	·06	·09	·09	·09	48	·13	·14
October ...	·10	·13	48	·10	·13	·17	·19	48	·07	·07	·09	·09	48	·07	·06
November.	·18	·14	48	·09	·12	·12	·14	48	·11	·09	·08	·07	48	·10	·07
December .	·10	·11	48	·17	·11	·10	·13	48	·06	·09	·08	·07	48	·07	·10

1868.	Glasgow. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.	Kew. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.
January...	·14	·16	...	...	...	...	...	12	·06	·05
February .	·13	·13	12	·06	·05	·10	·10	12	·05	·06
March ...	·13	·14	12	·04	·05	·08	·07	12	·04	·03
April	·12	·15	12	·09	·15	·08	·08	12	·04	·05
May	·11	·11	12	·08	·12	·07	·08	12	·04	·07
June	·15	·12	12	·05	·10	·06	·07	12	·06	·08
July	·11	·12	48	·11	·07	·06	·09	48	·15	·08
August ...	.12	·10	48	·08	·08	·05	·07	48	·04	·06
September.	·08	·09	48	·08	·07	·08	·07	48	·04	·06
October ...	·09	·09	48	·11	·11	·06	·06	48	·06	·05
November.	·08	·10	48	·10	·13	·06	·06	48	·06	·04
December .	·10	·09	48	·12	·09	·06	·06	48	·06	·05

1868.	Stonyhurst. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.	Valencia. (1) Mean Difference between Thermograph and Standard readings. dry.	(2) wet.	(3) No. of remeasurements made.	(4) Mean Difference between first and second measurements. dry.	(5) wet.
January...	·06	·11	12	·08	·12	...	...	...	...	...
February .	·11	·20	12	·08	·07	...	...	...	...	...
March ...	·18	.35	12	·09	·30	...	...	...	...	...
April	·12	·15	12	·10	·12	...	...	...	...	...
May	·10	·16	12	·10	·05	...	...	...	...	...
June	·10	·15	12	·09	·08	...	...	...	...	...
July	·13	·13	48	·15	·16	...	...	...	...	...
August ...	·08	.10	48	·07	·07	·09	·08	48	·18	·20
September.	·08	·09	48	·06	·10	·09	·12	48	·12	·10
October ...	·08	·08	48	·09	·09	·09	·12	48	·08	·08
November.	·05	·08	48	·10	·10	·09	·10	48	·08	·08
December .	·07	·09	48	·08	·07	·10	·11	48	·04	·05

It is believed that the results of this Table afford satisfactory evidence not only of the accuracy with which the Standard Thermometers are read, but also of the accuracy of tabulation from the traces. A tendency in the monthly mean differences to decrease from their first values at starting will be noticed in the case of all the observatories.

Anemograph.

The accuracy of the Anemograph is, like that of the Thermograph, liable to be deranged by three causes:—

(1) By a cause depending on the situation and exposure of the instrument.
(2) By instrumental deficiency, such as friction.
(3) By deficient traces and tabulations.

Situation of Instruments.

These instruments are placed on the highest points of the various observatories, and as far as possible out of the reach of local influences. The exposure may therefore be considered good in the case of all the observatories.

Instrumental Deficiencies.

Friction is the most important of these, and may be supposed to affect to a small extent both the records of direction and velocity. The axle of the direction-vane moves in a wooden bearing, which is saturated with oil. It is believed that when the instrument is regularly attended to, the friction consequent upon this arrangement can be kept very small.

As regards the influence of friction upon the velocity-records, this has been determined in the case of the Kew instrument, and also by Dr. Robinson for his Anemograph, which has been for many years in operation. The following friction coefficient has been adopted, with the concurrence of Dr. Robinson, as applicable to the records of all the Anemographs belonging to the Meteorological Committee:—

Observed.	miles.	miles.
For velocities from	0·0	add 1·5
to	0·5	
"	1·0	add 1·0
to	3·0	
"	4·0	add 0·5
to	10·0	

Errors of Trace and Tabulation.

It ought to be noticed that *both the direction- and the velocity-pencils* are working well and freely on the paper.

It is also to be noticed that, for all the observatories except Falmouth, the *needle on the cylinder* goes through the centre of the crosses marked on the metallic paper.

In Falmouth the velocity-pencil is slightly out in position, and in consequence that observatory has been directed to set to a point which is not quite in the centre of the crosses. The Falmouth instrument has also been oriented for this position of setting. A note of the proper position of setting for Falmouth is preserved at Kew, and the assistant there ought to inspect each Falmouth Anemogram to see that it has been properly set.

With regard to *date*, each curve when taken off the cylinder should have both the day of the week and of the month written upon it, and when it reaches Kew it ought to be inspected by the assistant there in order to see that the observer has attached the proper day of the month alongside the day of the week.

He should also see that the week's curves sent are dated consecutively.

With regard to *time*, a prick made in the small time-scale of the metallic sheet denotes in terms of the hour-lines ruled on this sheet, the moment of starting, and a similar prick that of taking off. These pricks ought to denote the true chronometer times of starting and taking off very nearly, if the instrumental clock has been properly regulated. All *stoppages* of the instrumental *clock* ought to be marked.

It ought also to be noticed that the *cylinder is well clamped*, otherwise the friction of the pencil upon the cylinder may occasionally overcome that of the clamp, in which case the cylinder will slip.

With regard to *errors of tabulation*, the assistant at Kew ought in the first place to ascertain that the curve is tabulated under its *proper date*. Probably an intelligent inspection of the direction- and velocity-records in connexion with the tabulated results will be sufficient to determine this point.

A simple system of *subsidiary tabulations* has been adopted in order to check the direction-results. The observer at the outlying observatory is requested to write down on a separate sheet in numbers the direction of the wind at each hour as read from the curve by his eye, and compare it, as in the case of the Barograph and Thermograph, with the tabulated results. The differences between the two columns or A — B ought to be inspected at Kew, and when they are greater than *two points* the case ought to be examined, and any error detected ought to be corrected at once. With respect to direction, fractional parts of a point ought not to be recorded.

With regard to *velocity-traces*, the action of the instrument is such as to give by a glance at a curve the whole space travelled over by the wind for that day. Perhaps, therefore, it will be a sufficient check upon the velocity-records if, in addition to an intelligent comparison of the traces and tabulations, each day's results are added up and the sum total compared with that derived by glancing at the curve. When the difference between these two daily sum totals is greater than *one-twentieth of the whole*, the tabulated velocities for that day ought to be gone over again, and if any error is detected it ought to be put right at once.

It is probably unnecessary to check the recorded oscillations, as these are of inferior scientific value, and additional labour bestowed upon them would appear to be superfluous.

Finally, in order to keep a check upon *small errors*, the system of making at Kew forty remeasurements for each month, both for direction and velocity, has been adopted.

The following Table exhibits the results of the method employed for testing the accuracy of the Anemograph tabulations as regards small errors.

It will be seen from this Table that the standard of accuracy as represented by the smallness of the mean monthly differences has gradually increased up to the end of the year.

1868,	Aberdeen.			Armagh.*			Falmouth.			Glasgow.			Kew.			Stonyhurst.			Valencia.		
	No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.	
		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
January	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
February	...	...	...	...	...	...	...	...	...	12	0·8	0·5	12	0·2	0·7	12	0·4	1·0	...	...	...
March	...	...	...	...	...	...	12	0·5	0·5	12	1·0	0·4	12	0·0	1·0	12	0·0	0·7	...	...	...
April	10	0·5	1·0	...	...	...	12	0·2	0·9	12	0·2	1·0	12	0·3	0·8	12	0·1	0·6	...	...	...
May.	12	0·4	0·8	...	...	...	10	0·3	1·1	12	0·2	0·7	12	0·1	1·0	12	0·7	0·5	...	...	...
June	12	0·5	0·9	...	...	...	12	0·2	1·1	12	0·7	0·3	12	0·5	0·9	10	0·5	0·3	...	...	...
July	48	0·1	0·5	...	...	...	48	0·3	0·6	48	0·3	0·9	48	0·1	0·9	48	0·2	0·5	...	...	...
August	48	0·2	0·5	...	...	...	48	0·3	1·0	48	0·2	0·6	48	0·1	0·5	48	0·4	0·5	48	0·2	0·9
September	48	0·2	0·6	...	...	...	48	0·1	0·9	48	0·2	0·8	48	0·1	0·5	48	0·4	0·5	48	0·2	1·0
October	48	0·3	0·7	...	...	...	48	0·3	0·6	48	0·4	0·5	48	0·3	0·4	48	0·5	0·5	48	0·4	1·0
November	48	0·4	0·6	...	...	...	48	0·2	0·8	48	0·4	0·7	48	0·3	0·3	48	0·3	0·5	48	0·3	1·2
December	48	0·3	0·8	...	...	...	48	0·2	0·8	48	0·3	0·7	48	0·2	0·5	48	0·3	0·6	24	0·3	1·2

* The Anemograph of Dr. Robinson is somewhat different from the others, and it is only since the beginning of 1869 that the method of checking his results has been finally decided on.

CODE of REGULATIONS adopted by the METEOROLOGICAL COMMITTEE for ensuring ACCURACY in the RESULTS derived from their SELF-RECORDING INSTRUMENTS.

In the first place a set of rules have been framed for the guidance of the various observatories, including the Central Observatory at Kew. Secondly, a set of forms have been constructed on which to register the deficiencies and mistakes in the returns from the various observatories, copies of which when filled up are forwarded to the Directors of these observatories on the one hand, and to the Meteorological Office on the other. Thirdly, a diary of operations has been constructed, from which each observatory may know the times at which the various documents ought to be sent to Kew. Fourthly, each month's results are laid before the Meteorological Committee, accompanied with the remarks of the Director of the Central Observatory, which are then printed in the minutes of that body*.

REGULATIONS FOR BAROGRAPH.

Outlying Observatory.

(1.) The curves, journals, and tabulation forms to be written upon according to the pattern furnished.

(2.) Always begin a new month with new forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) Clock to be set to Greenwich mean time at starting, and its error not to exceed two minutes in two days.

(4.) The Barograph Thermometer and the Standard Barometer, and its attached Thermometer, ought to be read five times a day if possible while the light is cut off by the clock-arrangement. The light remains cut off by this arrangement for four minutes, and it is necessary to read the Standard Barometer *at the end* of this interval—the exact points in the curve corresponding to certain known readings of the Standard may thus be determined. It ought to be noticed when the Standard is heaving or oscillating.

(5.) The instrument should always be started between 10 and 11 A.M. Greenwich mean time on those days mentioned in the diary.

(6.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve, noticed by the observer, should be inserted in the journal under the head of "Remarks," with the exact time attached thereto. Should the height of the Barometer-cistern be altered, or any change made which will affect the curve, this ought, as already mentioned, to be noticed; it is, however, considered that all such changes ought to be avoided.

(7.) The previous week's curves, journals, and tabulations should be sent to Kew every Thursday, as mentioned in the diary.

* In these remarks there is recorded, amongst other things, each blank in the traces during the month. The following were the blanks for February 1869:—

Anemograph (direction)	10	hourly records lost	out	of	4704.
Ditto (velocity)	20	"	"	"	4704.
Barograph..............................	13	"	"	"	4704.
Thermograph (dry bulb)...........	2	"	"	"	4704.
Ditto (wet bulb)......................	12	"	"	"	4704.

Central Observatory (Assistant).

(8.) The assistant at Kew shall examine each curve in order to see if there is any want of light or appearance of bagging, or of finger-marks, or of bad photography, and he shall occasionally see that the temperature bar is in proper action.

(9.) He shall see that the clock and clock-stop have been in good action for the time of the curve.

(10.) That the instrumental clock does not differ more than two minutes from the chronometer as recorded on the curve.

(11.) That the date written on the back of the curve agrees with that on the face.

(12.) That the curve is properly written upon after the pattern.

(13.) That in the Barograph Journal the proper day of the month is placed alongside of Sunday, and that the others follow consecutively.

(14.) That the times of starting and stopping the curve as recorded in the journal have been properly recorded on the face of the curve.

(15.) Finally, he shall ascertain, by means of a simple inspection of the curve, that the beginning and ending, as shown by the curve itself, are the same as those described on the face of the curve.

(16.) He shall see that the journal readings of the Standard Barometer are entered under their proper dates into the Barograph tabulation sheets.

(17.) Then examine in a general manner the accordance of the Barograph and Standard readings for each day. If these two tests be satisfactory, he may conclude that the tabulations and Standard readings have both been entered under their proper dates.

(18.) Check the accuracy of the subtractions made in the tables of subsidiary measurements furnished by the outlying observatory.

(19.) Investigate all cases where A − B is greater than ·02 in.; if an error be revealed in the tabulations, this error ought to be corrected at once. These corrections ought to be made before the next step in the process is commenced.

(20.) Then ascertain the accuracy with which the residual correction has been found according to the method described, and whenever it has been found necessary to alter the residual correction, a correction should also be made in the last column of the tabulation papers.

(21.) Then check after the manner described the accuracy with which the residual correction has been applied, producing a new column of corrected pressure, which he shall compare with the old one, and any error discovered by this comparison shall be corrected at once.

(22.) Portions of the curve too faint for the ordinary instrument, but capable of being measured by the ivory scale, shall be measured, corrected, and marked as specified.

Central Observatory (Director).

23. The assistant at Kew shall bring all curves and tabulations which exhibit deficiencies personally before the Director of the Central Observatory, and the latter shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand and to the Director of the observatory where the

failure occurred on the other, making any remark that may tend in his estimation to obviate in future the cause of failure.

(24.) He shall also communicate as above the monthly mean differences between the Barograph readings reduced, and the simultaneous Standard readings.

(25.) He shall also communicate as above the result of forty remeasurements for each observatory for each month, to be made at Kew, noting (1) the greatest difference, (2) the mean difference irrespective of sign, (3) the residual difference (if any), taking signs into account.

Regulations for Thermograph.

Outlying Observatory.

(1.) The curves, journals, and tabulation forms to be written upon according to the pattern furnished.

(2.) Always begin a new month with new forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) Clock to be set to Greenwich mean time at starting, and its error not to exceed two minutes in two days.

(4.) The Standard Thermometers should be read at least five times a day at those moments when the light is cut off by the clock-arangement. The mode of dealing with the wet bulb has been already described, p. lviii.

(5.) The instrument should always be started between 10 and 11 A.M. Greenwich mean time, on those days mentioned in the diary.

(6.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve noticed by the observer, should be inserted in the journal under the head of "Remarks," with the exact time attached thereto.

(7.) The muslin and connecting threads ought to be taken off the bulbs, washed and replaced as often as they become soiled.

(8.) The previous week's curves, journals, and tabulations should be sent to Kew every Thursday, as mentioned in the diary.

Central Observatory (Assistant).

(9.) The assistant shall examine each curve in order to see if there is any want of light, bagging, finger-marks, bad photography, or defective action of wet bulb, during however short a space of time.

(10.) He shall see that the clock and clock-stop have been in good action for the time of the curve.

(11.) That the instrumental clock does not differ more than two minutes from the chronometer as recorded on the curve.

(12.) That the date written on the back of the curve agrees with that in front.

(13.) That the curve is properly written upon after the pattern adopted.

(14.) That in the Thermograph Journal the proper day of the month is placed alongside of Sunday, and that the others follow consecutively.

(15.) That the times of starting and stopping the curve as recorded in the journal have been properly recorded on the face of the curve.

(16.) He shall ascertain, by means of a simple inspection, that the beginning and ending, as shown by the curve itself, are the same as those described in front of the curve.

(17.) That the journal readings of the Standard Thermometer are entered under their proper dates into the Thermograph tabulation sheets.

(18.) He shall examine in a general manner the accordance of the Thermograph and Standard readings for each day. If these two tests be satisfactory, he may conclude that the tabulations and Standard readings have both been entered under their proper dates.

(19.) Check the accuracy of the subtractions made in the tables of the subsidiary measurements.

(20.) Investigate all cases in which A — B is greater than 0°·5 Fahr.; and if an error is revealed, it ought to be corrected at once.

(21.) Examine both the corrected Standard reading and the corresponding tabulated one for all those cases in which there is a difference greater than 0°·5 between the two.

(22.) Compare the dry-bulb readings with the corresponding wet ones, marking and examining all those cases in which the latter appear higher than the former.

(23.) Check the accuracy of the maximum and minimum temperatures furnished by the outlying observatories.

(24.) Record the monthly mean differences between the simultaneous Standard and Thermograph readings.

(25.) Make forty remeasurements as specified.

Central Observatory (Director).

(26.) The assistant at Kew shall bring before the Director of the Central Observatory all curves, with their corresponding tabulations, that are deficient from any cause, and the Director shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand, and to the Director of the observatory where the failure occurred on the other, making any remarks that may tend in his estimation to obviate in future the causes of failure.

(27.) The Director of the Central Observatory shall also communicate as above the monthly mean differences between the simultaneous Thermograph and Standard readings, as well as the result of the forty remeasurements made at Kew.

Regulations for Anemograph.

Outlying Observatory.

(1.) The curves and tabulation forms to be written upon according to the patterns furnished.

(2.) Always begin a new month with new tabulation forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) The pricks on the curve, when compared with the Greenwich mean times of commencement and taking off, ought to agree with the latter within five minutes at each end.

(4.) The curve should be taken off at $10^h\ 30^m$ A.M., and a new one replaced if possible at $10^h\ 32^m$, Greenwich mean time.

(5.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve noticed by the observer, should be recorded on the blank part of the sheet of metallic paper, with the exact time attached thereto. The orientation should be tested once a month.

(6.) The previous week's curves and tabulations should be sent to Kew every Thursday, as recorded in the diary.

Central Observatory (Assistant).

(7.) The assistant at Kew shall examine each curve in order to see if both pencils work well and freely, and if the paper has been accurately attached to the cylinder, and if the cylinder has not slipped.

(8.) He shall see that the clock has been in good order during the time of the curve.

(9.) That the curve is properly written upon after the pattern adopted.

(10.) That in the writing upon the curve the proper day of the month is placed alongside the day of the week.

(11.) That the times of putting on and taking off as recorded by the pricker do not differ more than five minutes from the chronometer time.

(12.) He shall inspect the direction- and velocity-curves in connexion with the tabulated results, in order to ascertain that each curve is tabulated under its proper date.

(13.) Check the accuracy of the subtractions made in the tables of the subsidiary direction measurements.

(14.) Examine all cases in which A — B is greater than *two points*, and if an error is revealed it ought to be corrected at once.

(15.) Check the accuracy of the velocity tabulations, according to the method herein indicated.

(16.) Make forty remeasurements for each month, both for direction and velocity, as in the case of the other instruments.

Central Observatory (Director).

(17.) The assistant at Kew shall bring before the Director of the Central Observatory all curves, with their corresponding tabulations, that are deficient from any cause, and the Director shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand, and to the Director of the observatory where the failure occurred on the other, making any remarks that may tend in his estimation to obviate in future the causes of failure.

(18.) The Director of the Central Observatory shall also communicate as above the result of the forty remeasurements made at Kew.

I.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

__________________BAROGRAMS, &c.

(*Received at Kew,*__________________.) Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(A.) Want of light in curves	
(B.) Bagging in do.	
(C.) Finger-marks, &c., in do.	
3. Action of clock	
4. Regulation of do.	
(D.) Action of clock-stop	
5. Errors in dating curves	
(E.) Do. in entry or date of entry of journal readings of standard into tabulation sheets	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. of tabulation discovered by subsidiary tables	
(*c.*) Do. in calculating residual correction	
(*d.*) Do. in applying residual correction	
9. Ten remeasurements	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . . .	
(3.) *Residual difference*	

II.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

________________________THERMOGRAMS, &c.

(*Received at Kew*,___________________________.) Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(A.) Want of light in curves	
(B.) Bagging in do.	
(C.) Finger-marks, &c., in do.	
(*a.*) Defective action of wet bulb	
3. Action of clock	
4. Regulation of do.	
(D.) Action of clock-stop	
5. Errors in dating curves	
(E.) Do. in entry or date of entry of journal readings of standard into tabulation sheets	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. of tabulation discovered by subsidiary tables	
(*b.*) Do. in maxima and minima	
9. Ten remeasurements	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . . .	
(3.) *Residual difference*	

III.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

______________________ ANEMOGRAMS, &c.

(*Received at Kew,* ______________________.)

Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(*e.*) Action of pencils	
(*f.*) Errors of attachment of paper	
(*g.*) Slipping of cylinder	
3. Action of clock	
4. Regulation of do.	
5. Errors in dating curves	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. in direction discovered by subsidiary tables .	
(*h.*) Do. in velocity discovered by subsidiary arrangement . . . . , ...	
9 (*a.*) Ten remeasurements (*direction*)	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . .	
(3.) *Residual difference*	
9 (*b.*) Ten remeasurements (*velocity*)	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . .	
(3.) *Residual difference*	

Specimen of Diary of Operations for 1869. **JANUARY.**

Day of Month.	Day of Week.	No. of Bar. and Ther. sheets taken off this day.	No. of Anem. sheet taken off this day.	No. of Journals and Tabulations ending this day.	Send to Kew. Bar. and Ther. Curves, Nos. inclusive.	Anem. Curves, Nos. inclusive.	Journals and Tabulations, Nos.	Weather Report for	Remarks.
1.	Friday ...	1	1						
2.	Saturday...	......	2	1					
3.	**Sunday**...	2–3	3						
4.	Monday ...	......	4						
5.	Tuesday ...	4–5	5						
6.	Wednesday	......	6						
7.	Thursday..	6–7	7	...	1 to 3	1 to 3	1		
8.	Friday ...	......	8						
9.	Saturday...	8–9	9	2					
10.	**Sunday**...	......	10						
11.	Monday ...	10–11	11						
12.	Tuesday ...	......	12						
13.	Wednesday	12–13	13						
14.	Thursday..	......	14	...	4 to 11	4 to 10	2		
15.	Friday ...	14–15	15						
16.	Saturday...	......	16	3					Kew to send in documents for December 1868 to the central office.
17.	**Sunday**...	16–17	17						
18.	Monday ...	......	18						
19.	Tuesday ...	18–19	19						
20.	Wednesday	......	20						
21.	Thursday..	20–21	21	...	12 to 17	11 to 17	3		
22.	Friday ...	......	22						
23.	Saturday...	22–23	23	4					
24.	**Sunday**...	......	24						
25.	Monday ...	24–25	25						
26.	Tuesday ...	......	26						
27.	Wednesday	26–27	27						
28.	Thursday..	......	28	...	18 to 25	18 to 24	4		
29.	Friday ...	28–29	29						
30.	Saturday...	......	30	5					
31.	**Sunday**...	30–31	31	6					

FEBRUARY.

Day of Month.	Day of Week.	No. of Bar. and Ther. sheets taken off this day.	No. of Anem. sheet taken off this day.	No. of Journals and Tabulations ending this day.	Send to Kew. Bar. and Ther. Curves, Nos. inclusive.	Send to Kew. Anem. Curves, Nos. inclusive.	Send to Kew. Journals and Tabulations, Nos.	Send to Kew. Weather Report for	Remarks.
1.	Monday ...	......	32						
2.	Tuesday ...	32–33	33						
3.	Wednesday	......	34						
4.	Thursday..	34–35	35	...	26 to 31	25 to 31	5		
5.	Friday ...	......	36						
6.	Saturday..	36–37	37	7					
7.	**Sunday**...	......	38						
8.	Monday ...	38–39	39						
9.	Tuesday ...	......	40						
10.	Wednesday	40–41	41						
11.	Thursday..	......	42	...	32 to 39	32 to 38	6 and 7	January	
12.	Friday ...	42–43	43						
13.	Saturday..	......	44	8					
14.	**Sunday**...	44–45	45						
15.	Monday ...	......	46						
16.	Tuesday ...	46–47	47						
17.	Wednesday	......	48						
18.	Thursday..	48–49	49	...	40 to 45	39 to 45	8		
19.	Friday ...	......	50						
20.	Saturday..	50–51	51	9					
21.	**Sunday**...	......	52						Kew to send in January documents to the central office.
22.	Monday ...	52–53	53						
23.	Tuesday ...	......	54						
24.	Wednesday	54–55	55						
25.	Thursday..	......	56	...	46 to 53	46 to 52	9		
26.	Friday ...	56–57	57						
27.	Saturday..	......	58	10					
28.	**Sunday**...	58–59	59	11					

Recommendations adopted by the General Committee at the Exeter Meeting in August 1869.

[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 sum of £600 be placed at the disposal of the Council for maintaining the Establishment of the Kew Observatory.

That the Committee, consisting of Dr. Joule, Sir W. Thomson, Professor Tait, Dr. Balfour Stewart, and Professor G. C. Foster, be reappointed to effect a determination of the Mechanical Equivalent of Heat; and that the sum of £50 be placed at their disposal for the purpose.

That the Committee for reporting on the Rainfall of the British Isles be reappointed, and that this Committee consist of Mr. Charles Brooke, Mr. Glaisher, Professor Phillips, Mr. G. J. Symons, Mr. J. F. Bateman, Mr. R. W. Mylne, Mr. T. Hawksley, Professor Adams, Mr. C. Tomlinson, Professor Sylvester, Dr. Pole, and Mr. Rogers Field; that Mr. G. J. Symons be the Secretary, and that the sum of £50 be placed at their disposal for the ordinary purposes of the Committee, and that a further sum of £50 be granted for the purpose of providing additional rain-guages in certain districts where observations are not at present made.

That the Committee on Underground Temperature, consisting of Sir William Thomson, Dr. Everett, Sir Charles Lyell, Bart., Principal Forbes, Mr. J. Clerk Maxwell, Professor Phillips, Mr. G. J. Symons, Mr. Balfour Stewart, Professor Ramsay, Mr. Geikie, Mr. Glaisher, Rev. Dr. Graham, Mr. E. W. Binney, Mr. George Maw, and Mr. Pengelly, be reappointed with the addition of the name of Mr. S. J. Mackie; that Dr. J. D. Everett be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That the Committee on the Thermal Conductivity of Metals, consisting of Professor Tait, Professor Tyndall, and Dr. Balfour Stewart, be reappointed; that Professor Tait be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That the Committee on Tides, consisting of Sir W. Thomson, Professor Adams, Professor J. W. M. Rankine, Mr. J. Oldham, and Captain Richards, be reappointed, with the addition of the name of Mr. W. Parkes, and that they be instructed to institute as soon as possible a comparison between the results of the formulæ arrived at in their reports (those of observation and those of previous methods of reduction and calculation), and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Luminous Meteors, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. E. W. Brayley, Mr. Alexander Herschel, and Mr. C. Brooke, be reappointed; and that the sum of £30 be placed at their disposal for the purpose.

That Dr. Matthiessen, Professor Abel, and Mr. David Forbes be a Committee for the purpose of continuing their researches on the Chemical Nature of Cast Iron; and that the sum of £80 be placed at their disposal for the purpose.

That Mr. R. B. Grantham, Mr. J. Bailey Denton, Mr. J. R. Harrison, Mr. J. W. Wanklyn, W. Hope, and Dr. B. H. Paul be a Committee for the purpose of continuing their investigations on the treatment and utilization of sewage; and that the sum of £50 be placed at their disposal for the purpose.

That Sir Charles Lyell, Bart., Professor Phillips, Sir John Lubbock, Bart., Mr. John Evans, Mr. Edward Vivian, Mr. William Pengelly, Mr. George Busk, Mr. W. Boyd Dawkins, and Mr. W. Ayshford Sandford 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 £150 be placed at their disposal for the purpose.

That Dr. P. M. Duncan and Mr. Henry Woodward be a Committee for the purpose of continuing their Researches on British Fossil Corals; that Dr. P. M. Duncan be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. Henry Woodward, Dr. Duncan, Professor Harkness, and Mr. James Thomson be a Committee for the purpose of making and photographing further sections of such Mountain Limestone Fossils as require to be cut in order to display their structure; that Mr. Woodward be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That the Rev. W. S. Symonds, Mr. Lightbody, and the Rev. J. B. La Touche be a Committee for the purpose of investigating Sedimentary deposits in the river Onny; that the Rev. J. B. La Touche be the Secretary, and that £3 be placed at their disposal for the purpose.

That Dr. Bryce, Sir W. Thomson, Mr. D. Milne-Home, and Mr. Macfarlane be a Committee for the purpose of continuing the researches on Earthquakes in Scotland; that Dr. Bryce be the Secretary, and that the sum of £4 be placed at their disposal for the purpose.

That Professor Huxley, Mr. Westroppe, and Mr. W. H. Baily be a Committee for the purpose of continuing the investigation of the fossil contents of the two Kiltorcan quarries, co. Kilkenny; that Mr. W. H. Baily be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. W. S. Mitchell, Mr. Robert Etheridge, Professor J. Morris, Mr. G. Maw, and Mr. Henry Woodward be a Committee for the purpose of continuing the investigation of the Leaf-beds of the Lower Bagshot Series of the Hampshire Basin; that Mr. Mitchell be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That Dr. B. W. Richardson, Dr. Sharpey, and Professor Humphry be a Committee for the purpose of continuing researches on the physiological action of Organic Chemical compounds; that Dr. Richardson be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Mr. W. Carruthers, Professor Balfour, Dr. J. D. Hooker, and Professor Dickson be a Committee for the purpose of continuing investigations in the Fossil Flora of Britain; that Mr. Carruthers be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Spence Bate, Mr. Joshua Couch, Dr. McIntosh, Mr. Rowe, and Mr. J. Gwyn Jeffreys be a Committee for the purpose of continuing their research on the Marine Fauna of Devon and Cornwall; that Mr. Spence Bate be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. George Busk, Mr. H. T. Stainton, and the Rev. H. B. Tristram be a Committee for the purpose of drawing up a record of Zoological Literature of 1869; that Mr. George Busk be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. C. Stewart, Dr. Günther, and Mr. W. H. Flower be a Committee for the purpose of investigating the structure of the Ear in Fishes, and that Mr. Stewart draw up the Report on the subject, and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Arthur Gamgee, Mr. E. Ray Lankester, and Dr. M. Foster be a Committee for the purpose of investigating the amount of Heat generated in the Blood, in the process of arterialization; that Dr. Arthur Gamgee be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That the Metric Committee be reappointed, such Committee to consist of Sir John Bowring, The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., The Right Hon. C. B. Adderley, M.P., Mr. Samuel Brown, Dr. Farr, Mr. Frank P. Fellowes, Professor Frankland, Professor Hennessy, Mr. James Heywood, Sir Robert Kane, Professor Leone Levi, Professor W. A. Miller, Professor Rankine, Mr. C. W. Siemens, Colonel Sykes, M.P., Professor A. W. Williamson, Mr. James Yates, Dr. George Glover, Mr. Joseph Whitworth, Mr. J. R. Napier, Mr. H. Dircks, Mr. J. V. N. Bazalgette, Mr. W. Smith, Mr. W. Fairbairn, and Mr. John Robinson; that Professor Leone Levi be the Secretary, and that the sum of £25 be placed at their disposal for the purpose of being applied solely to scientific purposes, printing, and correspondence.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Mr. E. J. Lowe, Professor Frankland, Professor A. W. Williamson, Mr. Glaisher, Dr. Moffat, Mr. C. Brooke, Dr. Andrews, and Dr. B. Ward Richardson, for promoting accurate Meteorological Observations of Ozone be reappointed with the addition of the name of Sir Edward Belcher.

That Professor Sylvester, Professor Cayley, Professor Hirst, Rev. Professor Bartholomew Price, Professor H. J. S. Smith, Mr. W. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Rev. R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, and Mr. W. K. Clifford be a Committee (with power to add to their number) for the purpose of considering the possibility of improving the methods of instruction in elementary geometry, and that Mr. W. K. Clifford be the Secretary.

That the Committee on Electrical Standards, consisting of Professor Williamson, Professor Sir Charles Wheatstone, Professor Sir W. Thomson, Professor W. A. Miller, Dr. A. Matthiessen, Mr. Fleeming Jenkin, Sir Charles Bright, Mr. J. Clerk Maxwell, Mr. C. W. Siemens, Mr. Balfour Stewart, Dr. Joule, Mr. C. F. Varley, Professor G. C. Foster, and Mr. C. Hockin, be reappointed; and that Professor Fleeming Jenkin be the Secretary.

That Mr. W. H. L. Russell be requested to continue his Report on recent progress in the theory of Elliptic and Hyperelliptic Functions.

That Dr. Frankland and Mr. M'Leod be a Committee for the purpose of continuing their researches on the composition of the gases dissolved in deep-well water.

That Dr. Anderson and Mr. Catton be a Committee for the purpose of continuing the researches of Mr. Catton on the Synthesis of Organic Acids.

That Mr. Mallet be requested to prepare a Report on the ascertained facts of Volcanoes, on the general plan of his Report on Earthquakes.

That Mr. H. E. Dresser, Rev. H. B. Tristram, Professor Newton, Mr. J. E. Harting, and the Rev. H. Barnes, be a Committee for the purpose of continuing investigations on the desirability of establishing "*a close time*" for the preservation of our indigenous animals; and that Mr. H. E. Dresser be the Secretary.

That Colonel Lane Fox, Sir John Lubbock, Mr. Busk, Mr. Evans, and Mr. Stevens be a Committee for the purpose of examining the interior of Stonehenge, with instructions to apply to Sir Edward Antrobus for permission to do so.

That the Committee on Agricultural Machinery, consisting of the Duke of Buccleuch, the Rev. Patrick Bell, Mr. David Greig, Mr. J. Oldham, Mr. William Smith, C.E., Mr. Harold Littledale, The Earl of Caithness, Mr. Robert Neilson, Professor Rankine, Mr. F. J. Bramwell, Professor Willis, and Mr. Charles Manby, be reappointed; and that Messrs. P. Le Neve Foster and J. P. Smith be the Secretaries.

That the Committee on Boiler Explosions, consisting of Mr. W. Fairbairn, Mr. Joseph Whitworth, Mr. Lavington E. Fletcher, Mr. F. J. Bramwell (with power to add to their number), be reappointed with a view to their considering and reporting on any legislative measures which may be brought forward in reference to the prevention of steam-boiler explosions.

Involving Applications to Government.

That the President of the British Association, the President of the Geological Section, and Mr. Godwin-Austen, Vice-President of the Section, be a Committee for the purpose of calling the attention of Her Majesty's Government to the importance of completing, without delay, the valuable investigation into the composition and geological distribution of the Hæmatite Iron Ores of Great Britain and Ireland, which has been already in part published in the Memoirs of the Geological Survey.

That the Committee on the Laws regulating the Flow and Action of Water holding solid matter in suspension, consisting of Mr. T. Hawksley, Professor Rankine, Mr. R. B. Grantham, Sir A. S. Waugh, and Mr. T. Login, be reappointed, with authority to represent to Government the desirability of undertaking experiments bearing on the subject.

That the Committee appointed to report on the state of existing knowledge on the *stability*, *propulsion* and *sea-going qualities* of ships, and consisting of Mr. C. W. Merrifield, Mr. Bidder, Captain Douglas Galton, Mr. F. Galton, Professor Rankine, Mr. W. Froude, be reappointed; and that they be instructed to apply to the Admiralty to make the experiments recommended in their First Report.

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

That Professor Magnus's communication "On the Emission, Absorption, and Reflexion of Obscure Heat," be printed *in extenso* among the Reports.

That Professor Morren's communication "On the Chemical Action of Light discovered by Professor Tyndall," be printed *in extenso* among the Reports.

That Mr. Glaisher's observations made by the Captive Balloon be published in the Proceedings.

That Mr. Frederick Purdy's paper on the "Pressure of Taxation on Real Property," be printed *in extenso* among the Reports.

That Mr. F. J. Bramwell's paper "On the laws determining the fracture of materials when sudden changes of thickness take place," be printed *in extenso* in the Report.

That Mr. Joseph Whitworth's paper "On the penetration of Armour Plates by Shells with heavy bursting charges," be printed *in extenso* in the Report.

That Mr. Thomas Login's paper "On Roads and Railways in Northern India as affected by the abrading and transporting power of Water," be printed *in extenso* in the Proceedings.

Resolutions referred to Council by the General Committee at Exeter.

That the following Resolutions be referred to the Council for consideration and action if it seem desirable:—

(1) That the Council be requested to take into their consideration the existing relations between the Kew Committee and the British Association.

That the full influence of the British Association for the Advancement of Science should at once be exerted to obtain the appointment of a Royal Commission to consider—

1. The character and value of existing institutions and facilities for scientific investigation, and the amount of time and money devoted to such purposes.
2. What modifications or augmentations of the means and facilities that are at present available for the maintenance and extension of science are requisite; and,
3. In what manner these can be best supplied.

(2) That Professor R. B. Clifton, Mr. Glaisher, the Master of the Mint, Mr. Huggins, Dr. Matthiessen, Professor W. Hallows Miller, Dr. Balfour Stewart, Lieut.-Col. Strange, and Sir J. Whitworth, be a Committee for the purpose of reporting on Metric Standards, in reference to the communication from Professor Jacobi, appended hereto; and that the Council be empowered to petition the British Government in the name of the Association if they judge it expedient to do so.

"The Academy of Sciences of St. Petersburgh, observing that the Standard Metric Weights and Measures of the various countries of Europe and of the United States differ by sensible, though small, quantities from one another, express the opinion that the continuance of these errors would be highly prejudicial to science. They believe that the injurious effects could not be guarded against by private labours, however meritorious, and they have therefore recommended that an International Commission be appointed by the countries interested, to deal with this matter. They have decided to bring the subject before the Russian Government, and have appointed a Committee of their own Body, who have drawn up a careful Report containing valuable suggestions; and they have deputed Professor Jacobi to lay this Report before the British Association, and to request the Association to take action in reference to it."

(3) That the Council be requested to ascertain whether the action of Government in relation to the higher scientific education has been in accordance with the principles of impartiality which were understood to guide them in this matter; and to consider whether that action has been well calculated to utilize and develope the resources of the country for this end, and to favour the free development of the higher scientific education. That the Council be requested to take such measures as may appear to them best calculated to carry out the conclusions to which they may be led by these inquiries and deliberations.

(4) That the rules under which Members are admitted to the General Committee be reconsidered.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Exeter Meeting in August 1869. The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.

	£	s.	d.
Kew Observatory.			
The Council.—Maintaining the Establishment of Kew Observatory	600	0	0
Mathematics and Physics.			
*Joule, Dr.—Remeasurement of the Dynamical Equivalent of Heat (renewed)	50	0	0
*Brooke, Mr.—British Rainfall	100	0	0
*Thomson, Professor Sir W.—Underground Temperature	50	0	0
Tait, Professor.—Thermal Conductivity of Iron and other Metals	20	0	0
*Thomson, Professor Sir W.—Tidal Observations	100	0	0
*Glaisher, Mr.—Luminous Meteors	30	0	0
Chemistry.			
*Matthiessen, Dr.—Chemical Nature of Cast Iron	80	0	0
*Grantham, Mr.—Treatment and Utilization of Sewage	50	0	0
Geology.			
*Lyell, Sir C., Bart.—Kent's-Cavern Exploration	150	0	0
*Duncan, Dr. P. M.—British Fossil Corals	50	0	0
*Woodward, Mr. H.—Sections of Mountain-Limestone Fossils	25	0	0
Symonds, Rev. W. S.—Sedimentary Deposits in the River Onny	3	0	0
*Bryce, Dr.—Earthquakes in Scotland (renewed)	4	0	0
*Huxley, Professor.—Kiltorcan Fossils, Kilkenny	20	0	0
*Mitchell, Mr. W. S.—Leaf-beds of the Lower Bagshot series	15	0	0
Biology.			
*Richardson, Dr.—Physiological Action of Organic Compounds	30	0	0
*Carruthers, Mr.—Fossil Flora of Britain	25	0	0
*Bate, Mr. Spence.—Marine Fauna of Devon and Cornwall	20	0	0
*Busk, Mr.—Record of the Progress of Zoology	100	0	0
Stewart, Mr. C.—Structure of the Ear in Fishes	10	0	0
Gamgee, Dr.—Heat generated in the Arterialization of Blood	15	0	0
Statistics and Economic Science.			
*Bowring, Sir J.—Metrical Committee	25	0	0
Total	£1572	0	0

* Reappointed.

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

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	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	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
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	0
Railway Sections	38	1	6
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	10	0	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
	£830	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 1839	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	3
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 1839	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 Instrument, Azores	25	0	0
	£354	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
	£1241	7	0

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	1
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

1855.

	£	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	0
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
Ethyle and Methyle 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

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following Meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing Meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

Members and Committees who are entrusted with sums of money for collecting specimens of Natural History are requested to reserve the specimens so obtained for distribution by authority of the Association.

In each Committee, the Member first named is the person entitled to call on the Treasurer, William Spottiswoode, Esq., 50 Grosvenor Place, London, S.W., for such portion of the sum 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 shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings.

On Wednesday Evening, August 18, at 8 P.M., in the Victoria Hall, Dr. Joseph Dalton Hooker, F.R.S., F.L.S., President, resigned the office of President to Professor G. G. Stokes, D.C.L., F.R.S., who took the Chair, and delivered an Address, for which see page lxxxix.

On Thursday Evening, August 19, at 8 P.M., a Soirée took place in the Albert Memorial Museum.

On Friday Evening, August 20, at 8.30 P.M., in the Victoria Hall, Prof. Phillips, LL.D., F.R.S., F.G.S., delivered a Discourse on "Vesuvius."

On Saturday Evening, August 21, in the Victoria Hall, Prof. W. A. Miller, M.D., F.R.S., delivered a Discourse on "Experimental Illustrations of the modes of determining the Composition of the Sun and Heavenly Bodies by the Spectrum" to the Operative Classes of Exeter.

On Monday Evening, August 23, at 8.30 P.M., in the Victoria Hall, J. Norman Lockyer, F.R.S., delivered a Discourse on the "Physical Constitution of the Stars and Nebulæ."

On Tuesday evening, August 24, at 8 P.M., a Soirée took place in the Albert Memorial Museum.

On Wednesday, August 25, at 2.30 P.M., 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 Liverpool*.

* The Meeting is appointed to take place on Wednesday, September 14, 1870.

ADDRESS

OF

GEORGE GABRIEL STOKES, M.A., Sec. R.S.,

D.C.L. OXON., LL.D. DUBLIN,

FELLOW OF PEMBROKE COLLEGE, AND LUCASIAN PROFESSOR OF MATHEMATICS IN THE UNIVERSITY OF CAMBRIDGE,

PRESIDENT.

My Lords, Ladies, and Gentlemen,

As this is the first time that the British Association for the Advancement of Science has met in the City of Exeter, and it is probable that many now present have never attended a former Meeting, I hope the older members of the Association will bear with me if I say a few words in explanation of the objects for which the Association was instituted. In the first place, then, it aims at fulfilling an office which is quite distinct from that of the various scientific societies which are established in different parts of the country. These, for the most part, have for their leading object to make the voluntary labours of isolated workers in science available to the scientific world generally by receiving, discussing, and publishing the results which they may have obtained. The British Association, on the other hand, aims at giving *a more systematic direction* to scientific inquiry, and that in various ways.

In a rapidly progressing branch of science it is by no means easy to become acquainted with its actual state. The workers in it are scattered throughout the civilized world, and their results are published in a variety of Transactions and scientific periodicals, mixed with other scientific matter. To make oneself, without assistance, well acquainted with what has been done, it is requisite to have access to an extensive library, to be able to read with facility several modern languages, and to have leisure to hunt through the tables of contents, or at least the indices, of a number of serial works. Without such knowledge, there is always the risk that a scientific man may spend his strength in doing over again what has been done already; whereas with better direction the same expenditure of time and labour might have resulted in some substantial addition to our knowledge. With a view to meet this difficulty, the British Association has requested individuals who were more specially conversant with particular departments of science, to draw up reports on the present state of our knowledge in, or on the recent progress of, special branches; and the influence of the Association as a public body has been found sufficient to induce a number of scientific men to undertake the great labour of preparing such reports.

By thus ascertaining thoroughly what we already had, what we still wanted was made more clear; and, indeed, it was one special object of the reports I have mentioned to point out what were the more prominent desiderata in the various subjects to which they related. The Association was thus the better enabled to fulfil another of its functions, that of organizing means for the prosecution of researches which require cooperation. When the want is within the compass of what can be accomplished by individuals, the demand may be left to create the supply; but it often happens that a research can hardly be carried out without cooperation. It may, for instance, require a combination of the most profound theoretical knowledge with the greatest experimental skill, or an extensive knowledge of very dissimilar branches of science; or, again, the work to be done, though all of one kind, may be of such an extent as to be beyond the power of any one man. In such cases the limited power of the individual can only be supplemented by the principle of cooperation; and accordingly it becomes an important part of the business of the Association to organize committees for the prosecution of special researches. The researches thus undertaken at the request of the Association are published at length, along with the reports on the progress of science, in the first part of the annual volume.

In close connexion with the last must be mentioned another mode in which the Association contributes to the progress of science. Many researches require not only time and thought, but pecuniary outlay; and it would seem hard that scientific men who give their time and labour gratuitously to carrying out such researches should be further obliged to incur an expenditure which they often can ill afford. The Association accordingly makes grants of money to individuals or Committees for defraying the expenses of such researches. It appears from the report which has just been published that, reckoning up to the year 1867 inclusive, the sum of £29,312 4*s*. 1*d*. has been voted by the Association for various scientific objects. Deducting from this the sum of £23 16*s*. 0*d*. for the balances of grants not wholly expended, which were returned to the Association, we may say that £29,288 8*s*. 1*d*. has been expended in the manner indicated. When we remember that these grants were mostly of small amount, and do not include personal expenses, and that very many of the researches undertaken at the request of the Association do not involve money grants at all, we may form some idea of the amount of scientific activity which has been evoked under the auspices of the Association.

In the address with which the business of the Meeting is opened, it is usual for your President to give some account of the most recent progress of science. The task is by no means an easy one. Few indeed are familiar with science in all its branches; and even to one who was, the selection of topics and the mode of treating them would still present difficulties. I shall not attempt to give an account of the recent progress of science in general, but shall select from those branches with which I am more familiar some examples of recent progress which may, I hope, prove to be of pretty general interest. And even in this I feel that I shall have to crave your indulgence, for it is hard to be intelligible to some without being wearisome to others.

Among the various branches of physical science, astronomy occupies in many respects a foremost rank. The movements of the heavenly bodies must have occupied the attention and excited the interest of mankind from the earliest ages, and accordingly the first rudiments of the science are lost in the depths of antiquity. The grandeur of the subjects of contemplation which it presents to us have won for it especial favour, and its importance in relation to navigation has caused it to be supported by national resources. Newton's great discovery of universal gravitation raised it from the rank of a science of observation to that of one admitting of the most exact mathematical deduction; and the investigation of the consequences of this law, and the explanation thereby of the lunar and planetary disturbances, have afforded a field for the exercise of the highest mathematical powers on the part of Newton and his successors. Gradually the apparent anomalies, as they might have been deemed, in the motions of the heavenly bodies were shown to be necessary consequences of the one fundamental law; and at last, as the result of calculations of enormous labour, tables were constructed enabling the places of those bodies at any given time to be determined years beforehand with astonishing precision. A still more striking step was taken. When it had been shown by careful calculation that the apparent motion of the remotest of the planets then known to belong to our system could not be wholly explained on the theory of gravitation, by taking account of the disturbing powers of the other known planets, Adams in our own country, and Le Verrier in France, boldly reversed the problem, and instead of determining the disturbing effect of a known planet, set themselves to inquire what must be the mass and orbit of an unknown planet which shall be capable of producing by its disturbing force the unexplained deviations in the position of Uranus from its calculated place. The result of this inquiry is too well known to require notice.

After these brilliant achievements, some may perhaps have been tempted to imagine that the field of astronomical research must have been well-nigh exhausted. Small perturbations, hitherto overlooked, might be determined, and astronomical tables thereby rendered still more exact. New asteroids might be discovered by the telescope. More accurate values of the constants with which we have to deal might be obtained. But no essential novelty of principle was to be looked for in the department of astronomy; for such we must go to younger and less mature branches of science.

Researches which have been carried on within the last few years, even the progress which has been made within the last twelve months, shows how short-sighted such an anticipation would have been; what an unexpected flood of light may sometimes be thrown over one science by its union with another; how conducive accordingly to the advancement of science may be an Association like the present, in which not only are the workers at special sciences brought together in the Sectional Meetings, but in the General Meetings of the Association, and in the social intercourse, which, though of an informal character, is no unimportant part of our procedings; the cultivators of different branches of science are brought together, and have an opportunity of enlarging their minds by contact with the minds of others, who have been used to trains of thought of a very different character from their own.

The science of astronomy is indebted to that of optics for the principles whch regulate the construction of those optical instruments which are so essential to the astronomer. It repaid its debt by furnishing to optics a result which it is important we should keep in view in considering the nature of light. It is to astronomy that we are indebted for the first proof we obtained of the finite velocity of light, and for the first numerical determination of that enormous velocity. Astronomy, again, led, forty-four years later, to a second determination of that velocity in the remarkable phenomenon of aberration discovered by Bradley, a phenomenon presenting special points of interest in relation to the nature of light, and which has given rise to some discussion, extending even to the present day, so that the Astronomer Royal has not deemed it unworthy of investigation, laborious as he foresees the trial is likely to prove, to determine the constant of aberration by means of a telescope having its tube filled with water.

If in respect of these phenomena optics received much aid from astronomy, the latter science has been indebted to the former for information which could not otherwise have been obtained. The motions and the masses of the heavenly bodies are revealed to us more or less fully by astronomical observations; but we could not thus become acquainted with the chemical nature of these distant objects. Yet, by the application of the spectroscope to the scrutiny of the heavenly bodies, evidence has been obtained of the existence therein of various elements known to us by the chemical examination of the materials of which our own earth is composed; and not only so, but light is thrown on the state in which matter is there existing, which, in the case of nebulæ especially, led to the formation of new ideas respecting their constitution, and the rectification of astronomical speculations previously entertained. I shall not, however, dwell further on this part of the subject, which is now of some years' standing, and has been mentioned by more than one of your former Presidents, but will pass on to newer researches in the same direction.

We are accustomed to apply to the stars the epithet *fixed*. Night after night they are seen to have the same relative arrangement; and when their places are determined by careful measurement, and certain small corrections due to known causes are applied to the immediate results of observation, they are found to have the same relative distances. But when instead of days the observations extend over months or years, it is found that the fixity is not quite absolute. Defining as fixity invariability of position as estimated with reference to the stars as a whole, and comparing the position of any individual star with those of the stars in its neighbourhood, we find that some of the stars exhibit "proper motions," show, that is, a progressive change of angular position as seen from the earth, or rather as they would be seen from the sun, which we may take for the mean annual place of the earth. This indicates linear motion in a direction transverse to the line joining the sun with the star. But since our sun is merely a star, a line drawn from the star exhibiting proper motion to our sun is, as regards the former, merely a line drawn to a star taken at random, and therefore there is no reason why the star's motion should be, except accidentally, in a direction perpendicular to the line joining the star with our sun. We must conclude that the stars, including our own sun, or some of them at least, are moving in various directions in space, and that it is merely the transversal component of the whole motion, or rather of the motion relatively to our sun, that is revealed to us by a change in the star's apparent place.

How then shall we determine whether any particular star is approaching to or receding from our sun? It is clear that astronomy alone is powerless to aid us here, since such a motion would be unaccompanied by change of angular position. Here the science of optics comes to our aid in a remarkable manner.

The pitch of a musical note depends, as we know, on the number of vibrations which reach the ear in a given time, such as a second. Suppose, now, that a body, such as a bell, which is vibrating a given number of times per second, is at the same time moving from the observer, the air being calm. Since the successive pulses of sound travel all with the velocity of sound, but diverge from different centres, namely, the successive points in the bell's path at which the bell was when those pulses were first excited, it is evident that the sound-waves will be somewhat more spread out on the side from which the bell is moving, and more crowded together on the side towards which it is moving, than if the bell had been at rest.

Consequently the number of vibrations per second which reach the ear of an observer situated in the former of these directions will be somewhat smaller, and the number which reach an observer situated in the opposite direction somewhat greater, than if the bell had been at rest. Hence to the former the pitch will be somewhat lower, and to the latter somewhat higher, than the natural pitch of the bell. And the same thing will happen if the observer be in motion instead of the bell, or if both be in motion; in fact, the effect depends only on the *relative* motion of the observer and the bell in the direction of a line joining the two,—in other words, on the velocity of recession or approach of the observer and the bell. The effect may be perceived in standing by a railway when a train in which the steam-whistle is sounding passes by at full speed, or better still, if the observer be seated in a train which is simultaneously moving in the opposite direction.

The present state of optical science is such as to furnish us with evidence, of a force which is perfectly overwhelming, that light consists of a tremor or vibratory movement propagated in an elastic medium filling the planetary and stellar spaces, a medium which thus fulfils for light an office similar to that of air for sound. In this theory, to difference of periodic time corresponds difference of refrangibility. Suppose that we were in possession of a source of light capable, like the bell in the analogous case of sound, of exciting in the æther supposed at rest vibrations of a definite period, corresponding, therefore, to light of a definite refrangibility. Then, just as in the case of sound, if the source of light and the observer were receding from or approaching to each other with a velocity which was not insensibly small compared with the velocity of light, an appreciable lowering or elevation of refrangibility would be produced, which would be capable of detection by means of a spectroscope of high dispersive power.

The velocity of light is so enormous, about 185,000 miles per second, that it can readily be imagined that any motion which we can experimentally produce in a source of light is as rest in comparison. But the earth in its orbit round the sun moves at the rate of about 18 miles per second; and in the motions of stars approaching to or receding from our sun we might expect to meet with velocities comparable with this. The orbital velocity of the earth is, it is true, only about the one ten-thousandth part of the velocity of light. Still the effect of such a velocity on the refrangibility of light, which admits of being easily calculated, proves not to be so insensibly small as to elude all chance of detection, provided only the observations are conducted with extreme delicacy.

But how shall we find in such distant objects as the stars an analogue of the bell which we have assumed in the illustration drawn from sound? What evidence can we ever obtain, even if an examination of their light should present us with rays of definite refrangibility, of the existence in those remote bodies of ponderable matter vibrating in known periods not identical with those corresponding to the refrangibilities of the definite rays which we observe? The answer to this question will involve a reference, which I will endeavour to make as brief as I can, to the splendid researches of Professor Kirchhoff. The exact coincidence of certain dark lines in the solar spectrum with bright lines in certain artificial sources of light had previously been in one or two instances observed; but it is to Kirchhoff we owe the inference from an extension of Prevost's theory of exchanges, that a glowing medium which emits bright light of any particular refrangibility *necessarily* (at that temperature at least) acts as an absorbing medium, extinguishing light of the same refrangibility. In saying this it is but just to mention that in relation to radiant heat (from whence the transition to light is easy), Kirchhoff was preceded, though unconsciously, by our own countryman Mr. Balfour Stewart. The inference which Kirchhoff drew from Prevost's theory thus extended led him to make a careful comparison of the places of the dark lines of the solar spectrum with those of bright lines produced by the incandescent gas or vapour of known elements; and the coincidences were in many cases so remarkable as to establish almost to a certainty the existence of several of the known elements in the solar atmosphere, producing by their absorbing action the dark lines coinciding with the bright lines observed. Among other elements may be mentioned in particular hydrogen, the spectrum of which, when the gas is traversed by an electric discharge, shows a bright line or band exactly coinciding with the dark line C, and another with the line F.

Now Mr. Huggins found that several of the stars show in their spectra dark lines coinciding in position with C and F; and what strengthens the belief that this coincidence, or apparent coincidence, is not merely fortuitous, but is due to a common cause, is that the two lines are found associated together, both present or both absent. And Kirchhoff's theory suggests that the common cause is the existence of hydrogen in the atmospheres of the sun and certain stars, and its exercise of an absorbing action on the light emitted from beneath.

Now by careful and repeated observations with a telescope furnished with a spectroscope of high dispersive power, Mr. Huggins found that the F line, the one selected for observation, in the spectrum of Sirius did not exactly coincide with the corresponding bright line of a hydrogen spark, which latter agrees in position with the solar F, but was a *little* less refrangible, while preserving the same general appearance. What conclusion, then, are we to draw from the result? Surely it would be most unreasonable to attribute the dark lines in the spectra of the sun and of Sirius to distinct causes, and to regard their almost exact coincidence as purely fortuitous, when we have in proper motion a *vera causa* to account for a minute difference. And if, as Kirchhoff's labours render almost certain, the dark solar line depends on the existence of hydrogen in the atmosphere of our sun, we are led to infer that that element, with which the chemist working in his laboratory is so familiar, exists and is subject to the same physical laws in that distant star, so distant, that, judging by the most probable value of its annual parallax, light which would go seven times round our earth in one second would take fourteen years to travel from the star. What a grand conception of the unity of plan pervading the universe do such conclusions present to our minds!

Assuming, then, that the small difference of refrangibility observed between the solar F and that of Sirius is due to proper motion, Mr. Huggins concludes from his measures of the minute difference of position that at the time of the observation Sirius was receding from the earth at the rate of 41·4 miles per second. A part of this was due to the motion of the earth in its orbit; and on deducting the orbital velocity of the earth, resolved in the direction of a line drawn from the star, there remained 29·4 miles per second as the velocity with which Sirius and our sun are mutually receding from each other. Considering the minuteness of the quantity on which the result depends, it is satisfactory to find that Mr. Huggins's results as to the motion of Sirius have been confirmed by the observations of Father Secchi made at Rome with a different instrument.

The determination of radial proper motion in this way is still in its infancy. It is worthy of note that, unlike the detection of transversal proper motion by change of angular position, it is equally applicable to stars at all distances, provided they are bright enough to render the observations possible. It is conceivable that the results of these observations may one day lead to a determination of the motion of the solar system in space, which is more trustworthy than that which has been deduced from changes of position, as being founded on a broader induction, and not confined to conclusions derived from the stars in our neighbourhood. Should even the solar system and the nearer stars be drifting along, as Sir John Herschel suggests, with an approximately common motion, like motes in a sunbeam, it is conceivable that the circumstance might thus be capable of detection. To what wide speculations are we led as to the possible progress of our knowledge when we put together what has been accomplished in different branches of science!

I turn now to another recent application of spectral analysis. The phenomenon of a total solar eclipse is described by those who have seen it as one of the most imposing that can be witnessed. The rarity of its occurrence and the shortness of its duration afford, however, opportunity for only a hasty study of the phenomena which may then present themselves. Among these, one of the most remarkable, seen indeed before, but first brought prominently into notice by the observers who watched the eclipse of July 7, 1842, consists in a series of mountain-like or cloud-like luminous objects seen outside the dark disk of the moon. These have been seen in subsequent total eclipses, and more specially studied, by means of photography, by Mr. Warren De La Rue in the eclipse of June 18, 1860. The result of the various observations, and especially the study, which could be made at leisure, of the photographs obtained by Mr. De La Rue, proved conclusively that these appendages belong to the sun, not to the moon. The photographs proved further their light to be remarkable for actinic power. Since that time the method of spectral analysis has been elaborated; and it seemed likely that additional information bearing on the nature of these objects might be obtained by the application of the spectroscope. Accordingly various expeditions were equipped for the purpose of observing the total solar eclipse which was to happen on August 17, 1868. In our own country an equatorially mounted telescope provided with a spectroscope was procured for the purpose by the Royal Society, which was entrusted to Lieut. (now Captain) Herschel, who was going out to India, one of the countries crossed by the line of the central shadow. Another expedition was organized by the Royal Astronomical Society, under the auspices of Major Tennant, who was foremost in pressing on the attention of scientific men the importance of availing themselves of the opportunity.

Shortly before the conclusion of the Meeting of the Association at Norwich last year, the first results of the observations were made known to the Meeting through the agency of the electric telegraph. In a telegram sent by M. Janssen to the President of the Royal Society, it was announced that the spectrum of the prominences was very remarkable, showing bright lines, while that of the corona showed none. Brief as the message necessarily was, one point was settled. The prominences could not be clouds in the strict sense of the term, shining either by virtue of their own heat, or by light reflected from below. They must consist of incandescent matter in the *gaseous* form. It appeared from the more detailed accounts received by post from the various observers, and put together at leisure, that except in the immediate neighbourhood of the sun the light of the prominences consisted mainly of three bright lines, of which two coincided, or nearly so, with C and F, and the intermediate one nearly, but, as subsequent researches showed, not exactly, with D. The bright lines coinciding with C and F indicate the presence of glowing hydrogen.

This is precious information to have gathered during the brief interval of the total phase, and required on the part of the observers self-denial in withdrawing the eye from the imposing spectacle of the surrounding scenery, and coolness in proceeding steadily with some definite part of the inquiry, when so many questions crowded for solution, and the fruits of months of preparation were to be reaped in three or four minutes or lost altogether; especially when, as too often happened, the observations were provokingly interrupted by flying clouds.

But valuable as these observations were, it is obvious that we should have had long to wait before we could have became acquainted with the usual behaviour of these objects, and their possible relation to changes which may be going on at the surface of the sun, if we had been dependent on the rare and brief phenomenon of a total solar eclipse for gathering information respecting them. But how, the question might be asked, shall we ever be able so to subdue the overpowering glare of our great luminary, and the dazzling illumination which it produces in our atmosphere when we look nearly in its direction, as to perceive objects which are comparatively so faint? Here again the science of optics comes in aid of astronomy.

When a line of light, such as a narrow slit held in front of a luminous object, is viewed through a prism, the light is ordinarily spread out into a coloured band, the length of which may be increased at pleasure by substituting two or more prisms for the single prism. As the total quantity of light is not thereby increased, it is obvious that the intensity of the light of the coloured band will go on decreasing as the length increases. Such is the case with ordinary sources of light, like the flame of a candle or the sky, which give a continuous spectrum, or one generally continuous, though interrupted by dark bands. But if the light from the source be homogeneous, consisting, that is, of light of one degree of refrangibility only, the image of the slit will be merely deviated by the prisms, not widened out into a band, and not consequently reduced in intensity by the dispersion. And if the source of light emit light of both kinds, it will be easily understood that the images of the slit corresponding to light of any definite refrangibilities which the mixture may contain will stand out, by their superior intensity, on the weaker ground of the continuous spectrum.

Preparations for observations of the kind had long been in progress in the hands of our countryman Mr. Lockyer. His first attempts were unsuccessful: but undismayed by failure, he ordered the construction of a new spectroscope of superior power, in which he was aided by a grant from the sum placed annually by Parliament at the disposal of the Royal Society for scientific purposes. The execution of this instrument was delayed by what proved to be the last illness of the eminent optician to whom it had been in the first instance entrusted, the late Mr. Cooke; but when at last the instrument was placed in his hands, Mr. Lockyer was not long in discovering the object of his two years' search. On the 20th of October last year, in examining the space immediately surrounding the edge of the solar disk, he obtained evidence, by the occurrence of a bright line in the spectrum, that his slit was on the image of one of those prominences, the nature of which had so long been an enigma. It further appeared from an observation made on November 5 (as indeed might be expected from the photographs of Mr. De La Rue, and the descriptions of those who had observed total solar eclipses) that the prominences were merely elevated portions of an extensive luminous stratum of the same general character, which, now that the necessity of the interposition of the moon was dispensed with, could be traced completely round the sun. Notices of this discovery were received from the author by the Royal Society on October 21 and November 3, and the former was almost immediately published in No. 105 of the Proceedings. These were shortly afterwards followed by a fuller paper on the same subject.

Meanwhile the same thing had been independently observed in another part of the world. After having observed the remarkable spectrum of the prominences during the total eclipse, it occurred to M. Janssen that the same method might allow the prominences to be detected at any time; and on trial he succeeded in detecting them the very day after the eclipse. The results of his observations were sent by post, and were received shortly after the account of Mr. Lockyer's discovery had been communicated by Mr. De La Rue to the French Academy.

In the way hitherto described a prominence is not seen as a whole, but the observer knows when its image is intercepted by the slit; and by varying a little the position of the slit a series of sections of the prominence are obtained, by putting which together the form of the prominence is deduced. Shortly after Mr. Lockyer's communication of his discovery, Mr. Huggins, who had been independently engaged in the attempt to render the prominences visible by the aid of the spectroscope, succeeded in seeing a prominence as a whole by somewhat widening the slit, and using a red glass to diminish the glare of the light admitted by the slit, the prominence being seen by means of the C line in the red. Mr. Lockyer had a design for seeing the prominences as a whole by giving the slit a rapid motion of small extent, but this proved to be superfluous, and they are now habitually seen with their actual forms. Nor is our power of observing them restricted to those which are so situated that they are seen by projection outside the sun's limb; such is the power of the spectroscopic method of observation that it has enabled Mr. Lockyer and others to observe them right on the disk of the sun, an important step for connecting them with other solar phenomena.

One of the most striking results of the habitual study of these prominences is the evidence they afford of the stupendous changes which are going on in the central body of our system. Prominences the heights of which are to be measured by thousands and tens of thousands of miles, appear and disappear in the course of some minutes. And a study of certain minute changes of position in the bright line F, which receive a simple and natural explanation by referring them to proper motion in the glowing gas by which that line is produced, and which we see no other way of accounting for, have led Mr. Lockyer to conclude that the gas in question is sometimes travelling with velocities comparable with that of the earth in its orbit. Moreover these exhibitions of intense action are frequently found to be intimately connected with the spots, and can hardly fail to throw light on the disputed question of their formation. Nor are chemical composition and proper motion the only physical conditions of the gas which are accessible to spectral analysis. By comparing the breadth of the bright bands (for though narrow they are not mere lines) seen in the prominences with those observed in the spectrum of hydrogen rendered incandescent under different physical conditions, Dr. Frankland and Mr. Lockyer have deduced conclusions respecting the pressure to which the gas is subject in the neighbourhood of the sun. I am happy to say that Mr. Lockyer has consented to deliver a discourse during our Meeting, in which the whole subject will doubtless be fully explained.

I have dwelt perhaps too long on this topic, and I cannot help fearing that

I may have been tedious to the many scientific men to whom the subject is already perfectly familiar. Yet the contemplations which it opens out to us are so exalted, and the proof which it affords of what can be accomplished by the union of different branches of science is so striking, that I hope I may be pardoned for occupying your time. I cannot, however, leave the subject of Astronomy without congratulating the Association on the accomplishment of an object which originated with it, and in the promotion of which it formerly took an active part. It was at the Meeting of the Association at Birmingham in 1849, under the presidency of the Rev. Dr. Robinson, that a resolution was passed for making an application to Her Majesty's Government to establish a reflector of not less than three feet aperture at the Cape of Good Hope, and to make such additions to the staff of that observatory as might be necessary for its effectual working. This resolution met with the hearty concurrence of the President of the Council of the Royal Society, who suggested that the precise locality in the Southern hemisphere where the telescope should be erected had best be left an open question. This modification having been adopted by your Council, the application was presented to Earl Russell, then First Lord of the Treasury, by representatives of both bodies early in 1850. A reply was received from Government to the effect that though they agreed with the Association as to the interest which attached itself to the inquiry, yet there was so much difficulty attending the arrangements that they were not prepared to take any steps without much further enquiry. This reply was considered so far favourable as not to forbid the hope of success if the application were renewed on a suitable opportunity. The subject was again brought before the Association by Colonel (now General Sir Edward) Sabine, in his opening address as President at the Belfast Meeting in 1852. The result was that the matter was again brought before Government by a Committee of the British Association acting in conjunction with a Committee of the Royal Society, by means of an application made to the Earl of Aberdeen. By this time the country was engaged in the Russian war, in consequence of which, it was replied, no funds could then be spared; but a promise was given that when the crisis then impending was past, the matter should be taken up, a promise which the retirement from office and subsequent death of Lord Aberdeen rendered of no avail.

But though failing in its immediate object, the action of the British Association in this matter has not remained fruitless. A few years later the subject was warmly taken up at Melbourne, and after preliminary correspondence between the Board of Visitors of the Melbourne Observatory and the President and Council of the Royal Society, and the appointment by the latter body of a Committee to consider and report on the subject, in April 1864 a proposition was made to the Colonial Legislature for a grant of £5000 for the construction of a telescope, and was acceded to. Not to weary you with details, I will merely say that the telescope has been constructed by Mr. Grubb, of Dublin, and is now erected at Melbourne, and in the hands of Mr. Le Sueur, who has been appointed to use it. It is a reflector of four feet aperture, of the Cassegrain construction, equatorially mounted, and provided with a clock-movement. Before its shipment, it was inspected in Dublin by the Committee appointed by the Royal Society to consider the best mode of carrying out the object for which the vote was made by the Melbourne Legislature; and the Committee speak in the highest terms of its contrivance and execution. We may expect before long to get a first instalment of the results obtained by a scrutiny of the southern heavens with an instrument far more powerful than any that has hitherto been applied to them—results which will at the same time add to our existing knowledge and redound to the honour of the Colony, by whose liberality this long-cherished object has at last been effected.

As I have mentioned an application to the Government on the part of the Association which was not successful, it is but right to say that such is not generally the result; I will refer to one instance. At the Cambridge Meeting of the Association in 1862, a Committee, consisting of representatives of the Mechanical and Chemical Sections, was appointed for the purpose of investigating the application of gun-cotton to warlike purposes. At the Newcastle Meeting, in the following year, this Committee presented their Report. It was felt that a complete study of the subject demanded appliances which could be obtained only from our military resources, and at the Newcastle Meeting a resolution was passed recommending the appointment of a Royal Commission. This recommendation was adopted, and in 1864 a Commision was appointed, which was requested to report on the application of gun-cotton to Civil as well as to Naval and Military purposes. The Committee gave in their report last year, and that report, together with a more recent return relative to the application of gun-cotton to mining and quarrying operations, has just been printed for the House of Commons.

A substance of such comparatively recent introduction cannot be fairly compared with an explosive in the use of which we have the experience of centuries. Yet, even with our present experience, there are some purposes for which gun-cotton can advantageously replace gunpowder, while its manufacture and storage can be effected with comparative safety, since it is in a wet state during the process of manufacture, and is not at all injured by being kept permanently in water, but merely requires to be dried for use. Even should it be required to store it in the dry state, it is doubtful whether, with the precautions indicated by the chemical investigations of Mr. Abel, any greater risk is incurred than in the case of gunpowder. In the blasting of hard rocks it is found to be highly efficient, while the remarkable results recently obtained by Mr. Abel leave no doubt of its value for explosions such as are frequently required in warfare. General Hay speaks highly of the promise of its value for small arms; but many more experiments are required, especially as a change in the arm and mode of ignition require a change in the construction of the cartridge. In heavy ordnance, the due control of the rapidity of combustion of the substance is a matter of greater difficulty; and, though considerable progress has been made, much remains to be done before the three conditions of safety to the gun, high velocity of projection, and uniformity of result, are satisfactorily combined.

By the kindness of Dr. Carpenter, I am enabled to mention to you the latest results obtained in an expedition which could not have been undertaken without the aid of Government, an aid which was freely given. Last year Dr. Carpenter and Professor Wyville Thomson represented to the President and Council of the Royal Society the great importance to Zoology and Palæontology of obtaining soundings from great depths in the ocean, and suggested to them to use their influence with the Admiralty to induce them to place a gun-boat, or other suitable vessel, at the disposal of those gentlemen and any other naturalists who might be willing to accompany them for the purpose of carrying on a systematic course of deep-sea dredging for a month or six weeks. This application was forwarded to the Admiralty with the warm support of the President and Council, and was readily acceded to. The operations were a good deal impeded by rough weather, but nevertheless important results were obtained. Dredging was successfully accomplished at a depth of 650 fathoms; and the existence was established of a varied and abundant submarine Fauna, at depths which had generally been supposed to be either azoic, or occupied by animals of a very low type; and the character of the Fauna and of the mud brought up was such as to point to a chalk formation actually going on.

It seemed desirable to carry the soundings to still greater depths, and to examine more fully the changes of temperature which had been met with in the descent. Another application was accordingly made to the Admiralty in the present year, and was no less readily acceded to than the former; and a larger vessel than that used last year is now on her cruize. I am informed by Dr. Carpenter that dredging has been successfully carried down to more than 2400 fathoms (nearly the height of Mont Blanc), and that animal life has been found even at that depth in considerable *variety*, though its *amount* and *kind* are obviously influenced by the reduction of temperature to Arctic coldness. A very careful series of temperature soundings has been taken, showing, on the same spot, a continuous descent of temperature with the depth, at first more rapid, afterwards pretty uniform. Thermometers protected from pressure by a plan devised by Dr. Miller were found to maintain their character at the great depths reached, the difference between them and the best ordinary thermometers used in the same sounding being exactly conformable to the pressure corresponding with each depth, as determined by the experiments previously made in smaller depths. All the observations hitherto made go to confirm the idea of a general interchange of polar and equatorial water, the former occupying the lowest depths, the latter forming a superficial stratum of 700 or 800 fathoms. The analyses of the water brought up indicate a large proportion of carbonic acid in the gases of the deep waters, and a general diffusion of organic matter.

I must turn for a few moments to another application recently made to Government, which has not been successful. The application I have in view was made, not by the British Association or other Scientific Societies in their corporate capacity, but by a body composed of the Presidents of the British Association and of the Royal and other leading Scientific Societies; and its object was, not the promotion of Science directly, but the recognition of preeminent scientific merit. In the history of science few names, indeed, hold so prominent a place as that of Faraday. The perfect novelty of principle and recondite nature of many of his great discoveries are such as to bear the impress of genius of the highest order, and to form an epoch in the advance of science; and while his scientific labours excited the admiration of men of science throughout the world, his singularly genial disposition, and modest unassuming character, won for him the love of those who had the happiness of numbering him among their personal friends. At a meeting of the Presidents of the Scientific Societies to which I have alluded, it was resolved to erect a statue in memory of Faraday. He was a man of whom England may well be proud, and it was thought that it would be a graceful recognition of his merits if the monument were erected at the public expense. The present Chancellor of the Exchequer, however, did not think it right that the recognition of scientific merit, however eminent, should fall on the taxation of the country, though even in a pecuniary point of view the country has received so much benefit from the labours of scientific men. The carrying out of the resolution being thus left to private exertion, a public meeting, presided over by H.R.H. the Prince of Wales, was held in the Royal Institution, an establishment which has the honour of being identified with Faraday's scientific career. At this Meeting a Committee was formed to carry out the object, and a subscription list commenced. By permission of the Secretaries of this Association, an office has been opened in the reception-room, where those Members of the Association who may be desirous of taking part in the movement will have every facility afforded them.

In chemistry, I do not believe that any great step has been made within the last year; but perhaps there is no science in which an earnest worker is so sure of being rewarded by making some substantial acquisition to our knowledge, though it may not be of the nature of one of those grand discoveries which from time to time stamp their impress on different branches of science. I may be permitted to refer to one or two discoveries which are exceedingly curious, and some of which may prove of considerable practical importance.

The Turaco or Plantain-eater of the Cape of Good Hope is celebrated for its beautiful plumage. A portion of the wings is of a fine red colour. This red colouring-matter has been investigated by Professor Church, who finds it to contain nearly six per cent. of copper, which cannot be distinguished by the ordinary tests, nor removed from the colouring-matter without destroying it. The colouring-matter is in fact a natural organic compound of which copper is one of the essential constituents. Traces of this metal had previously been found in animals, for example, in oysters, to the cost of those who partook of them. But in these cases the presence of the copper was merely accidental; thus oysters that lived near the mouths of streams which came down from copper-mines assimilated a portion of the copper salt, without apparently its doing them either good or harm. But in the Turaco the existence of the red colouring-matter which belongs to their normal plumage is dependent upon copper, which, obtained in minute quantities with the food, is stored up in this strange manner in the system of the animal. Thus in the very same feather, partly red and partly black, copper was found in abundance in the red parts, but none or only the merest trace in the black.

This example warns us against taking too utilitarian a view of the plan of creation. Here we have a chemical substance elaborated which is perfectly unique in its nature, and contains a metal the salts of which are ordinarily regarded as poisonous to animals; and the sole purpose to which, so far as we know, it is subservient in the animal economy is one of pure decoration. Thus a pair of the birds which were kept in captivity lost their fine red colour in the course of a few days, in consequence of washing in the water which was left them to drink, the red colouring-matter, which is soluble in water, being thus washed out; but except as to the loss of their beauty it does not appear that the birds were the worse for it.

A large part of the calicos which are produced in this country in such enormous quantities are sent out into the market in the printed form. Although other substances are employed, the place which madder occupies among dye-stuffs with the calico-printer is compared by Mr. Schunck to that which iron occupies among metals with the engineer. It appears from the public returns that upwards of 10,000 tons of madder are imported annually into the United Kingdom. The colours which madder yields to mordanted cloth are due to two substances, alizarine and purpurine, derived from the root. Of these, alizarine is deemed the more important, as producing faster colours, and yielding finer violets. In studying the transformations of alizarine under the action of chemical reagents, MM. Graebe and Liebermann were led to connect it with anthracene, one of the coal-tar series of bodies, and to devise a mode of forming it artificially. The discovery is still too recent to allow us to judge of the cost with which it can be obtained by artificial formation, which must decide the question of its commercial employment. But assuming it to be thus obtained at a sufficiently cheap rate, what a remarkable example does the discovery afford of the way in which the philosopher quietly working in his laboratory may obtain results which revolutionize the industry of nations! To the calico-printer indeed it may make no very important difference whether he continues to use madder, or replaces it by the artificial substance; but what a sweeping change is made in the madder-growing interest! What hundreds of acres hitherto employed in madder-cultivation are set free for the production of human food, or of some other substance useful to man! Such changes can hardly be made without temporary inconvenience to those who are interested in the branches of industry affected; but we must not on that account attempt to stay the progress of discovery, which is conducive to the general weal.

Another example of the way in which practical applications unexpectedly turn up when science is pursued for its own sake is afforded by a result recently obtained by Dr. Matthiessen, in his investigation of the constitution of the opium bases. He found that by the action of hydrochloric acid on morphia a new base was produced, which as to composition differed from the former merely by the removal of one equivalent of water. But the physiological action of the new base was utterly different from that of the original one. While morphia is a powerful narcotic, the use of which is apt to be followed by subsequent depression, the new base was found to be free from narcotic properties, but to be a powerful emetic, the action of which was unattended by injurious after-effects. It seems likely to become a valuable remedial agent.

In relation to mechanism, this year is remarkable as being the centenary of the great invention of our countryman James Watt. It was in the year 1769 that he took out his patent involving the invention of separate condensation, which is justly regarded as forming the birth of the steam-engine. Little could even his inventive mind have foreseen the magnitude of the gift he was conferring on mankind in general, and on his own country more particularly. In these days of steamers, power-looms, and railways, it requires no small effort to place ourselves in imagination in the condition we should be in without the steam-engine. It needs no formal celebration to remind Britons of what they owe to Watt. Of him truly it may be said "*si monumentum requiras circumspice.*"

With reference to those branches of science in which we are more or less concerned with the phenomena of life, my own studies give me no right to address you. I regret this the less because my predecessor and my probable successor in the Presidential Chair are both of well-known eminence in this department. But I hope I may be permitted as a physicist, and viewing the question from the physical side, to express to you my views as to the relation which the physical bear to the biological sciences.

No other physical science has been brought to such perfection as mechanics; and in mechanics we have long been familiar with the idea of the perfect generality of its laws, of their applicability to bodies organic as well as inorganic, living as well as dead. Thus in a railway collision when a train is suddenly arrested the passengers are thrown forward, by virtue of the inertia of their bodies, precisely according to the laws which regulate the motion of dead matter. So trite has the idea become that the reference to it may seem childish; but from mechanics let us pass on to chemistry, and the case will be found by no means so clear. When chemists ceased to be content with the mere ultimate analysis of organic substances, and set themselves to study their proximate constituents, a great number of definite chemical compounds were obtained which could not be formed artificially. I do not know what may have been the usual opinion at that time among chemists as to their mode of formation. Probably it may have been imagined that chemical affinities were indeed concerned in their formation, but controlled and modified by an assumed vital force. But as the science progressed many of these organic substances were formed artificially, in some cases from other and perfectly distinct organic substances, in other cases actually from their elements. This statement must indeed be accepted with one qualification. It was stated several years ago by M. Pasteur, and I believe the statement still remains true, that no substance the solution of which possesses the property of rotating the plane of polarization of polarized light had been formed artificially from substances not possessing that property. Now several of the natural substances which are deemed to have been produced artificially are active, in the sense of rotating the plane of polarization; and therefore in these cases the inactive, artificial substances cannot be absolutely identical with the natural ones. But the inactivity of the artificial substance is readily explained on the supposition that the artificial substance bears to the natural, the same relation as racemic acid bears to tartaric,—that it is, so to speak, a mixture of the natural substance with its image in a mirror. And when we remember by what a peculiar and troublesome process M. Pasteur succeeded in separating racemic acid into the right-handed and left-handed tartaric acids, it will be at once understood how easily the fact, if it be a fact, of the existence in the natural substance of a mixture of two substances, one right-handed and the other left-handed, but otherwise identical, may have escaped detection. This is a curious point, to the clearing up of which it is desirable that chemists should direct their attention. Waiving then the difference of activity or inactivity, which, as we have seen, admits of a simple physical explanation, though the correctness of that explanation remains to be investigated, we may say that at the present time a considerable number of what used to be regarded as essentially natural organic substances have been formed in the laboratory. That being the case, it seems most reasonable to suppose that in the plant or animal from which those organic substances were obtained they were formed by the play of ordinary chemical affinity, not necessarily nor probably by the same series of reactions by which they were formed in the laboratory, where a high temperature is commonly employed, but still by chemical reactions of some kind, under the agency in many cases of light, an agency sometimes employed by the chemist in his laboratory. And since the boundary line between the natural substances which have and those which have not been formed artificially is one which, so far as we know, simply depends upon the amount of our knowledge, and is continually changing as new processes are discovered, we are led to extend the same reasoning to the various chemical substances of which organic structures are made up.

But do the laws of chemical affinity, to which, as I have endeavoured to infer, living beings, whether vegetable or animal, are in absolute subjection, together with those of capillary attraction, of diffusion, and so forth, account for the formation of an organic structure, as distinguished from the elaboration of the chemical substances of which it is composed? No more, it seems to me, than the laws of motion account for the union of oxygen and hydrogen to form water though the ponderable matter so uniting is subject to the laws of motion during the act of union, just as well as before and after. In the various processes of crystallization of precipitation, and so forth, which we witness in dead matter, I cannot see the faintest shadow of an approach to the formation of an organic structure, still less to the wonderful series of changes which are concerned in the growth and perpetuation of even the lowliest plant. Admitting to the full as highly probable, though not completely demonstrated, the applicability to living beings of the laws which have been ascertained with reference to dead matter, I feel constrained at the same time to admit the existence of a mysterious *something* lying beyond,—a something *sui generis*, which I regard, not as balancing and suspending the ordinary physical laws, but as working with them and through them to the attainment of a designed end.

What this *something*, which we call life, may be, is a profound mystery. We know not how many links in the chain of secondary causation may yet remain behind; we know not how few. It would be presumptuous indeed to assume in any case that we had already reached the last link, and to charge with irreverence a fellow-worker who attempted to push his investigations yet one step further back. On the other hand, if a thick darkness enshrouds all beyond, we have no right to assume it to be impossible that we should have reached even the last link of the chain; a stage where further progress is unattainable, and we can only refer the highest law at which we stopped to the fiat of an Almighty Power. To assume the contrary as a matter of necessity, is practically to remove the First Cause of all to an infinite distance from us. The boundary, however, between what is clearly known and what is veiled in impenetrable darkness is not ordinarily thus sharply defined. Between the two there lies a misty region, in which loom the ill-discerned forms of links of the chain which are yet beyond us. But the general principle is not affected thereby. Let us fearlessly trace the dependence of link on link as far as it may be given us to trace it, but let us take heed that in thus studying second causes we forget not the First Cause, nor shut our eyes to the wonderful proofs of design which, in the study of organized beings especially, meet us at every turn.

Truth we know must be self-consistent, nor can one truth contradict another, even though the two may have been arrived at by totally different processes, in the one case, suppose, obtained by sound scientific investigation, in the other case taken on trust from duly authenticated witnesses. Misinterpretations of course there may be on the one side or on the other, causing *apparent* contradictions. Every mathematician knows that in his private work he will occasionally by two different trains of reasoning arrive at discordant conclusions. He is at once aware that there must be a slip somewhere, and sets himself to detect and correct it. When conclusions rest on probable evidence, the reconciling of apparent contradictions is not so simple and certain. It requires the exercise of a calm, unbiassed judgment, capable of looking at both sides of the question; and oftentimes we have long to suspend our decision, and seek for further evidence. None need fear the effect of scientific inquiry carried on in an honest, truth-loving, humble spirit, which makes us no less ready frankly to avow our ignorance of what we cannot explain than to accept conclusions based on sound evidence. The slow but sure path of induction is open to us. Let us frame hypotheses if we will: most useful are they when kept in their proper place, as stimulating inquiry. Let us seek to confront them with observation and experiment, thereby confirming or upsetting them as the result may prove; but let us beware of placing them prematurely in the rank of ascertained truths, and building further conclusions on them as if they were.

When from the phenomena of life we pass on to those of mind, we enter a region still more profoundly mysterious. We can readily imagine that we *may* here be dealing with phenomena altogether transcending those of mere life, in some such way as those of life transcend, as I have endeavoured to infer, those of chemistry and molecular attractions, or as the laws of chemical affinity in their turn transcend those of mere mechanics. Science can be expected to do but little to aid us here, since the instrument of research is itself the object of investigation. It can but enlighten us as to the depth of our ignorance, and lead us to look to a higher aid for that which most nearly concerns our wellbeing.

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REPORTS

ON

THE STATE OF SCIENCE.

Report of a Committee appointed at the Nottingham Meeting, 1866, *for the purpose of Exploring the Plant-beds of North Greenland, consisting of* Mr. Robert H. Scott, Dr. Hooker, Mr. E. H. Whymper, Dr. E. P. Wright, *and* Sir W. C. Trevelyan, *Bart.**

In their preliminary Report, which was presented to the Association at the last Meeting, the Committee stated that the sum voted by the Association had been handed over to Mr. Edward Whymper, one of their members, who was in Greenland at the time of the Meeting.

In the course of the autumn he returned to England, bringing his collection of fossil plants with him.

The Committee then resolved to forward the entire collection to Prof. Heer, at Zurich, for the purposes of identification and description, and they accordingly made application to the Government-Grant Committee of the Royal Society for a grant of money to pay for the carriage of the specimens to and from Zurich.

The Government-Grant Committee, who had formerly assisted the expedition to Greenland by a most liberal grant of money, at once acceded to the second application, and the fossils were sent to Switzerland in the course of last spring (1868).

As soon as they are sent back, a complete series of the specimens will be forwarded to the British Museum, in accordance with the conditions laid down by the Association at the time the money was voted.

The Committee append hereto Mr. Whymper's Report of his journey, and a notice forwarded by Prof. Heer, giving an account of the most important results obtained by this expedition.

Report of Proceedings to obtain a Collection of Fossil Plants in North Greenland for the Committee of the British Association. By Edward Whymper.

July 1868.

Sir,—I arrived at the Colony of Jakobshavn, North Greenland, on the 16th of June, 1867, but was unable to start for Atanekerdluk, distant northwards about sixty English miles, before August the 19th. In the meantime I purchased the only boat that could be spared, and obtained as much infor-

* Read at the Norwich Meeting, 1868.

mation as possible from the Danes and from the natives respecting the localities we were about to visit. From the information so obtained, it was evident that the fossil stores on the hill of Atanekerdluk had already been well ransacked, and that we could not hope to meet with any great novelties in that direction. I obtained, however, some amber, through the natives, from a locality on Disco Island, which had not been examined, and heard of two other places where fossil wood had been discovered. These places, Ujarasuksumitok and Kudliset, are described at length further on. I also secured by purchase several specimens from Atanekerdluk, and a few fossil shells from Paitorfik in the district of Umenak *.

We were ready to start by the middle of August, but the natives on whom we had relied for a crew preferred to go south, to a dance at Claushavn; and it was owing to the kindness of the trader at Jakobshavn, who gave us a passage in a blubber-boat returning to Ritenbenk, that we were at length enabled to start on our journey. We got to Ritenbenk at 1.30 A.M. on the 20th of August, and in spite of the inconvenient hour at which we arrived, were received with the greatest warmth and hospitality by Mr. Anderson. On the evening of the same day we again started; this time with a strong force, by the advice of Mr. Anderson, the trader. There were now with me two boats, one hired at Ritenbenk, eleven native men and women, and Messrs. Brown and Tegner (naturalist and interpreter). I tried hard to engage the natives to go as far as Umenak, but failed to get them to promise to go further than Atanekerdluk.

We started at 10.30 P.M., and our course soon took us into the midst of the Tossukatek ice-stream, a great assemblage of icebergs large and small, which were given off from a glacier whose summit we could just see on the horizon. This ice-stream was remarkable for the enormous number of icebergs it contained, and was also notable for the small amount of moraine matter upon them. Really large blocks of rock we did not see, and those of a yard in diameter were rare; but there was abundance of small stones, of grit, and of sand upon the bergs. There is no doubt that beneath the course of the Tossukatek ice-stream, as below all others †, there are conglomerate strata in course of formation, which cannot now be seen, but which may possibly be presented to the view of future travellers.

Shortly after passing through this ice-stream we arrived at the small settlement of Sakkak ‡. This place stands by the water's edge at the entrance of a great valley running into the heart of the Noursoak peninsula. A considerable river that flows down this valley falls into the sea a little to the north of the settlement, and appears to form the boundary line of the granite districts which we were just quitting, and the trap formation upon which we were just entering.

A solitary Danish man lives at this place, and has done so for twenty-

* Astarte sulcata, *Costa.*	Mya truncata, *Fabr.*
—— crebricostata, *Forbes.*	Cardium —— ?
—— elliptica, *Brown.*	

† On the voyage up Davis Straits we were becalmed off Rifkol, a noted landmark, and anchored on some banks in eighteen fathoms. These banks have certainly been greatly increased, if not originated, by the deposition of matter from the icebergs of the Jakobshavn ice-stream. At the time we were anchored a large number of small bergs were aground upon them, breaking up and revolving all around. We took the opportunity to put down the dredge, and although we only worked from the ship side, and consequently over a very limited amount of bottom, we brought up in two or three hauls fragments of granite, gneiss (some with garnets), syenite, quartz, hornblende, greenstone, and mica-slate. The sounding-lead showed a fine sand bottom, and the anchor flukes brought fetid mud.

‡ The word Sakkak means, according to Giesecke, "sunside," *i. e.* southerly aspect.

four years. He says that the glaciers which can be seen from his house, both on the Noursoak peninsula and upon Disco Island, are steadily increasing; so much so that their progress can be noted every year. This statement coincides with the observation of Sir C. Giesecke nearly sixty years ago. The latter says*, speaking of the route to Umenak, "formerly they drove generally over Gamle Ritenbenk†, but for several years the road has become impassable in consequence of the 'iceblink' by which the whole continent there is covered. The same will take place with the new road at present in use." The glaciers to the south were, however, as far as I observed them, decidedly shrinking.

At Sakkak we were joined by a native guide for Atanekerdluk, named Gudemann, and also by two others who volunteered their services. We continued our journey after a brief halt, and arrived at our destination shortly after 1 A.M. on August the 22nd.

The name Atanekerdluk is applied by the natives to a basaltic peninsula, about half a mile in length, connected with the mainland by a sandy neck, which is apparently covered by the sea at spring-tides. A bay with a sandy beach stretches about two miles to the south, and at its further extremity there is another promontory, of columnar basalt, named Imnarsoit. Between these two promontories, and indeed along the whole of the shore from the above-mentioned valley at Sakkak to the most northern point of the Noursoak peninsula, mountains rise from the water's edge and attain in some places a height of 5000 to 6000 feet. Behind the peninsula of Atanekerdluk they do not, however, attain a height greater than 3600 or 3800 feet. They are cut up by numerous small valleys and ravines.

The position of Atanekerdluk is indicated at a great distance by means of three mountain-peaks of symmetrical form. The fossil bed is one-third way up the most northern of these, and between it and the central one. Under the guidance of Gudemann we started for it at midday on the 22nd. The sides of the hill on which it is situate (an outlying buttress of the mountain already mentioned) were of considerable steepness, and channelled in many places by small streams. It was mainly composed of sand and of shales, and was strewn with disintegrated fragments of hardened clays, sandstones, and basalt. The most prominent features were the dykes of trap which appeared in numerous places‡, sometimes as regular in form as built walls, and in others picturesque as Rhine castles. Five, if not six, of these dykes appeared at different places in the section of the coast between the headlands of Atanekerdluk and Imnarsoit.

It has been already mentioned that this locality had been frequently visited§ before 1867 for the sake of its fossil deposit. This was evident by numerous fragments that we found in the course of our ascent, which had been dropped by others in descending, and it seemed at first as if the deposit was very extensive. We found it in fact to be confined within narrow limits. It did not appear to extend a greater length than 400 feet, with a maximum depth of 150 feet. In most places the portion exposed was nothing more than a seam a few feet in depth. It was on a shelf of the hill at the height of 1175 feet||; the southern end was exposed on the north side

* Giesecke's MS. Journal, year 1811.

† The Danish name for the settlement of Sakkak.

‡ These, as well as the other points of Atanekerdluk, were illustrated by a reference to a photograph of a drawing made from my sketch taken on the spot.

§ By Danes, or by natives collecting for Danes.

|| The mean of eight observations by aneroid. Capt. Inglefield gives the height 1084 feet.

of the most prominent of the ravines already referred to. The length of the deposit, that is to say the face of the hill on which it was found, fronted the Waigat, due west, magnetic.

I took from England, besides hammers, picks, and shovels, all the necessaries for blasting; but these latter were unnecessary. The seam was for the most part enclosed by sand, and specimens were obtained with ease. The division of labour was as follows:—The natives (fourteen) collected, Mr. Tegner interpreted, and I selected. I directed Mr. Brown to collect specimens of the different strata in order that sections might be prepared*. The specimens are before me, and comprise:—basalt; sandstone containing nodules of basalt rather smaller than an ordinary walnut; indurated black mud, probably derived from decomposed basaltic rock; limestone; calcareous mud, containing lime and alumina; calcareous mud with layers of vegetable matter; sandstones of different degrees of fineness; sandstone containing a large amount of alumina; coarse sandstone, about equivalent to the millstone grit of Derbyshire and Yorkshire; coarse conglomerate sandstone, with fragments of silica about the size of common horse-beans; calcareous sandstones of different degrees of fineness (effervescing readily when hydrochloric acid is applied); fine-grained calcareous sandstone, in which the lime effervesces when hydrochloric acid is applied, and containing mica distributed in patches with silica; calcareous sandstone, with layers of vegetable matter; ferruginous conglomerate (grains of quartz, cemented together by oxide of iron); hard clay of black colour; fine hardened mud containing vegetable impressions; streaks of clay, with layers of coal one-sixteenth of an inch thick; bituminous shale; and lignite†. After a hard day's work we returned to our camp, in a ruined native house by the shore. It froze sharply during the night.

On the 23rd we resumed work, and by the close of the day had made a large collection of good specimens. It was my endeavour to select, as far as possible, perfect specimens of individual species, rather than fine slabs containing numerous species. Unfortunately a large number of the finest specimens were irremediably smashed in transit down the hill; this was due much more to the brittleness of the specimens and the steepness of the descent than to carelessness. The natives indeed worked admirably.

On the 24th we finished our work at this locality. A trench had been dug by this time 20 feet in length, to a depth of 5 feet, completely through the seam, and the section showed:—

		ft.	in.	
1.	Stratum of fine sand, light grey colour	1	7	deep.
2.	„ similar to No. 1, darker		8	„
3.	„ fine white sand		8	„
4.	„ similar to No. 2		9	„
5.	„ „ No. 3		6	„
6.	„ yellow sand.			

The impressions of leaves were found for the most part in stratum No. 1, or upon the surface; they were also obtained from Nos. 2, 3, 4, but I believe not lower. Those found in the uppermost and upon the surface were ordinarily in hard clay, red in colour, due to oxide of iron. These did not suffer much by transportation; but the surface had apparently undergone a careful scrutiny, and few very perfect specimens were obtained from it.

* The sections have not yet been handed to me.

† These specimens have been named by Prof. J. Tennant, who has obliged me by examining and naming all the specimens referred to in this Report.

The impressions in the softer and more brittle shales were obtained some depth below the surface; these yielded the best specimens, but they suffered greatly in transit. Those found at the greatest depth were almost invariably in lumps of hard clay that fractured irregularly; these differed from the others in being of an iron-grey colour. They have reddened since they have been exposed to the atmosphere. The trench was dug about midway between the extremes of the deposit, and examination at other points showed a similar arrangement. The hill at this part was mainly composed of sand, enclosing numerous thin seams of brittle indurated clay, red in colour, containing a good deal of iron and of moderately fine-grained sandstones.

We were unable to find the "perfect stem, standing four feet out of the side of the hill," spoken of by Capt. Inglefield *, and it was unknown to the natives. It was said to have stood on the edge of a precipice, in the ravine on the south of the hill, and it has probably been buried in a fall that appears to have taken place not very long ago. In the sides of this ravine, both above and below the leaf-deposit, numerous beds of lignite are exposed, at least one being of considerable thickness. I brought home from this bed a block 1 foot 9 inches in thickness, a portion of which has been analyzed in the laboratory of Mr. T. W. Keates of Chatham Place, with the following result:—

"Specific gravity	1·369		
Gaseous and volatile matter		45·45	
Moisture		·75	
			46·20
Sulphur			·55
Coke { Fixed carbon		47·75	
Coke { Ash		5·50	
			53·25
			100·00

The lignite contains a trace of bitumen; the coke is non-caking, and of little use."

In this lignite we found small pieces of amber, the largest being about the size of a common pea. We also found amber, but in still smaller fragments, in the leaf-deposit itself. It was nowhere abundant.

The scantiness of the living vegetation at Atanekerdluk offered a marked contrast to the luxuriance displayed in the leaf-deposit. Although this was the sunny side of the Waigat Strait and the hills were completely free from snow, vegetation was as meagre as upon Disco Island itself. The drifting of the sand accounts for this doubtless to some extent. The largest dead wood measured less than an inch and a half in diameter, and the largest growing wood less than an inch.

The most remarkable natural object at Atanekerdluk is a trap pinnacle †. The surrounding soil has been removed, leaving this portion of a former dyke standing perfectly isolated. Its height is about eighty feet.

On the evening of August the 24th we rowed across the Waigat to a little settlement on Disco Island, named Unartuvarsok, immediately opposite to Atanekerdluk. At this part the Waigat is nearly twelve miles across, and its passage took us more than four hours.

* Private Journal of Capt. E. A. Inglefield, quoted in "A Report on the Miocene Flora of North Greenland," by Prof. O. Heer, 1866. Journal of the Royal Dublin Society, vol. iv.

† A photograph of which from a drawing made from a sketch taken on the spot was exhibited.

Unartuvarsok is now the only inhabited place on the whole of the Waigat side of Disco Island, and the sole inducement to visit it lay in the expectation that we should be able to find a native who knew the localities of Ujarasuksumitok and Kudliset. In this we were not disappointed; the native catechist (teacher) offered to act as guide, and moreover invited us to pass the night in his house. We did so, and found the atmosphere most filthy.

Early on the following morning we again started, passing at a short distance from the settlement some remarkable peaks that stood in advance of the great basaltic cliffs which are the chief features of Disco Island. These cliffs are everywhere crowned by glaciers, which occasionally, but rarely on the Waigat side of the island, pour over and advance towards the shore. Near the settlement of Unartuvarsok there are two or three points, at least, at which this glacier-plateau could be reached without much difficulty*.

Coal-seams are exposed at a number of points both along the Waigat and on the coast between Flakkerhuk and Godhavn. Dr. Rink mentions† five places at which it is found along these shores; there are at least three others, —one spoken of by Giesecke; another near to Issungoak Ness, from which I obtained amber through the natives; and a third nearer to Godhavn. At the time of our visit fossil wood had been found:—1st, at Iglutsiak, near Godhavn; 2nd, at Signifik, between the last-named place and Flakkerhuk; 3rd, at Ujarasusuk (Ujarasuksumitok); and 4th, at Kulfelden (Kudliset). Specimens from these places are in the University Museum at Copenhagen, and on my return I obtained, through the courtesy of Professor Johnstrup, duplicate specimens from the first two named. Until the time of our visit leaves had not, however, been found, with the exception of a few specimens by Dr. Lyall. Amber had, however, been found at several places; and from this fact, and from the statement by Giesecke that he had himself observed impressions of leaves (apparently *Angelica Archangelica*), there was little doubt but that a more careful search would yield results. It was most important to find the place spoken of by Giesecke as Ritenbenk's Kulbrund. There was difficulty in doing so: the natives differed among themselves; but we now know that this name is applied equally to all the places along the Waigat coast of Disco from which coal has been taken for Ritenbenk. At the present time coal for that colony is only taken from one place on Disco, namely, Ujarasuksumitok; but it has been taken from several others, and hence we were much puzzled to determine the precise point to which Giesecke referred.

On arrival at Ujarasuksumitok it was found that the coal was exposed in the cliff by the shore, at a height of about fifty feet above the sea. It had been worked a length of fifty feet to a depth of four and a half: one could not say what was the entire depth of the seam, as the lower part was covered up by débris. All the natives were put to work, but for some hours we failed to find anything more than wood (up to five inches diameter), charred stems,

* The coast-line of the Waigat strait is laid down very inexactly in existing maps. The chart of Dr. Rink, which is probably the best, makes the Disco coast very nearly a straight line from the promontory called Issungoak Ness to the shores opposite to Hare Island. In fact the coast-line from the above-named point to halfway up the strait is formed by one great bay that includes numerous smaller ones. We coasted these, and remarked that for a considerable distance from the shore they were extremely shallow. At a distance of a half English mile, or even more, there were places with a depth of only eight or nine feet. The whole of the Waigat, indeed, appeared to be shallow. Small icebergs were aground in numerous places in the very centre of it.

† Grönland Geographisk og Statistisk beskrevet, vol. i. pp. 172, &c.

doubtful impressions, and a few grains of amber. I then went along the coast towards the north, and was at length rewarded by finding a fair specimen, containing leaves, in the bed of a small stream. It was in hardened, warm-coloured clay, similar to that obtained at Atanekerdluk. I followed the stream to its source, a height of about 1000 feet, without finding anything more. Then returning, I went to the south, and in another and larger torrent-bed found several others. The natives, now put on the right track, soon brought in a fair collection. Gudemann was the fortunate discoverer of the *Magnolia* cone, to which Prof. Heer refers, and he was greatly surprised at the reward it produced him.

All the specimens collected at this place were obtained from these two torrent-beds: Mr. Brown, who followed the fossils up to their source, reported that they came from a thin seam difficult to get at. As it was becoming a question whether the boats would carry all the specimens we had already collected, I decided to push onwards the same night to Kudliset, which, from reports received, seemed a more promising place for investigation.

We arrived there about midnight, and camped very smartly. The weather had already become sufficiently cold to freeze the salt water in the bays at night, and during the whole day fresh water remained frozen in the little pools on the land. The whole of this part of Disco Island was very dismal. Its aspect allows the sun to shine upon it for but a small portion of the day*, and all animal life seemed to shun it. A few ptarmigan were the only living creatures we saw on the land during the days we passed on these shores. There was little wonder that the natives were already wishing to return. They were ill-protected from the weather; for, from reasons which need not be mentioned, it was impossible to allow them to enter the tents, and they had only such shelter as they could obtain by piling up turf and stones, and covering themselves with a few small blankets and spare skins which we had brought with us.

At this place (Kudliset) coal (lignite) was exposed in a cliff on the south side of the bed of a small stream in two seams, 4 feet apart, for a length of about 30 feet, difficult to get at. They were 105 feet (by aneroid) above the sea, and distant from it about 300 yards. The lowest seam, 2 feet thick, was resting on a bed of indurated clay, and between the seams was a coarse and very loose, crumbly sandstone. The uppermost seam, one foot thick, was capped by a finer and harder sandstone which I could not measure. The whole, above and below, was enclosed by sand.

In the torrent-bed we quickly found some considerable masses of fossilized wood, and I followed the stream upwards in hopes of finding leaves. At a height of about 800 feet I obtained agates in basalt, and following the stream to its source (about 1000 feet above the sea), came nearly to the foot of the great basaltic cliffs. The specimens collected here include hardened clays which have taken form in cavities in the basalt. Returning to my party I found that they had in the meantime obtained some indifferent and fair specimens from the torrent-bed, and from the sandstone above the coal. We afterwards added to their number, but the coarseness of the stone prevented any very good specimens from being obtained. We also secured some good specimens of fossil wood, about one foot in diameter. Nodules of argil-

* The Danish man at Sakkak informed me that the coal was got out easily enough during the summer time, but that at a depth of 12 feet it remained frozen throughout the year. On arriving at the frozen coal, they commonly wait two or three days to allow it to thaw, before continuing to work it.

laceous oxide of iron, having usually in the centre kernels of the same, were abundant in the stream and in the soil at its sides.

After a half-day's work we had apparently exhausted this locality. The specimens obtained were again chiefly taken from the torrent-bed. It was a matter of difficulty, if not of danger, to get any from the sandstone above the coal; and as the natives were murmuring frequently at being taken away further than they had agreed, I sent Mr. Brown to the south with one boat, to examine the coast, and then proceed to Ritenbenk, *viâ* Atanekerdluk, while I went with the other boat as far north along the Disco shore as the natives would go. A little further along the coast I found some doubtful impressions of leaves in a great wilderness of stones brought down by a glacier-torrent, and about three miles still further north came to the magnificent gorge in the sandstone cliffs by the shore, to which I have vainly endeavoured to do justice in the view exhibited*. One mile after this the cliffs by the shore came to an end, and the coast apparently continued quite flat until opposite Hare Island. The natives agreed that no coal was visible along the whole of this shore, and we crossed to Mannik, on the opposite side of the Waigat. Here there was a small thin seam of coal, exposed in a cliff not far from the shore; but I obtained nothing from it, and we continued our course to Atanekerdluk, arriving shortly after midnight; here we passed the night of the 27th August. The next day was occupied in loading the boat with the specimens we had left there, in sketching, and in completing the examination of the locality. At 4 P.M. we started for Sakkak, and left it at 8.30, arriving at Ritenbenk on the morning of the 29th August. Mr. Brown had arrived about twelve hours before, but, like ourselves, had failed to make any fresh discoveries.

At Ritenbenk we remained three days, with foul weather. During this time the collections, including many hundred specimens, amounting to considerably more than half a ton in weight, were repacked. We were then favoured, by the kindness of Mr. Anderson, with a passage in a blubber-boat to Godhavn, at which place we arrived on September the 4th, after a most disagreeable voyage. On the 10th we sailed on board the brig 'Hoalfisken,' and arrived at Copenhagen on October the 22nd.

In conclusion it is right to observe that these collections could not have been made excepting by means of the facilities afforded by the Danish authorities. We may feel a natural satisfaction that so many as eighty species should have been discovered by the labours of Professor Heer; but it should be remembered that they are primarily due to the invaluable information given by Herr C. S. M. Olrik, the Director of the Greenland Trade. Scarcely less are our thanks due to Herr K. Smith, the present Inspector of North Greenland, and to Herr Anderson, of Ritenbenk; both of these gentlemen gave much assistance, at considerable personal trouble, which was of the greatest service.

To Robert H. Scott, Esq., EDWARD WHYMPER.
Secretary of the Committee of the British Association.

Preliminary Report on the Fossil Plants collected by Mr. Whymper *in North Greenland, in* 1867. *By* Prof. OSWALD HEER.

The fossil plants which have been sent to me by Mr. Whymper have come partly from Disco Island and partly from Atanekerdluk.

* At this part some boulders of granite, probably transported by sea-ice, were lying on the shore.

The specimens from Disco occur in a coarse-grained sandstone which is at times yellowish, and at times reddish-grey. They were collected at two localities on the eastern side of the island, on the shore of the Waigat, in lat. 70°, or thereabouts. One of these is named Kŭdlisot (Kudliset), the other is Ujararsusuk (Ujarasuksumitok), and lies some miles to the south of Kudlisot. This place is also called Ritenbenk's coal-mine, because of a considerable seam of brown coal which occurs in the sandstone, and is sometimes wrought by the colonists of Ritenbenk.

The collection contains thirteen species from these two localities, viz. eleven from Kudlisot, and six from Ujararsusuk; four species are common to both. Two of these may be described as the commonest trees of the district. One is a conifer (*Sequoia Couttsiæ*), the other a plane. The collection contains splendid specimens of the *Sequoia*; and with one twig from Ujararsusuk we find the scales of the cone in good preservation, while among the delicate twigs from Kudlisot there is an entire cone. The twigs and cones are precisely similar to those which are so common at Bovey Tracey in Devonshire, and which have also been found in the Hempstead beds in the Isle of Wight. This remarkable tree, which I have described as *Sequoia Couttsiæ*, and which is closely allied to *Sequoia gigantea* (*Wellingtonia gigantea*, Lindl.), extends accordingly from the south of England to North Greenland, and has ripened its fruit in the latter region. Not less remarkable is the plane, of which the collection contains very fine leaves; it resembles the American plane, from which it is not easily distinguishable.

Among the other plants from this locality we may name a fern (*Aspidium Meyeri*), which is covered with fruit, a reed, the amber-tree of Europe (*Liquidambar Europæum*, Braun), a Christ-thorn (*Paliurus Colombi*), and a *Dryandra* (*D. acutiloba*), which was only known to occur in the Wetterau and at Bilin, in Bohemia.

The most remarkable discovery, without doubt, is that of two cones of *Magnolia*. In my 'Flora Arctica' I have already identified the leaves of a *Magnolia* (*M. Inglefieldi*), and have shown that in respect of their size and leathery texture they approach those of *M. grandiflora*, L. Now we find these cones coming to light and confirming the identification of the leaves. In addition to a cone of the same size as that of *M. grandiflora*, there is a spray with a large bud, very similar to those of *Magnolia*. At Kudlisot several fragments of leaves were collected.

Of the thirteen species from Disco three are entirely new, and besides seven had not previously been recognized as Greenland species.

Atanekerdluk lies on the opposite side of the Waigat, on the peninsula of Noursoak, and in the same latitude as Kudlisot. This locality has already afforded the abundant collections which have been brought to Dublin and London, and to Copenhagen and Stockholm, and which are described in my 'Flora Fossilis Arctica.' At this place Mr. Whymper has collected a great number of plants, in fact the greater portion of his collection. The majority of the species contained in the slabs were already known, as might have been expected. The Poplars and *Sequoiæ* (*S. Langsdorffi*, Brgn.) are very abundant, and the twigs and leaves at times cover the entire surface of the stone. We can recognize the male and female flowers in addition to the cones. The M'Clintockias, which are in themselves so remarkable, and the leaves of oaks and hazelnuts are not rare, and are sometimes very well preserved.

I have hitherto recognized sixty species; but as many of the slabs have not yet been worked out, it is probable that this number will be increased. One-fourth of these, *i. e.* fifteen species, are new, or at least new to Greenland, and of these the following deserve special notice:—

1. A Sassafras (*Sassafras Ferretianum*), closely allied to the North-American species. This species I had obtained from Menat in France, and it also occurs at Senegaglia.

2. The fruit of a *Nyssa*, like a species from Bovey and from Salzhausen.

3. A very perfect leaf of a Snowball (*Viburnum Whymperi*, Hr.).

4. Leathery leaves of a plant which probably belongs to the Aralias (*Aralia Browniana*, Hr.).

5. A new species of *Cornus* and a new *Cratægus*.

Important though the discovery of these new species is as extending our knowledge of the Miocene Flora, it is not more so than the additional information as to known Arctic forms which has been afforded by this expedition, as tending to correct, or rather to confirm their identifications.

Among these we should name a very beautiful Fern (*Hemitellites Torellii*), which differs widely from all those of the temperate zone; the leaf-part of a *Salisburia*, which in its form approaches very closely to the Japanese species; a perfect leaf of *Quercus Lyellii*, Hr.; the leaf of a Vine (*Vitis arctica*, Hr.); several fragments of leaves of nut-trees, and of *Magnolia Inglefieldi*; and the fruit of *Menyanthes*, which species I have already identified by means of the leaves.

On the whole the collection contains sixty-seven species, of which twenty-two are new to Greenland, and are accordingly additions to our knowledge of the fossil flora of the Arctic Zone.

To these may be added three specimens of the fauna, two insects and a bivalve. One of the insects exhibits elytra in very good preservation, and belongs to the Coleoptera, the other to the Hemiptera. The bivalve is a freshwater species (*Cyclas*), and confirms the view that the deposit of Atanekerdluk, which contains so many plants, is a freshwater formation.

Report of a Committee, consisting of Mr. C. W. Merrifield, *F.R.S.*, Mr. G. P. Bidder, Captain Douglas Galton, *F.R.S.*, Mr. F. Galton, *F.R.S.*, Professor Rankine, *F.R.S.*, *and* Mr. W. Froude, *appointed to report on the state of existing knowledge on the Stability, Propulsion, and Sea-going Qualities of Ships, and as to the application which it may be desirable to make to Her Majesty's Government on these subjects. Prepared for the Committee by* C. W. Merrifield, *F.R.S.*

The subject referred to us is a very large one, and having regard both to the space which a complete report on such a matter would require and to the time at our disposal for making it, we have thought it best to lay before the present Meeting a First Report, in which we confine ourselves to the *resistance which ships offer to propulsion*, and to their *behaviour in respect of rolling*. These are, in their several directions, the preliminary subjects necessary to the inquiry committed to us; and they are also the parts of naval science on which exact experiment appears to be most urgently needed, both for the direct knowledge of these branches, and also as a foundation for experiments on propulsion and the other applications which depend upon them. Knowledge of the work to be done should precede the selection of the tool with which it is to be performed.

RESISTANCE.

Total Resistance.

The question of resistance may be treated in two ways,—either in gross, as regarding the power required to drive a vessel of certain form and dimensions at a specified rate; or in detail, as regarding the exact way in which the vessel and the propeller act and react upon the water which they disturb. Hitherto there has been but little connexion established between the phenomena of detail and the general result, the former not being understood with any reasonable degree of certainty, and the latter also being far from settled with precision.

The variable elements which go to make resistance what it is are chiefly velocity, form, condition of surface, and absolute dimension. The effect of form is as varied as the number of forms which can be given to a floating body. As regards dimension, assuming the forms to be geometrically the same, it has been found that vessels of different absolute size do not correspond in the degree of resistance which they encounter, whether in smooth water or in waves. It will also be seen that the absolute length of a ship, considered irrespectively of breadth or depth, has a direct influence on the resistance.

As regards velocity, it is usual to assume, in books on hydrodynamics, that the resistance of water varies as the square of the speed. For the purposes of naval architecture, this can only be taken to be roughly true under certain limiting conditions, beyond which the law of the squares deviates widely from the observed facts. It appears to be probable that this increase, as the square of the speed, is rather a minimum than a general rule of increase, and that such a minimum is only attained by ships of good form, and of a length which is a certain function of the speed. The vague words *good form* are used designedly, it being still uncertain what the best form may be, and what extent of deviation from it takes the vessel out of its operation. When the vessel is shorter than a certain limit of length depending on the velocity, the resistance seems to increase more rapidly than the square, and the power needed to drive the ship consequently increases faster than the cube of the velocity.

It may save confusion to remark that the measure of *resistance* is referred to a unit of distance, while *power* is referred to a unit of time. For any law of resistance, therefore, the power varies as the product of the resistance and speed, and where the velocity varies we have simply to use the corresponding integral formula.

As already remarked, the *leading formulæ* of the resistance of water are

$$R \propto V^2, \; HP \propto RV \propto V^3,$$

the latter being the strictly necessary consequence of the former. There is but little disagreement among writers up to this point. But the moment we attempt either to assign values to the constants of the equations which they imply, or to introduce the corrections depending on the complex phenomena, which always, more or less, mask the mere question of fluid resistance, we find very little agreement.

The chief elements of the resistance of water to a body moving through it are:—

(1) The *direct head-resistance* due to the work of thrusting the water to the right and left, with or without vertical motion, in order to make way for the body to pass.

(2) The *skin-resistance*, or friction of the water on the surface of the moving body, combined with the effect of surface eddies and other minute phenomena.

(3) The *back pressure*, due to the diminished pressure in rear of the moving body and in wake of any corners or unfairness of surface which may cause eddies.

(4) In addition to these, there are the phenomena of capillarity and of the viscosity of water. These are of importance as regards minute bodies, including even small models; but for large ships they are sufficiently accounted for in the arbitrary constant of skin-resistance. This fourth head may therefore be neglected, except when we wish to pass from ships to models.

For extreme shapes it does not appear that the three leading elements of resistance can be grouped under one term; but there is reason to believe that, for vessels of a certain form, they all involve, with a respectable degree of approximation, the square of the velocity, and also that the forms for which this is true are among those which offer, *cæteris paribus*, the least resistance. Under these circumstances, the formulæ depending on skin-resistance may be made to include the other two by merely altering the constants. We conjecture that, when authors state that certain elements of resistance may practically be neglected, they usually mean that they can be accounted for in assigning the values to the arbitrary constants, which, in any case, must be determined from experiment. We have named vessels *of a certain form*; this form must be regarded as still unknown, except with reference to some limitations of a negative character, even these being rather indefinite. They include a fine entrance, and a fine run, and an absolute length of not less than the length of the trochoidal wave moving with the same velocity. The actual determination of the form of least resistance is not only unsolved, but the data of the problem are yet unknown.

The first formulæ that occur are the well-known coefficients of steam-ship performance—

$$\frac{(\text{Speed})^3 \times (\text{displacement})^{\frac{2}{3}}}{\text{Indicated horse-power}}.$$

$$\frac{(\text{Speed})^3 \times \text{area of midship section}}{\text{Indicated horse-power}}.$$

As affording a rough measure of comparison, the tabulation of these formulæ for different ships is extremely convenient. But they are of very little assistance in settling a theory. Even for the same vessel, tried under apparently similar conditions, these coefficients do not appear to be constant quantities. Moreover, the varying efficiency of the steam-engine and of the propeller, considered as machines for the transmission of power, are inseparably grouped with the work of overcoming resistance. When the consumption of coal is substituted for the I.H.P., the efficiency of the furnace and boiler also comes in. Some of these remarks apply to Mr. Hawksley's approximate formula,—

$$\text{Velocity in statute miles} = 27\left(\frac{\text{effective horse-power}}{\text{wetted surface in } \square'}\right)^{\frac{1}{3}};$$

but this was only intended for rough purposes.

We may here mention a formula given by Mr. Greene, in a paper read at the Franklin Institute of New York, and reprinted in the 'Mechanics' Magazine' for 8th July, 1864. It proceeds on the assumption that the power expended in overcoming back pressure and friction in the engine varies directly as the speed—

$$H.P. = D^{\frac{2}{3}} V (\cdot 1552 + \cdot 0046846 V^2),$$

the constants being obtained empirically.

Most modern formulæ for resistance take account of the form of the vessel, in such a manner as to require the use of the drawings of the exterior surface of the ship. The Swede, Chapman, in his well-known treatise on shipbuilding, assumes that the surface of the vessel may be divided into small portions, the resistance of each of which will be proportional to the projection of its area, to the sine squared of the inclination, and to the square of the velocity; with a certain small correction on account of the currents which are set up by the ship's own motion, and which modify the pressures. But he himself saw reason from subsequent experiments to doubt whether the law of the sine squared, or even that of the velocity squared, was applicable to the forms which he used.

Euler* and most of the older writers use the sine squared of the inclination as the factor representing the effect of obliquity; and this theory has been revived by Mr. Hawksley in a discussion at the Institution of Civil Engineers, reported in their 'Proceedings' for 1856, vol. xvi. p. 356. But we think that there is now ample experimental ground for believing that, whether or not this law be true with respect to an infinitesimal portion of a plane receiving the impact of a thin jet of water, it is not true either of plane surfaces of considerable extent, or, as a differential formula, of curved surfaces. It evidently fails to take account of the effect of the stream which is set up along the surface in deflecting the impact of water on the part of the surface further back from the entrance. The assumption that this has no effect is not one which can be admitted without proof; and the experimental evidence tends the other way. Chapman's later experiments, the experiments of the French Academy, and those of Col. Beaufoy† are all against the hypothesis of the sine squared of the inclination. The supposition that the sine squared of the inclination represents the effect of the obliquity of the afterbody is still more open to doubt than when it is applied to the forebody.

As a contribution to the history of the subject, the following translation from a tract of M. Dupuy de Lôme will be interesting:—

"Romme, in his Memoir for the Academy of Sciences, in 1784, while giving an account of the experiments made by him at Rochefort on models of ships, one of which represented a 74, and, again, in his work on the 'Art de la Marine,' had very succinctly laid down that this resistance was independent of form. 'Provided,' he went on to say, 'the water-lines have a regular, fair curvature, as is the case in modern vessels, the greater or less fullness of the bow or stern neither increases nor diminishes the resistance of the water to their progress.'

"In direct contradiction to this too summary rule, which has long obstructed the progress of naval architecture, my experience leads to five principles, which I state as follows:—

"1°. Among vessels of similar geometrical form, of different size, but all having their immersed surface exceedingly smooth, and driven at the same

* See his 'Scientia Navalis' (St. Petersburgh, 1749), vol. i. p. 213. See also D'Alembert, 'Traité de l'Equilibre et du Mouvement des Fluides,' ed. of 1770, p. 226.

† See Chapman (by Inman), p. 257; Bossut, 'Hydrodynamique,' vol. ii. p. 396; Beaufoy, p. lxxxvii. See also Scott Russell's 'Naval Architecture,' p. 168; or Proceedings of Civil Engineers, vol. xxiii. p. 346, as to the French experiments.

speed, the pressure needed to attain this speed increases more slowly than the surface of the greatest transverse section. It is near the truth to say that, for similar forms, the resistance per square metre of midship section, at the same speed, decreases as the vessel increases, in the ratio of the square roots of the radii of curvature of its lines, these radii being themselves proportional to the linear dimensions of the ships; it is therefore wrong to compare the resistance of different ships by means of experiments made on models to reduced scales*.

"2°. If the same vessel be driven at different speeds, the force needed to obtain these velocities increases less rapidly than the square of the speed, while that is small. The force increases as the square for ordinary rates of 3 to 5 metres per second, according to the condition of the surface in respect of smoothness. Beyond that speed it increases faster than the square†.

"3°. The diminution of the angle of entrance, and the lengthening of the radius of curvature of the lines which the water has to follow, especially in the replacement in wake of the stern by the water coming up from below, are the principal means of diminishing the resistance. This has the greater influence the greater the driving-power. For very slow motion, the influence of form is less than that of surface friction.

"4°. The sharpness of the bow, both above and below the water-line, which has in calm water the effect just mentioned, has more marked advantages in a heavy sea-way.

"5°. The smoothness of the wetted surface plays a considerable part in the resistance; and this part, due to friction, varies but little with the speed.

"I add that the resistance of the hull increases markedly in narrow channels, and still more where the depth of water does not much exceed the draught of the ship; so that experiments ought to be made in deep water.

"Finally, my numerous observations on the resistance of ships, in calm weather and open sea, agree, with a close approach to exactness, with the following formula, which I have since adopted as the measure of the resistance:—

$$R=KS(V^2+0{\cdot}145\,V^3)+K^1 S^{3\ 1}\surd V.$$

"In this formula, I call—

S, the area of midship section in square inches.

S^1, the product of the mean girth (wetted), into the extreme length, also in square metres.

V, the speed in metres per second.

K, a coefficient varying with the form, diminishing inversely as the square root of the radii of the curvature of the longitudinal sections, and also diminishing with the mean angle of entrance. This second reduction amounts to about 15 per cent., as the mean angle of entrance comes down from 45° to 15°. It is therefore about $\frac{1}{2}$ per cent. for each degree between those limits.

K^1, a coefficient independent of the form, and varying only with the smoothness of the wet skin. This coefficient may increase in the ratio of 1 to 10, from 0·3 for bottoms very smoothly covered with good copper,

* M. Réech, Director of the Ecole d'Application du Génie Maritime, has long since pointed out in his lectures the error frequently made of comparing the resistance of vessels of various forms by means of experiments upon models driven at the speed proper to the vessels themselves.—*Note by the French author.*

† I am here speaking of vessels only partially immersed, not of vessels which are entirely under water.—*Note by the French author.*

and the heads of the nails well beaten down, to 3·0 for hulls covered with weed and barnacles.

R is the resistance expressed in kilogrammes, and corresponding to the speed V.

"For each ship experimented upon, two trials are sufficient to determine K and K^1.

"For the 'Napoléon,' while clean, the copper being oxidized, not greased, I found

$$K=1{\cdot}96, \quad K^1=0{\cdot}44,$$

from which I obtain for the general expression for the resistance to the passage of the ship through the water,

$$R=1{\cdot}96S(V^2+0{\cdot}145V^3)+0{\cdot}440S^1\sqrt[3]{V}.$$

A Table previously given shows that during the trial trip of the 'Napoléon' the values of S and S^1 were—

S between 99 and 100 square metres.
S^1 between 1580 and 1610 square metres.

* * * *

"The power needed to obtain this speed is obtained from this calculation by multiplying the resistance, so calculated, by the velocity."

The above remarks are translated from a memoir published by M. Dupuy de Lôme on the occasion of his candidature for the French Academy in 1865–66. It is reprinted in M. Flachat's 'Navigation à Vapeur Trans-océanienne,' vol. i. p. 206.

It may not be out of place to mention, in explanation of M. Dupuy de Lôme's remarks about the angle of entrance, that the architects of the Imperial Navy avoid the use of the hollow bow. There is at most a slight concavity at the fore-foot. Hence the angle of entrance has a meaning which is sometimes lost in modern English practice.

M. Bourgois, in his memoir * on the resistance of water, gives formulæ which may be grouped under the general form of

$$R=B^2V^2\left[K_1+K_2\frac{lV^2}{B^2}+K_3\frac{S}{B^2V}\right],$$

B^2 being the area of midship section, S the wet surface, and l the breadth extreme. K_1, K_2, and K_3 are constants which vary with different classes of vessels.

The dependence of the resistance of ships upon the theory of waves appears to have been first insisted upon by Mr. Scott Russell. That gentleman seems to have been the first to discover that there was a relation between the length of the ship and the velocity of advantageous propulsion, this relation being taken directly from the theories of the solitary and of the trochoidal waves. We will state his theory of resistance in as few words as possible.

Scott Russell's Theory of the Form of Least Resistance.

A vessel may be divided longitudinally into three portions, bow, straight middlebody (if any), and afterbody. The midship section may be of any shape whatever, the resistance due to it depending on its area and wet

* Published at Paris, by Arthur Bertrand, *s.a.* See also Sonnet, 'Dictionnaire des Mathématiques Appliquées,' art. "Résistance des Fluides."

girth only. The forebody must have for its level sections curves of sines (harmonic curves) whose equation may be written as

$$x=\frac{l\theta}{\pi},\ y=\tfrac{1}{2}b(1+\cos\theta),$$

b being the half breadth of the ship at any level, and l the length of the forebody, which must not be less than the length of the "solitary wave," which has the same speed as the ship is intended to have, in order that the resistance may be the least possible. The afterbody is to have trochoids for its level lines, their equation being

$$x=\frac{l^1\theta}{\pi},+\tfrac{1}{2}b\sin\theta,\ y=\tfrac{1}{2}b(1+\cos\theta),$$

l^1 being the length of the afterbody, which is not to be less than that of one half of the oscillating or trochoidal wave of the same speed as the ship. The straight middlebody may be of any length whatever, as it will only affect the resistance by increasing the surface for friction; or, subject to these conditions, the resistance of the ship will be expressed by

$$(K\oplus+K^1S)\,V^2,$$

where $\oplus$ represents the area of midship section, and S the wetted surface. K and K^1 are coefficients, the former of which may be roughly stated at $\frac{1}{10}$ of that due to a flat plate drawn flatwise through the water, and the latter depending upon the condition of the surface. For a pure wedge bow, whose angle is ϵ, Mr. Scott Russell considers that the resistance varies as $\left(\frac{\pi}{2\pi-\epsilon}\right)^2$, ϵ lying between the limits of 12° and 144°; and where the bow is compounded of this and of the wave form, he gives, as a rough measure of the resistance, a formula obtained by compounding this, in such proportion as may properly represent the geometrical combination of form, with the resistance due to the wave form.

As far as can be judged by Mr. Scott Russell's published writings, there appears to be some unsettled ground in his theory relatively to the shape of the afterbody. The form of the bow is simply that of one-half the profile of a solitary wave of translation, laid horizontally instead of vertically. The form of the stern is also taken from the form of the wave, which is set up when a hollow in the surface of water has to be filled up; but it is nowhere made clear whether this form ought to be given to the level sections, or to the vertical longitudinal sections, or whether some compromise should be made between the two; and it seems probable that the author himself was doubtful on the subject. The experiments recently made under the direction of the Committee of the British Association appointed to make experiments on the difference between the resistance of water to floating and immersed bodies (Report for 1866, p. 148) seem to indicate that that doubt is still unsettled.

Without hazarding an opinion as to whether this form is really that of least resistance, it appears certain that the curves used are among those along which fluid particles can glide smoothly, without causing supernumerary diverging waves in the liquid.

The general formula for the length of a ship given by this theory is:—

$$\text{Forebody in feet}=\frac{2\pi}{g}V^2 \text{ in feet per second;}$$

$$\text{Afterbody}=\frac{4\pi}{3g}V^2 \text{ in feet per second.}$$

The following are the values of the factor and its logarithm, which give the length of the forebody in feet, when the velocity is given in—

Feet, per second.	0·19518	log = 9·29045.
Knots, per hour	0·5561	log = 9·74515.
Statute miles, per hour ..	0·41985	log = 9·62310.

Professor Rankine states, as the result of his own observation, that it is possible to shorten the bow to two-thirds of the length given by this formula, without materially increasing the resistance, but that it is very disadvantageous to shorten the afterbody.

In the 'Proceedings of the Institution of Civil Engineers,' vol. xxiii. (for 1864), p. 321, is a paper by Mr. G. H. Phipps, on the "Resistance of Bodies passing through the Water." Mr. Phipps considers that the total resistance may be subdivided as follows, into additive parts:—

Head-resistance—varying directly as the midship section, and inversely as the square of the projection ratio of the bow.

Stern-resistance—a similar function for the stern.

Friction-resistance—varying directly as the surface immersed.

Additional Head-resistance—an empirical correction assumed to be a function of the draught of water.

The sum of these resistances is then multiplied by the square of the velocity.

The paper was followed by a discussion in which most of the leading English writers on fluid resistance took part. The paper and discussion thus constitute a very fair *résumé* of the opinions then held on the subject in this country.

Mr. Phipps considers that the coefficient of friction of water on the outer surface of a vessel is less than on the inner surface of a pipe; and this is, to a certain extent, in accordance with the experiments of Darcy on the friction of water in pipes, which led to the conclusion that the coefficient of friction consists of two terms—one constant, and the other varying inversely as the diameter of the pipe.

Mr. John I. Thornycroft, C.E., in a paper read before the Institution of Naval Architects this year, and which will appear in their forthcoming volume of 'Transactions,' gives the following formula, the form of which is derived from experiments on the flow of water in pipes:—

$$\text{I. H. P.} = \text{V}h\left\{\text{S}f\frac{3n}{2n+l}\text{V}^{1\cdot7} + \phi\text{S.C.}\frac{n^{\frac{1}{3}}+3}{l^{\frac{1}{3}}+3}\text{V}^{3\cdot7}\right\},$$

where S = the wetted surface, V = the velocity in knots, l = the length, h, f, n, C are constants empirically determined:

$$\log h = \bar{3}\cdot65450,$$
$$\log f = \bar{2}\cdot10170,$$
$$\log \text{C} = \bar{2}\cdot20041,$$
$$n = 380,$$
$$\phi\text{S} = \int(\sin\theta)^{2\cdot5}\,ds,$$

ds representing an elementary portion of the surface, S, and θ the angle which this portion of the surface makes with the line of motion. It will be noticed that the formula involves a large number of constants, more or less arbitrarily determined.

Professor Rankine, in a paper in the 'Transactions of the Institution of

Naval Architects' for 1864 (the substance of which is repeated in a treatise on 'Shipbuilding: Theoretical and Practical'), states that the processes amongst the particles of water through which resistance to the ship's motion may be caused indirectly may be thus enumerated:—

1. The distortion of the particles of water.
2. The production of currents.
3. The production of waves.
4. The production of frictional eddies.

The first cause he regards as having no appreciable effect on actual ships, although possibly sensible in small models. Of the second cause (the production of currents), Professor Rankine remarks that it "never acts upon a well-designed ship; for such a ship is so formed that the particles of water glide over her surface throughout its whole length, and are left behind her with no more motion than such as is unavoidably impressed upon them through adhesion and stiffness; and hence the failure of the earlier theories of the resistance of ships, which were founded on experiments made with flat plates, wedges, and blocks of unfair shapes."

Mr. Rankine then gives a detailed account of the waves which accompany a vessel driven at a speed greater than the limit to which she is properly adapted, showing that they diverge from the course of the vessel at an angle depending on the proportion in which their speed of advance is less than her speed, and thus carry off energy, which is lost; and he proceeds to state: "The conclusion to be drawn from these principles is, that for each vessel there is a certain limit of speed, below which the resistance due to the production of waves is insensible; and that as soon as that limit is exceeded, that resistance begins to act, and increases at a very rapid rate with the excess of speed. .... Through the discoveries of Mr. Scott Russell, a vessel can be designed in which this kind of resistance shall be insensible up to a given limit of speed; and therefore the resistance due to waves has no sensible action on a well-formed ship." These remarks of course apply only to waves formed by the ship, and not to sea-waves which she may have to encounter.

"The resistance due to frictional eddies thus remains alone to be considered. That resistance is a combination of the direct and indirect effects of the adhesion between the skin of the ship and the particles of water which glide over it; which adhesion, together with the stiffness of the water, occasions the production of a vast number of small whirls or eddies in the layer of water immediately adjoining the ship's surface." Instead of assuming that the frictional resistance is simply proportional to the actual immersed surface, Mr. Rankine uses what he calls the *augmented surface*, which is obtained by multiplying each infinitesimal element of the surface by the cube of the ratio which the velocity of gliding of the water over that portion bears to the speed of the ship, and summing them. Let s be the actual surface, and q the velocity-ratio of gliding; then the augmented surface is $\int q^3\,ds$; and if, further, V be the speed, g gravity, w the heaviness of water, and f the coefficient of friction, then

$$\text{Eddy-resistance} = V^2 f \frac{w}{2g} \int q^3\,ds.$$

Taking the cubic foot as the unit, $\frac{w}{2g}$ does not differ much from unity for sea-water, and the formula thus reduces to $V^2 f \int q^3\,ds$.

It is, of course, impossible to calculate $\int q^3\,ds$ in detail for every ship; and it therefore becomes necessary to find some auxiliary formula. In the 'Philosophical Transactions' for 1863, pp 134–37, Mr. Rankine has shown that the augmented surface of a trochoidal ribbon on a given base and of given breadth may be found by multiplying their product by the following coefficient of augmentation:—

$$1+4(\sin\phi)^2+(\sin\phi)^4,$$

in which ϕ is the angle which the inflexional tangent makes with the base. For a ship in which the stream-lines or tracks of the particles of water are trochoids, it would be a sufficient approximation to integrate,

$$\text{length}\times\tfrac{1}{2}\text{ breadth}\times\{1+4(\sin\phi)^2+(\sin\phi)^4\}$$

with regard to the draught of water, considering both the angle ϕ and the half-breadths as variable elements to be determined from the drawings. Where the stream-lines are not trochoids, ϕ may be taken as the angle of greatest obliquity. But the theory has been only partially extended to three dimensions; and indeed if it were possible to do so, the mere introduction of a third variable would not meet the case, unless account were taken of the vertical displacement of the surface of the water consequent upon the uniformity of pressure at that surface.

The resistance determined by the calculation of the augmented surface includes in one quantity both the direct adhesive action of the water on the ship's skin, and the indirect action through increase of the pressure at the bow and diminution of the pressure at the stern.

For the coefficient of friction, Professor Rankine takes $f=0{\cdot}0036$ for surfaces of clean painted iron. This is the constant part of the expression deduced by Professor Weisbach from experiments on the flow of water in pipes. The corresponding coefficient deduced from Darcy's experiments is 0·004.

The augmented surface in square feet, multiplied by the cube of the speed in knots, and divided by the I. H. P., gives *Rankine's coefficient of propulsion**. In good clean iron vessels this ranges about 20,000; while in H.M. Yacht 'Victoria and Albert' (copper sheathed) it reached 21,800. Its falling much below 20,000 is considered to indicate that there is some fault either in the ship or in her engines or propeller, or else that the vessel is driven at a speed for which she is not adapted.

Professor Rankine adds that "as for misshapen and ill-proportioned vessels, there does not exist any theory capable of giving their resistance by previous computation."

This, again, raises the question, What are *good* forms? According to Professor Rankine's theory, they are forms along which a particle of water can glide smoothly. Among these, as a particular case, Mr. Scott Russell's wave-lines appear to be included. But these are by no means the only ones which satisfy the problem of smooth gliding, or of stream-lines. Another method of constructing curves fulfilling this condition has been given by Mr. Rankine in a series of papers published respectively in the 'Philosophical Transactions' for 1863, p. 369, and in the 'Philosophical Magazine' for October 1864, and January 1865. Elementary descriptions of this method are given in the 'Engineer' of the 16th of October 1868, and in a treatise on 'Shipbuilding: Theoretical and Practical.' Their theory has not yet been carried very far; and when we have reference to three dimensions, it does not appear

* For examples of that coefficient, see the 'Civil Engineer and Architects' Journal' for October 1860, and the "Report of the Committee of the British Association on Steamship Performances," 1868.

that any specific mathematical form is to be preferred in respect of its total resistance to a long, fine, fair ship, either drawn or modelled by eye by a practised draughtsman or modeller.

A possible connexion between the resistance of ships and their depths of immersion has been pointed out by Mr. Rankine in some papers published in the 'Proceedings of the Royal Society' for 1868, p. 344, in the 'Reports of the British Association' for 1868, in the 'Transactions of the Institution of Naval Architects' for 1868, and in the 'Engineer' of the 28th August and 30th October, 1868. He shows from theory, corroborated by his own observations, and by those of Mr. John Inglis, junior, that every ship is accompanied by waves, whose velocity of advance is $\sqrt{gk}$, g being gravity, and k the *mean depth of immersion*, found by dividing the displacement by the area of water-section. So long as the speed does not exceed $\sqrt{gk}$, these waves cannot produce any additional resistance; but when the speed exceeds that limit, the waves are made to diverge from the ship at the angle whose cosine is $\frac{\sqrt{gk}}{\text{speed}}$, and thus to carry away energy, like the other diverging waves previously mentioned.

The form of the midship section does not appear to exercise any influence on the resistance to propulsion in still water, except so far as it affects the extent of wetted surface exposed to the action of the water. If the wet girth and the breadth at the water-line be given, the form of greatest area will be a segment of a circle; but this will not be the solution of the question which usually presents itself, namely, given the breadth and the draught required, the form for which the ratio of area to surface shall be the greatest possible. In the particular case in which the draught is half the breadth, it is easily seen that the ratio of area to girth is the same for a semicircular as for a rectangular section, and therefore that the solution lies between these extreme cases. It does not appear that the general problem has yet been solved, and perhaps, as the really practical problem relates to the ship and not to the midship section, it is of secondary interest. A restricted solution has been given by Mr. James Robert Napier in a paper read before the Glasgow Philosophical Society, and reprinted in the 'Mechanics' Magazine' for 24th April, 1863, vol. ix. p. 311, and in the 'Engineer' for 1st May, 1863, vol. xv. p. 245.

The best ratio for good propulsion of length to breadth and draught, even when it is assumed that the length exceeds Scott Russell's limit, is not yet known. This is not perhaps of practical importance, inasmuch as considerations of economy, capacity, and handiness generally settle these proportions, without much reference to a theoretical maximum of efficient propulsion. But the extent to which an increase of breadth or depth, leaving other things unaltered, affects the propulsion itself can hardly be regarded as within our settled knowledge.

The resistance of the air to a ship's hull is not a point to be neglected in practice or in experiment; but it is not one which we propose to discuss here.

The above contains an abstract of nearly all that is known concerning the TOTAL RESISTANCE of a ship in smooth and deep water. We do not consider it necessary in this Report to enter into the question of the increased resistances due to shallow water, narrow channels, or a rough sea. We may sum up the result in the broad statement that there exists no generally recognized theory or rule for calculating the resistance of a ship. Many such rules have been put forth; but they do not agree in their form or in their result, and the credit of each consequently rests, as a practical matter, on the reputation of its author.

Resistance considered in Detail.

It cannot be said that our knowledge of the detailed phenomena which accompany the motion of a floating body through the water extends far below the surface of the liquid. Meanwhile the following things appear to be known.

For any vessel driven through the water by any power which does not react on the fluid there must be a certain movement of the surrounding liquid, chiefly in the direction of the vessel's motion, which shall be sufficient to absorb the work done by the propelling force; for this is really nothing else than the work done by the power in overcoming the resistance. Much of this is masked by oscillatory movement. Now the setting up of an oscillation involves an expenditure of work; but the maintenance of the oscillation, once established, is independent of the force which caused it, to just the same extent that it takes work to set a pendulum swinging, but once set going, the continuance does not depend on the starting force. It follows that making a wave takes up propelling work; but that a wave once started maintains itself, or dies out, as the case may be, independently of the propeller, which it can only affect by getting in its way.

In a vessel of good form thrust through a fluid, we first meet with a head-pressure which relieves itself by the formation of a head swell, which disperses itself all round if time be allowed for it, either by the sharpness of the vessel's entrance, or by a slow rate of advance. This fixes a limit of speed, which cannot be advantageously exceeded, dependent on the length of entrance as well as on its form,—on the length alone if the form fulfil certain conditions. If the vessel be pushed beyond the speed of dispersion of this wave, it has to be pushed up hill at a loss of useful work.

The frictional resistance of the surface of the ship also carries a stream of water in the direction of the ship's motion. In fact, nearly the whole work of friction is expended on producing this stream, which forms a part of the ship's wake.

The necesssity of filling up the vacuum which would otherwise be left in rear of the ship also produces a following stream, accompanied with waves.

In vessels driven at a speed beyond what is suited to their form and dimensions, there are also supernumerary waves, an account of which will be found in Professor Rankine's writings already referred to.

In vessels of unfair form there will further be violent eddies or whirlpools, as well as extra waves. Seeing that it takes an expenditure of work to make these, it is clear that least resistance means least disturbance. In reality very little is known about these eddies. Their surface-action has been observed, and may easily be seen in dirty water, with froth especially; but their extent in depth, and their amplitude as the depth increases, are utterly unknown; and the other phenomena are not sufficiently well understood to admit of the effect of these being got at by exhaustion, that is to say, by being equated to the unexplained residue from the effects of the other known causes. Very little, again, is known about the direction in which the replacement aft takes place. The water may of course pour in either laterally or from behind, or it may well up from underneath as a wave. More or less, it probably does all three, and the proportion in which it does each is among the things which neither experiment nor theory has as yet revealed.

Theoretically it is of no importance whether we consider the ship in motion and the water at rest, or the ship at rest and the water in motion in an opposite direction. Practically the conditions are modified by the consideration that a stream of water almost always has a sloping surface, in which case a resolved part of gravity is one of the active forces*. Besides this, streams useful for experiment are restricted in depth and width, and the conditions of narrow and shallow channels introduce foreign considerations of a very complicated character.

Propulsion.

We do not consider it advisable in the present Report to enter into the question of propellers, except so far as may be necessary to the choice of experiments.

All propellers, except sails, tow-ropes, and punt-poles, do their work by the reaction arising from their driving a stream of water in the opposite direction to the ship's motion, or to their stopping or reversing streams already flowing in that direction. This is the case with oars, paddle-wheels, screws, and water-jets alike. But while they thus have one principal action in common, they are wholly different in their detailed effect upon the currents and waves which accompany the ship, and in the way in which these currents and waves react upon them. Thus the oars of a row-boat send two streams aft, at such a distance from the sides of the boat as to interfere very little with, and to be very little interfered with by, the waves and eddies due to the boat's motion. In the screw-propeller, on the other hand, a large proportion of the wake current is either stopped or reversed by the action of the screw, which also interferes with, and is it itself reacted upon by, the wave of replacement. These interferences are so large in amount as not unfrequently to mask the whole of the *slip*, from the reaction of which the propulsion is obtained, giving rise to the phenomenon of *apparent negative slip*. For a theoretical account of what is supposed to take place under these circumstances, we refer to the following Papers in the 'Transactions of the Institution of Naval Architects,' and the discussions which took place upon them:—

Rankine, "On the Mechanical Principles of the Action of Propellers."
Froude, "Note on the above Paper," vol. vi. for 1865, p. 13 *et seq.*
Reed, "On Cases of Apparent Negative Slip," vol. vii. for 1866, p. 114 *et seq.*
Rankine, "On Apparent Negative Slip."
Froude, On the same.
Rigg, "On the Relations of the Screw to its Reverse Currents," vol. viii. for 1867, p. 68 *et seq.*
Rigg, "On the Reverse Currents and Slip of Screw-propellers," vol. ix. for 1868, p. 184.
See also Bourne, 'On the Screw-propeller,' second edition, chap. iii., and Rankine, 'Shipbuilding: Theoretical and Practical,' pp. 88, 89, 247, and 259.

We consider it to be beyond doubt that the theoretical investigations of this part of the subject have been extended in advance of the point at which fresh experimental foundations ought to be laid for them.

* This remark is due to Bourgois. See his Memoir, *sup. cit.* p. 3.

Former Experiments on Resistance.

The first important experiments were those made by Bossut, Condorcet, and D'Alembert, by direction of Turgot. The results were published as a separate work in 1777, and a very full abstract of them is given by Bossut in his 'Hydrodynamique.' The chief results are summarized by Bossut as follows:—

That the resistance of the same body at different speeds, whatever be its shape, varies very nearly as the square of the speed.

That the direct head-resistance of a plane surface is sensibly proportional, at the same speed, to the area of the surface.

That the measure of the direct resistance of a plane surface is the weight of a fluid column which has that surface for its base, and whose height is that due to the velocity.

That the resistance to oblique motion, other things being alike, does not diminish by a law at all approaching that of the squares of the sines of angles of incidence; so that for sharp entrances, at least, the former theory must be completely abandoned.

Mr. Scott Russell has remarked that between certain limits the observed resistances of wedge-bows could be represented with a close degree of approximation by a formula of the form

$$R=K\left(\frac{\pi}{2\pi-\epsilon}\right)^2,$$

where K is a constant, π stands for 180°, and ϵ is the angle of the wedge, which is supposed to be of not less than 12°, and not more than 144°. See his 'Naval Architecture,' p. 168, and 'Transactions of Civil Engineers,' vol. xxiii. p. 346.

The next experiments of importance are those of De Chapman, published in his 'Architectura Navalis Mercatoria.' The result of these has already been mentioned. He performed some fresh experiments at Carlscrona, in 1795, which seemed to lead to somewhat different conclusions. See Inman's translation of De Chapman, pp. 41 and 257.

We then come to Beaufoy's experiments in the Greenland Dock from 1794–98. This enormous series of experiments can only be regarded as establishing very few facts, among which we may mention:—

That the resistance to oblique surfaces does not vary as the sine squared of the angle of incidence.

That for *unfair* bodies, such as he experimented upon, the resistance increases faster than the square of the velocity.

That increase of length, within certain limits, has a tendency to decrease resistance.

That friction of the wetted surface enters largely into the resistance.

That friction of the wetted surface appeared to increase in a ratio somewhat less than that of the velocity squared,—between $v^{1\cdot7}$ and $v^{1\cdot8}$.

He also arrives at the conclusion that bodies immersed to a depth of 6 feet experience less resistance than at the surface; but in the case of an iron plane towed flatwise, he found that resistance increased with the depression.

The whole of these experiments lose much of their value from having been tried on small models, and on bodies which are not ship-shape.

The 'Philosophical Transactions' for 1828 contain an account of experiments performed by Mr. James Walker in the East-India Import Dock. A bluff-bowed boat was towed across the dock by a rope and winch, worked by labourers, the rope being fast to a spring weighing-machine on board the boat. The boats tried were of somewhat bluff form, and it was found that the resistance varied only roughly as the velocity squared, increasing faster than that at high speeds. The drawings of the boats are not given with all the detail that could be desired, nor is the condition of their surface minutely described; but the experiment was in the right direction, being upon actual boats meant for use, and of a size far exceeding the models of previous experimenters.

Some experiments by Mr. Colthurst, both on the forms of floating bodies as affecting their resistance to motion, and on the friction of wetted surfaces, are given at p. 339 of vol. xxiii. of the 'Civil Engineers' Transactions.'

We also refer to the Report of the Committee appointed by the British Association upon the comparative resistance of bodies wholly and partially immersed (B. A. Reports, vol. for 1866, p. 148). The Committee decided to print the observed facts without any deductions. It is not necessary to the purposes of this Report that we should discuss them. We have already alluded to the difficulty which they indicate as being felt with respect to the way in which the water of replacement flows in at the stern.

We will next refer to the experiments of Captain Bourgois, which were begun at Indret, in 1844. He first had several boats from 22 to 25 feet long towed by the 'Pelican' steamer, then under his orders, and later a small merchant schooner of a little over 60 feet long, and afterwards the 'Fabert,' a brig 98 feet long. These vessels were simply towed, and their actual resistances measured with a traction-dynamometer. Similar experiments have also been tried in France with the screw-steamer 'Sphinx,' 109 feet long; with the screw despatch-boat 'Marceau,' 131 feet long (with its screw upon deck), and with the 74-gun ship 'Duperré,' 180 feet long, built by Sané. Probably nothing could be better than the experiments thus made, and it is from these that M. Bourgois has derived the coefficients of the formulæ which he has given. But, unfortunately, the particulars of the ships experimented upon are not given in great detail, nor are their drawings published. The only particulars given are the length and breadth on the water-line, the draught, and the area of midship-section immersed, but without wet surface, or even displacement.

M. Bourgois's memoir has no date; but it is evidently later than 1853, since he mentions that as the date of the experiment. It also contains some results of trials of propellers set to work against a dynamometer with the vessel made fast, and some trials depending upon the measurement of the power exerted by the engine. But we do not propose to discuss the trials on steam-ship performance. Not only is this the work of another Committee, but, inasmuch as they introduce the uncertain effects of the engine and propeller, they fail to give any accurate account of the resistance of the water.

In the earlier history of the subject, it was supposed that models would most aptly represent ships at the same speed both for the ship and the model. The experiments at the East-India Import Dock in 1827 and 1828 seem to show a dissatisfaction with the results of small models; and some time later, M. Réech, the Director of the Ecole d'Application du Génie Maritime in France, pointed out that models of different sizes intended for comparison should be made to move at velocities varying as the square roots of their lineal dimensions. In this case the actual resistances would vary as the cube of the lineal dimensions. This would follow from the theory of the resistance of submerged bodies, on the supposition that the resistance varies as the square of the speed. If, again, we consider Mr. Scott Russell's theory of the length of ships (that their extreme speed should not exceed that of an oscillating wave, bearing a definite ratio of length to that of the ship), we arrive at the same conclusion, the length of the wave varying as the velocity squared.

Proposed Experiments.

The experiments upon resistance which we consider most important to be made are these:—

That a ship of considerable size and fine form should be carefully selected; a screw steam-ship, with a screw capable of being lifted, with a clear deck, offering no unnecessary resistance to the air, and with little or no rigging.

That her form should be carefully measured in dock (her lines taken off, as it is technically called), and sight-marks carefully laid down, so as to ascertain whether she deforms in any way when afloat.

That she should be towed at various speeds, from the slowest that can be rated to the fastest that can be obtained; and that the resistance should be ascertained by a traction-dynamometer, self-recording.

That the place selected for the experiments should be a deep inland water, free from ground-swell, and such that the speed of the ship can be observed from the land as well as from the vessel. The water also should be clear enough to admit of being seen through to a considerable depth. The place, if tidal at all, should be free from cross tides or irregular currents. These conditions, it is believed, may be found both in Norway and on the west coast of Scotland.

Careful observations should also be made with a view to ascertain the direction and velocity of the local currents caused by the ship's motion. What these should be will demand careful consideration, having regard both to the ship and to the place selected, and to the *personnel* of the observers.

The same remarks will apply to the precautions necessary to prevent interference by the currents thrown back by the towing-vessel or vessels, and to eliminate other sources of error. It is of especial importance that the ship which is being towed should be kept clear of the wake of the towing-vessel or vessels. It might be necessary for this purpose to have two tug-boats with hawsers meeting at an angle in the form of the letter Y.

It is desirable that these experiments should be performed with at least two vessels considerably differing both in size and proportions, and, for each of them, with different condition as regards smoothness of surface.

A third class of experiments should also be made to determine the rate of retardation of a vessel which has been made to attain a certain velocity, and then (the propelling-power suddenly ceasing to act upon her) is allowed to come gradually to rest through the resistance of the water.

It would be desirable that the same vessels (and as nearly as possible under similar conditions of draught and trim) should be made use of for trials of propulsion, and that in these, again, a dynamometer should be interposed between the engine and the propeller; and in this case also the local currents and waves due to the joint disturbance of ship and propeller should be observed.

We consider that experiments of the kinds which we have proposed have now become necessary, not only to the theory of resistance, but also to the practical calculations of the effect of steering- and propelling-apparatus, and incidentally to the design of these and to the apportionment of engine-power and driving-speed.

Such experiments are quite beyond the means of any body but the Government of a naval power in time of peace, possessing ships which must be exercised with their crews and staff of officers. There would of course be extra expense attending such trials; but this expense is in no way commensurate with that of building experimental vessels, or arriving tentatively at the suitable forms and positions for propellers.

We therefore recommend that the Council of the British Association should authorize a deputation to apply to the Admiralty to provide for such a set of experiments in the course of the summer of 1870; also, that the Council should appoint a Committee, consisting of three Members of the Association, to confer with officers of the Admiralty respecting the detail of the experiments, and that the Admiralty should be requested to give an opportunity to the Members of that Committee of taking a share in the observations, in order that they may be enabled to make an independent report upon the results.

ROLLING OF SHIPS.

Stability and Free Oscillation.

The statical stability of a ship in still water depends upon two equations and an inequality.

Its weight must equal that of the fluid it displaces, or it will adjust itself by changing its water-line. This involves a first equation.

The centre of gravity of the displaced water must be in the same vertical line with the centre of weights, or there will be a couple which will produce rotation; after which the ship will take up a fresh position. This involves a second equation.

In case of a small angular displacement, the centre of gravity of the displaced water (or CENTRE OF BUOYANCY) must move out faster than the centre of weights; otherwise, on the slightest derangement, there will be an upsetting couple, that is to say, the equilibrium is unstable. This involves an inequality.

The arm of the couple is the horizontal distance between the centres of weight and buoyancy. The moment of the couple is the product of this into the weight, or, what is the same thing, the displacement of the ship. If the centre of buoyancy moves out faster than the centre of weight as the ship heels, there is a righting couple; if not, there is an upsetting couple, which tends to bring the ship to some new position of equilibrium.

If we consider a vessel having a plane of symmetry like that in which the masts, stern, stern-post, and keel of ordinary ships lie, and rolling transversely, we gain much in geometrical simplicity, and also in simplicity of language. We are enabled to deal with the mechanical questions by means of plane geometry, and we are still able to extend them, when necessary, by the ordinary rules of the composition of motion. For this purpose we have only to consider the axis of motion as parallel to the plane of symmetry and to the water-section. The statical stability, as already remarked, is measured by the weight, and by the horizontal distance between the centres of weight and buoyancy. But when these coincide in horizontal position, as they do when there is equilibrium, we are driven to some other measure in order to avoid indeterminateness at the limit. For this purpose we avail ourselves of the point at which the vertical line through the centre of buoyancy strikes the plane of symmetry, or *middle-line plane*, as it is technically called. The limiting position of this intersection, when the angular deviation is indefinitely small, is called the METACENTRE. This metacentre is the critical point below which, if the centre of weight be kept, there will be stable equilibrium.

It is shown in books on hydrostatics that if a floating body receive a *small* inclination, the two water-sections intersect in a line passing through the centre of gravity of each, and also that the line passing through two successive centres of buoyancy tends to parallelism with the water-section. It follows that the stability of a ship, statically considered, may be measured by the statical stability of a solid, whose centre of gravity coincides with that of the ship, but whose surface, instead of floating in water, rests on a horizontal table. This representative surface is the surface formed by the centres of buoyancy of the ship at different inclinations. The metacentre of the ship is then the centre of greatest or of least curvature of this representative surface, called the *surface of buoyancy*, according to whether we consider transverse rolling or longitudinal pitching.

When we pass from statics to dynamics, the righting or upsetting force simply represents an acceleration. But if the ship be considered as concentrated at its centre of gravity (in disregard of the actual distribution of weights in respect of inertia), the same geometrical considerations hold, and the space through which the centre of gravity rises or falls as the surface of buoyancy rolls is called the measure of *dynamical stability**. It is simply proportional to the integral of the statical stability taken with reference to the angle of inclination. Its product into the displacement gives the *mechanical work* required to heel the ship, considered as concentrated at its centre of gravity, to a given angle. An example of its use is in the solution of the problem of finding how much a ship would lie over to a sudden gust, strong enough, if it came on gradually, to heel the ship to a given angle. The rough solution is that she would lie over to double the angle of the statical stability; and this remark is of importance in judging of the safe limits of a ship's stability. This solution, it is to be observed, takes no account of the moment of inertia of the ship about its centre of gravity, and very little account of external form.

Experiment and theory both go to prove that the time in which a ship performs a complete double oscillation varies but very little, whether the amplitude of the oscillation be small or large. Hence every ship has its equivalent pendulum. If k be the radius of gyration of the ship, μ the distance between the metacentre and the centre of gravity, the length of the equivalent pendulum is $\frac{k^2}{\mu}$, the periodic time† is $2\frac{\pi k}{\sqrt{g\mu}}$, and the greatest angular velocity is $\frac{2\sqrt{g\mu}}{k}\sin\frac{1}{2}\theta$, where θ is the amplitude, or departure from the vertical; but the approximation in this last formula is much less than in that for the time.

Dupin has shown that the free rolling of a ship, regarded without refer-

* The true dynamical stability is the actual work done in heeling; but the words are ordinarily used in the sense stated in the text.

† The time here used is that of a double oscillation; *i. e.* the time which elapses between the bob of the pendulum passing the lowest point twice in the same direction. There is very often confusion between double and single oscillations, both with analysts and in the records of experiments.

ence to the disturbance or resistance of the water, is analogous to the free rolling and sliding, on a smooth plane, of the surface which is the envelope of its planes of flotation, the centre of gravity, the upward pressure of the fluid, and the moment of inertia being supposed to remain unaltered. But although this statement reads simply enough, the expressions for the time and the period, which result from it, are exceedingly complex. An investigation of it, subject to the sole restriction that the transverse section of the surface enveloping the planes of flotation shall be circular, has been given by Canon Moseley in the 'Philosophical Transactions' for 1850, p. 626, and is reprinted in his 'Engineering and Architecture.' The resulting expression depends upon a hyperelliptic integral. But we are without evidence as to how far the restriction is fulfilled by ordinary ships; and we do not find reason for supposing that the variation of the radius of curvature, which is thus taken as constant, has ever been practically investigated. There is, however, no difficulty in extending the formula to the general case; but it does not appear that the integration can be effected without introducing restrictions. At any rate the value of the integral has not yet been traced, except for small oscillations, when it reduces to the one previously given. There is a reduction in some particular cases*, and notably in the case of isochronous ships. Professor Rankine† has shown that the condition of isochronism is that the curve of buoyancy should be the second involute of a circle described about the centre of gravity.

It does not appear that the arithmetical consequences of the variation of the law connecting time and angular velocity in unresisted free rolling have ever been worked out. It would be a very laborious business; and we shall see by-and-by that it is not the chief problem.

* Let k be the radius of gyration, λ the height of the metacentre above the centre of buoyancy, H_1 and H_2 the *depths* of the centres of gravity and buoyancy—all taken for the upright position. Also let θ be the inclination and θ_1 the extreme, and ρ the *height* of the centre of curvature *above* the actual plane of flotation. Then Canon Moseley's formula gives for the periodic time of the double oscillation

$$\frac{\sqrt{2}}{g}\int_{-\theta_1}^{+\theta_1} d\theta \sqrt{\frac{k^2+(H_1+\rho)^2\sin^2\theta}{\{H_1-H_2+\frac{1}{2}\lambda(\cos\theta+\cos\theta_1)\}(\cos\theta-\cos\theta_1)}}.$$

It will be observed that $(H_1+\rho)\sin\theta$ is nothing but the horizontal distance between the centre of gravity of the ship, and that of the plane of flotation; or, in other words, the perpendicular from the centre of gravity on the normal to the flotation-envelope. It seems, at the same time, simpler and more general to use this (which we may call ν), instead of considering the curvature. We thus get for the periodic time

$$\frac{\sqrt{2}}{g}\int_{-\theta_1}^{+\theta_1} d\theta \sqrt{\frac{k^2+\nu^2}{\{H_1-H_2+\frac{1}{2}\lambda(\cos\theta+\cos\theta_1)\}\{\cos\theta-\cos\theta_1\}}}.$$

Now, if ν be constant, that is to say, if the flotation-envelope be the involute of a circle described round the centre of gravity of the ship, this reduces to a complete elliptic integral of the first kind; but the solution is not mechanical unless $\nu=0$, or the flotation-envelope reduces to a point. When, moreover, the centres of gravity and buoyancy coincide, H_1-H_2 vanishes, and the integral may be at once transformed to its regular expression by writing $\sin\theta=\sin\theta_1\sin\phi$. We then get for the periodic time

$$4\frac{\sqrt{k^2+\nu^2}}{\sqrt{\lambda g}}\int_0^{\frac{1}{2}\pi}\frac{d\phi}{\sqrt{1-\sin^2\theta_1\sin^2\phi}}.$$

The time at any moment is got by integrating from $-\theta_1$ to any value of θ instead of to $+\theta_1$.—C. W. M.

† See Trans. I. N. A. vol. v. for 1864, p. 34. See also Froude "On Isochronism of Oscillation in Ships," Trans. I. N. A. vol. iv. for 1863, p. 211.

Reverting to the approximate formulæ for small oscillations—

$$\text{periodic time}=2\frac{\pi k}{\sqrt{g\mu}}=2\,t,\ \text{suppose};$$

$$\text{greatest angular velocity}=\frac{2\sqrt{g\mu}}{k}\sin\tfrac{1}{2}\theta,$$

$$=\frac{2\pi}{t}\sin\tfrac{1}{2}\theta,$$

we see that the periodic time of the oscillation varies directly as the radius of gyration, and inversely as the square root of the metacentric height. This teaches us how to regulate the periodic time of a ship, either in settling her design, or in the distribution of her weights. We see, for instance, that a vessel with a rising floor and flaring sides tends to quick rolling, by having a high metacentre; that a cargo of railway-bars has the same effect, by bringing down the centre of gravity; and that running-in the guns and sending down the masts has a similar tendency, by decreasing the radius of gyration. The expression for the greatest angular velocity has been sometimes interpreted as indicating that quick rollers roll through large angles. The fact appears to be experimentally true, but its inference from this formula involves reasoning in a circle. The formula only shows that for the same amplitude the greatest angular velocity varies inversely as the time; but this tells us nothing about the amplitude, while the formula itself is obtained on the supposition that the amplitude is small.

The position of the ship's centre of gravity and the length of the radius of gyration cannot, practically, be obtained by calculation. The centre of gravity is generally found by shifting some known weights through known distances, and observing the angular motion. The displacement and metacentre are of course known by calculation, and the problem is then the same as if the ship were suspended from her metacentre*. The radius of gyration is found by observing the time of a small oscillation in still water, and then eliminating the effect of resistance†.

As the metacentre depends upon the moment of inertia of the plane of flotation, it is different for pitching from what it is for rolling, and so for any intermediate position‡. Practically, the metacentre for rolling varies from 0 to 20 feet (as an extreme limit) above the water-line, while that for pitching is from 70 to 400 or more feet high. The moment of inertia of the ship also varies greatly with the direction of the axis about which it is taken.

Free Rolling in a Resisting Medium.

The experiments of Messrs. Fincham and Rawson, undertaken at the suggestion of Canon Moseley§, led to the conclusion that for vessels of semicircular section in which the disturbance of the water is the least possible,

* The method, with an account of some experimental determinations on several of H.M.'s ships, will be found in the Trans. Nav. Arch. vol. i. p. 39. See also v. p. 1; vi. p. 1; vii. p. 205.

† As to this, see Mr. Rankine's Note in Trans. I. N. A. vol. v. pp. 31, 32.

‡ See Dupin, 'Applications de Géométrie.' He shows that the metacentric heights for rolling and pitching are, in fact, only the two principal radii of curvature of the surface of centres of buoyancy; and hence the metacentres for intermediate positions may be found by the help of the ellipse of curvature.

§ See Phil. Trans. for 1850, and Moseley's 'Engineering and Architecture,' pp. 616, 617.

the dynamical stability found by experiment differed very little from that derived from the rise and fall of the centre of gravity; but in the case of a model of triangular section, the stability found by experiment was in defect. In the semicircular model the extreme inclination produced by the sudden application of the force was, with a fair degree of approximation, double that due to its statical effect. With the triangular model the extreme was less than double the statical inclination. This is nothing more than might be expected from the disturbance of the water which would be set up by the angular model, and which would, of course, take up part of the work. But this experimental confirmation of theory is highly satisfactory; and, however we may now look back upon the matter, it is really upon these experiments that the confirmation of our theories rests.

In a resisting medium, the amplitude of the oscillations is very quickly affected, but the periodic time undergoes very slight change. But the period *is* altered to a slight extent. On this subject we refer, first, to the account given by Poisson, Stokes, and other writers on mechanics, concerning the oscillation of a pendulum in air; secondly, to Mr. Froude's experiments * on a pendulum oscillating in water; and thirdly, to Professor Rankine's paper on keel-resistance †, in which the measure of diminution is given on a certain hypothesis.

Bessel and Poisson have pointed out that the virtual loss of weight due to oscillation in a resisting medium is greater than that due to the mere immersion. Mr. Moseley makes the same remark with reference to the rolling of ships.

Professor Rankine has investigated the effect of the steadying-action of a keel on the rolling in smooth water, on the assumption that the moment of the righting couple is simply proportional to the inclination, and also that the moment of resistance to rolling, caused by the action of the water on the keel and floor, is proportional to the angular velocity. He finds ‡ that the periodic time is altered from

$$\frac{2\pi k}{\sqrt{g\mu}} \text{ to } \frac{2\pi k}{\sqrt{g\mu}\sqrt{1-\frac{g c^2}{4\mu k^2}}},$$

where c is a constant depending on the moment of the resistance; so that

$$c=\frac{\text{moment of resistance of water}}{\text{displacement} \times \text{angular velocity}},$$

the effect of the resistance thus lengthening the periodic time in the same

* Trans. Inst. Nav. Arch. vol. iii. p. 31. Mr. Froude has there shown that when a pendulum or ship performs isochronous oscillations in a medium the resistance of which varies as the square of the velocity, the amplitudes of the successive oscillations, as reduced by resistance, will form successive ordinates of a curve, which approaches, with a great degree of exactness, to an equilateral hyperbola, referred to one of its asymptotes, equal periods of the oscillations being represented by successive equal increments of the abscissa.

The experiments with a pendulum as exhibited in the diagram (plate 2 of the volume referred to) accord very closely with the law which may be thus expressed:—If θ_0 be the initial amplitude, and θ_m that of the mth oscillation, then that at the end of any other, say nth will be

$$\theta_n=\frac{m\,\theta_0\,\theta_m}{(m-n)\,\theta_m+n\,\theta_0}.$$

† Trans. Inst. Nav. Arch. vol. v. pp. 30, 31.

‡ Ibid.

proportion as if the inertia of the rolling mass were increased in the ratio of unity to

$$1 - \frac{g c^2}{4 \mu k},$$

and periodic rolling in smooth water becoming impossible when $g c^2$ is equal to or greater than $4 \mu k^2$.

Of Easy and Uneasy Ships.

There is much vagueness in the use of these terms. They are generally applied promiscuously to the practical hindrance caused by motion to the persons engaged in working or manœuvring the ship, to the inconvenience felt by passengers, to the straining of a ship's structure, or the tendency to shift her cargo, or to break away half-fastened weights, like boats or guns.

These all appear to depend in varying proportions on the following exact data:—

The extent or amplitude of angular motion.

The rapidity of angular motion.

The acceleration of linear motion.

But the rapidity of linear motion and the angular acceleration (except so far as this affects bending stress, or as it involves linear acceleration at a distance from the instantaneous axis) do not appear to have much practical influence.

In still water the only motion which is sufficiently great to cause inconvenience is that of rolling. Rolling sometimes produces as secondary phenomena both pitching and dipping; but neither of these are sufficient in extent, in still water, to produce inconvenience. The rolling, however, may be considerable, especially in the case of a ship going unsteadily before the wind. But if the water itself be oscillating, even moderately, or if there be a gusty wind, then a synchronism between any two of the five movements—the wind, the waves, the rolling, the pitching, or the dipping* or even (to a lesser extent) their concord at regular intervals—may cause them to enhance the effects one of another to such an extent as to become inconvenient, and in certain cases dangerous. In the case of a thoroughly uneasy ship in the most unfavourable circumstances, the axis of angular motion may assume any and every position, and the linear acceleration may take all conceivable directions; but although any particular point may describe the most irregular curves, both in form and speed, relatively to the vessel's course, yet the chief source of practical danger in open water depends upon the accumulation of motion arising from synchronism.

It appears to have been generally observed that vessels which have a short period of rolling, also roll through large angles. In this way the uneasiness of the rolling undergoes a double increase as the period diminishes. Further and more exact experiment is required before we can say how far it is connected by synchronism with wave-motion, or whether it is an independent phenomenon. Our present theories do not show it to be a necessary consequence of rolling in smooth water.

Waves.

We do not consider it necessary to go into a formal discussion of this subject. As regards the behaviour of ships, it is quite sufficient to assume that

* Dipping is the name given to the vertical oscillation of the ship as a whole relatively to the surface of the water.

the profile of a simple wave is trochoidal, and that the particles of water move in circles in a vertical plane, at right angles to the ridges and valleys of the waves. The consequences of this motion are briefly as follows, on the assumption that the depth of water is unlimited.

The diameter of the circle in which a surface-particle moves is the height of the wave from hollow to crest. Particles which in still water would be at a lower level, describe smaller circles in the same period. A horizontal plane (in the still water) is thus converted into a wave-surface of the same period, but of reduced amplitude of oscillation*. The velocity of the particles (and on this depends the *impact* of a wave) is simply the circumference of one of these circles divided by the periodic time.

If we consider a column of particles which is vertical in still water, that column oscillates in wave-water like corn-stalks in a gust of wind, and it also oscillates vertically. But it always slopes *towards* the crest of the wave, and the obliquity thus induced goes to enhance that due to the wave-slope; so that if we regard the profile of a wave, a small portion of water, rectangular when still, undergoes a double deformation, the horizontal surfaces following the wave-slope, and the vertical surfaces being deflected towards the crest, both causes tending to increase the angular deformation instead of to preserve rectangularity.

The crest of the wave being sharper than the hollow, and the quantity of water invariable, the horizontal plane which lies halfway between valley and crest is higher than the mean, or still-water, level; and its elevation has been shown to be equal to the height due to the velocity of revolution of the particles.

Considered as trochoids, the wave-profiles are traced by a point within a circle rolling *under* a horizontal line. The line midway between valley and crest is the line of centres.

The particles of water above the line of centres are moving forwards, as regards the direction of advance of the wave; those below that line backwards. The particles in the front face of the wave are rising, and those in the rear-face falling.

The wave whose period is $\frac{1}{n}$th of a second has a length of $\lambda = \frac{g}{2\pi n^2}$, whence we find the number of waves to a second to be $n = \sqrt{\frac{g}{2\pi\lambda}}$. The velocity of wave-propagation, that is to say, of the apparent advance of the wave in a deep sea, is $n\lambda = \sqrt{\frac{g\lambda}{2\pi}} = \frac{g}{2\pi n}$. In other words, the speed of the wave-crest varies as the periodic time, and the length of the wave varies as their product, or as the square of either.

The vertical disturbance of a particle whose depth in still water would be k is

$$h^{k} = h\epsilon^{-\frac{2\pi}{\lambda}}$$

h being the height of the surface-wave.

* Drawings of the structure of a trochoidal wave will be found in the British Association Reports for 1844, plate 56; Trans. I. N. A. vol. i. for 1860, plate 7, vol. iii. for 1862, plate 3, vol. iv. for 1863, plate 10, and vol. vi. for 1865, plate 10; 'Shipbuilding: Theoretical and Practical,' Rankine, p. 69; Scott Russell, 'Naval Architecture,' plate 117.

No wave can be sharper than a cycloidal wave; for if the trochoid were looped, the particles in the loop would be unsupported. When the wave form tends to pass the cycloid, it must break.

The extreme observed height of ocean-waves appears to be about 40 feet, and the greatest observed length 600 feet; these would have a periodic time of 11 seconds (roughly); their crest would advance at a rate of 33 knots an hour, and the velocity of the surface-particles would be about 11·4 feet per second. In short waves of the same height the particles of water move faster, in the inverse ratio of the period; but the mass of moving water at the crest of the longer wave is the greater in the ratio of

$$\lambda - \pi h : \lambda^1 - \pi h,$$

where λ and λ^1 are the lengths, and h the height. If, therefore, the above-mentioned wave were shortened to 200 feet, the surface-particles would be moving at a note of 20 feet a second, while the mass of water in the crest would be about one-sixth. From such data it is easy to infer both the destructive effect of impact from the top of a wave, and the relative quantity of water which a ship would take on board in shipping a sea.

The front and rear of a trochoidal wave are exactly similar. Observation, as well as theory, shows that this is true to an extent not commonly believed for ordinary waves. The exceptions are, when the wind is sufficient to push the tops of the waves at extra speed, and when the water shoals rapidly. But even here the relative steepness of the advancing face is exaggerated by most observers. Until a wave is about to break, the actual difference of slope remains very small.

It should be borne in mind that circular orbits and trochoidal wave-surfaces are only approximations, although near enough to the truth for purposes connected with the rolling of ships. In particular, it appears both from theory and observation that there is almost always some progressive motion combined with the orbital motion; and also that waves begin to break long before their crests attain a form so sharp as that of the cusped cycloid, the two slopes at the crest of a breaking wave cutting each other at right angles, or nearly so*.

The ordinary wave of a rough sea is usually an aggregate of waves of different period, and not unfrequently of different direction. For rough purposes, it is sufficient to draw each system of waves separately and add their corresponding ordinates, to get the resulting surface. This can hardly be relied upon in extreme cases; and, in any case, the motion of each particle is not according to any one or more wave-systems separately, but it is a motion compounded of what would be due to each separately if the others were not.

Oscillations of a Ship among Waves.

A Treatise on 'Shipbuilding: Theoretical and Practical†,' edited by Professor Rankine, contains, in a very clear and condensed form, a *résumé* of nearly all that was known on this subject up to 1864 inclusive. The following abstract is chiefly taken from that work:—

It is to be observed that what follows relates to the composition of the ship's oscillation with that of a simple trochoidal wave. The complete problem of a ship's behaviour, depending as it does on wind, waves, rolling, pitching, dipping, yawing, variable head-resistance and lateral resistance,

* See Phil. Mag. Nov. 1864.

† See pp. 72, 77 of that work.

and direction of motion relatively both to wind and waves, is far too complicated even for statement in an exact mathematical form.

If a ship floating passively in the water, and without any progressive motion, were wholly without stability, her centre of gravity, centre of buoyancy, and metacentre coinciding in one point, the motion assumed by that point would be exactly that of the centre of gravity of the mass of water displaced by the ship—that is to say, it would revolve once in each wave-period in a vertical circle of the same diameter, with the orbits of the particles of water situated in the same layer.

This motion of the ship has received the name of *passive heaving*, that term being understood to comprehend the swaying from side to side, as well as the rising and sinking, of which the orbital motion is compounded.

Half the difference between the extent of heaving of the ship and the height of the waves is the extent to which, during the passage of the waves, her depth of immersion amidships is liable to be alternately increased above and diminished below her depth of immersion in smooth water. It appears that deep immersion and large horizontal dimensions, but especially deep immersion, tend to diminish the extent of the heaving motion of the ship as compared with that of the waves, and that the effect of those causes in producing this diminution is greatest among comparatively short waves.

The weight of the ship, being combined with the centrifugal force due to her heaving motion, gives a resultant reaction through her centre of gravity inclined to the vertical in a direction which, for passive heaving, is perpendicular to the wave-surface traversing the ship's centre of buoyancy (a surface which may be called the *effective wave-surface*); and that direction is the *apparent* direction of gravity on board the ship, as indicated by plumb-lines, pendulums, suspended barometers and lamps, spirit-levels, and the positions assumed by persons walking or standing on deck. The equal and opposite resulting pressure of the water, acting through the centre of buoyancy, is in like manner compounded of actions due to weight and centrifugal force; and it acts in a line normal to the effective wave-surface, that is to say, parallel to the resultant reaction of the ship. Those two forces balance each other, not when the ship's upright axis is vertical, but when it is normal to the effective wave-surface; and when she deviates from that position, they form a righting couple tending to restore her to it. Thus the stability of a ship among waves, instead of tending to keep her steady, as in smooth water, tends to keep her *upright to the effective wave-surface*; and such is the motion of any vessel or other floating body having great stability and small inertia, such as a light raft. This may be called *passive rolling*, or *rolling with the waves*.

Passive rolling is modified by the inertia of the ship, which makes her tend to perform oscillations in the same periodic time as in still water, by the impulse and resistance of the particles of water against her keel and the sharp parts of her hull, which tend, under certain circumstances, to make her roll against the waves, that is, inclining towards the nearest wave-crest, and by other circumstances.

The tendency to keep upright to the effective wave-surface may be distinguished from the tendency to keep truly upright, by calling the former *stiffness* and the latter *steadiness*. In smooth water stiffness and steadiness are the same thing; amongst waves they are different, and to a certain extent opposed; that is to say, the means used for obtaining one of those qualities are sometimes prejudicial to the other. Stiffness is favourable to the dryness of the ship, and to the power of carrying sail; steadiness is favourable to her strength and durability, and the safety of her lading, and, in ships of war, to the power of working guns in rough weather.

A ship whose course is either oblique or transverse to the wave-crests is made by the waves to perform a series of longitudinal oscillations, which may be called *passive pitching and scending.*

In all the oscillatory movements which a ship performs among waves, two series of oscillations are combined—those in which the ship keeps time with the waves, being her passive or forced oscillations, and those which she performs in periods depending on her own mass and figure, as in smooth water, being what may be called her free oscillations. The tendency and ultimate effect of the resistance of the water is to destroy the free oscillations after a certain time, so that the forced oscillations alone are permanent.

Passive heaving, or the motion of a ship when each of her particles performs an orbital motion, similar and equal to that of a certain particle of the water in which she floats, takes place when the ship floats amongst waves without having progressive motion.

The progression of the ship, when under way, alters the action of the waves upon her in various ways, which depend mainly upon the *apparent period* of the waves relatively to the ship (that is, the interval of time between the arrival of two successive crests at the ship), and upon the *apparent slope* of the effective wave-surface in a direction athwart the ship, the latter circumstance being connected mainly with forced rolling oscillations.

When the apparent periodic time of the waves is modified by the progressive motion of the ship, the time during which the forces act which produce the heaving motion of the ship is altered in the ratio of the apparent period to the true period; and the extent of the heaving motion is also altered in a proportion which, for moderate deviations of the apparent from the true period, varies nearly as the square of that ratio. This law, however, does not continue to hold for a very great increase of the apparent period, the extent of heaving being less than the ratio first mentioned.

Hence the heaving motion of a ship is more extensive than that of the effective wave-surface, when the angle made by her course with the direction of advance of the waves is acute, and less extensive when that angle is obtuse.

Yawing, or swerving of the vessel from side to side by oscillation about an upright axis, is, when produced by the waves, the effect of the lateral swaying, which forms the horizontal component of the heaving motion, taking place with different velocities, or in opposite directions at the bow and stern of the vessel. The forces producing it are greatest when her course lies diagonally with respect to the direction of advance of the waves.

For reasons already stated, a very light and stiff ship tends to float like a raft rolling *with the waves,* and assuming at every instant the same slope with the effective wave-surface.

Let a board, having very little inertia, and no stability, be placed so as to float upright in smooth water; then, when the water is agitated by waves, that board will accompany the motions of the originally upright columns of water—that is to say, it will roll *against the waves,* inclining at every instant in a direction contrary to the slope of the effective wave-surface.

It has been shown by Mr. Scott Russell * that the condition of the broad and rounded parts of a ship, and of her hull between wind and water, is

* Trans. I. N. A. for 1863.

analogous to that of a raft; while the condition of the keel, the sharp part of the floor, and the gripe and dead wood (or fine parts of the ends) is analogous to that of the board floating edgewise, so that the ship is under the action of two conflicting sets of forces—gravity, centrifugal force, and pressure (constituting what may be called stiffness), tending to make her roll with the waves, like the raft; and the action of the water on the keel and sharp parts of the hull, which may be called *keel-resistance*, tending to make her roll against the waves, like the board, and hence that she will take some kind of intermediate motion.

It has been pointed out, however, by Mr. Froude and Professor Rankine * that there is an essential distinction between the two sets of forces before mentioned, in consequence of which, though conflicting, they are not directly opposed—namely, that the stiffness is an active force, which tends not only to prevent the ship from deviating from a position upright to the effective wave-surface, but to restore her to that position after she has left it, with a force increasing with the deviation; while the keel-resistance is merely a passive force, opposing the deviation of the ship from the position of the originally vertical columns of water, with a force depending, not on that deviation, but on the velocity of the relative motion of the ship and the particles of water, and not tending to restore the ship to any definite position. Hence those two kinds of force cannot directly counteract, but only modify one another.

For the mathematical investigation of the action of those forces reference must be made to the original papers in the 'Transactions of the Institution of Naval Architects.' The following are the general conclusions:—

The permanent rolling of a ship of very great stability, and without any sensible keel-resistance, is governed by the motion of the effective wave-surface, so that she rolls *with the waves* or like a raft.

When the period of unresisted rolling of the vessel is to the wave-period as $\sqrt{2} : 1$, the permanent rolling is wholly governed by the motion of the originally vertical columns of water; so that she rolls *against the waves*, like a board of no stability floating edgewise.

In both of the preceding cases the vessel is upright when the trough or crest of a wave passes her, and her angle of heel is equal to the steepest slope of the effective wave-surface.

When the period of unresisted rolling of the vessel is less than the above value, her upright positions occur *before* the arrival of the troughs and crests of the waves, and her angle of heel is *greater* than the steepest slope of the effective wave-surface.

The greatest angle of heel in permanent rolling occurs when the period of unresisted rolling of the ship is *equal to that of the waves*, and it exceeds the slope of the waves in a proportion which is the greater the less the keel-resistance, and becomes infinite when the keel-resistance vanishes. Thus isochronism with the waves is the worst quality that a ship can have as regards steadiness and safety.

When the period of unresisted rolling of the vessel exceeds that of the waves in a greater ratio than that of $\sqrt{2} : 1$, her upright positions occur *after* the arrival of the troughs and crests of the waves, and her angle of heel is less than the steepest slope of the waves.

The forced or passive oscillations of ships are those which produce the most severe strains, because of their continual recurrence, the free oscillations being gradually extinguished by the resistance of the water. It

* Trans. I. N. A. for 1863-64.

appears, however, that the periodic time of the free oscillations has an important influence on the extent of the forced oscillations, especially in rolling, the most unfavourable proportions for the periodic time of free rolling to that of passive rolling being those which lie near equality, and between equality and $\sqrt{2} : 1$; for the equality of these periods tends to produce an excess of rolling to which it would be difficult to fix a limit, and the ratio of $\sqrt{2} : 1$, and those near it, make the ship roll against the waves, thus throwing her into positions in which there is a risk of the wave-crests breaking into her.

A period of free rolling much less than that of passive rolling gives great stiffness, and makes the ship accompany the motions of the effective wave-surface. A period of free rolling exceeding $\sqrt{2}$ times that of passive rolling is favourable to steadiness, provided that this lengthened period be produced by the inertia of the ship, and not by insufficient statical stability.

The action of the water on a deep keel, on a sharp floor, or on fine ends below water tends to moderate the extent of rolling produced by coincidence, whether exact or approximate, of the periods of free and passive rolling; but at the same time it lessens the effect of a long period of free rolling in producing the same result.

A deep draught of water is favourable, on the whole, to steadiness, but not to stiffness.

Should the centre of gravity rise and fall relatively to the water in rolling, and the periodic time of the dipping motion so generated happen to be either exactly or nearly one half of that of the passive rolling, the result will be uneasy motion.

The steady pressure of the wind on the sails promotes steadiness, at a certain angle of heel depending on the moment of that pressure; the sudden gusts of the wind produce lurching.

As to *pitching*, *scending*, and *yawing*, it is chiefly important that, for the sake of dryness and safety, those oscillations should be performed in a lively manner among waves; and that object is best promoted by keeping the longitudinal radius of gyration short, as compared with the length of the ship—that is, by taking care not to place heavy weights in her ends.

The true principles of a ship's rolling among waves and their leading consequences were first set forth by Mr. Froude, in a series of papers in the 'Transactions of the Institution of Naval Architects,' in 1861, 1862, and 1863. Mr. Froude appears to have been the first to state the proposition that the tendency of the ship to roll among waves is primarily due to her tendency to keep upright to the effective wave-surface, and that the force which induces this tendency is very approximately the same as her *stiffness* or resistance to heeling in still water. The disposition of a ship to follow the average motion of the portion of the wave which she displaces is, however, controlled (as has been pointed out by Mr. Crossland) by the circumstances that the wave-water is continually undergoing a deformation of which the ship's hull is not susceptible. Mr. Froude has also shown * that if two plates be hinged together, so that, when in still water, they would float at an inclination of 45° to the vertical, and if the hinge be parallel to the wave-crest, the effect of the wave-motion is simply to open or close the angle between them, and not to alter (sensibly) the horizontal and vertical lines which bisect the angle externally and internally.

As there is nothing to show that the rigidity of the angle between the

* See Trans. I. N. A. vol. vi. for 1865, p. 181.

plates would tend to make any marked alteration in the invariability of direction of the bisectors, the theoretical establishment of this fact is of great importance. Its meaning is that the effect of bilge-keels is to increase the time, and, in a greater degree still, to diminish the amplitude of the oscillation, and that the use of bilge-keels is the direct mode of effecting this object.

The problem of safe rolling is not quite the same with that of easy rolling. A roll towards the wave-crest is well known as one of the most dangerous things that can happen to a ship in a high-crested sea-way, for the whole crest of the wave may then break inboard. Even when the ship follows the oscillations of the vertical lines, the wave-particles come flat on the ship's bulwarks and side. If she floats quite vertically she is still in the position of a cliff resisting a wave of the same period, whose height is the difference of heights of the surface-wave and of the mean effective wave acting upon her.

As regards the impact of a wave, the most violent blow that a wave can give is against a surface parallel to the inflexional tangent and to the wave-crest, and at a level with the line of inflexion. The motion of the particles is then normal to the wave-surface. This remark, of course, does not apply to shore-waves.

Throughout the discussion of the ship's oscillation among waves, it has been tacitly assumed that the wave-period itself might be regarded as constant. This is very far from either representing the facts or the practical problem of the shipbuilder. The wave which a vessel has to encounter may be anything, from the 11-seconds wave, 600 feet long, to a mere ripple. Practically, a vessel will not roll to waves whose length is much less than her breadth, nor will she pitch much among short waves. But, dismissing these from consideration, it may still be impossible to avoid some contingency in which a ship's period of free rolling may be equal to the wave-period. Obviously, the remedy in this case is for her commander not to keep her *broadside-on*. As a rule, no commander ever would do so in a dangerous sea-way; and even where comfort only is concerned, it is usually open to him either to shorten the effective (that is to say, the *apparent* wave-period) by putting her head a little to the swell, or to lengthen the apparent wave-period by putting her head a little off. He *must* do one of these things if he meets with actual and exact synchronism in anything like heavy weather.

As a practical matter, Professor Rankine remarks: "It would appear that a very close approximation to the form and proportions which are most favourable to steadiness has, in some cases, been realized by practical trials alone, and that independently of the steadying action of sails; for there are vessels which, when under steam alone, in any moderate swell keep their decks very nearly parallel to the horizon. It is of great importance that the lines and dimensions, and distribution of the weights of ships, which have been found by experience to possess this excellent quality, should be carefully recorded for the information of naval architects.

"On the other hand, there are vessels (especially screw-steamers) whose ordinary extent of rolling each way is from three to four times the slope of the waves."

On the subject of Waves, we refer to the following papers and treatises:—

Weber, 'Wellenlehre.'

Airy, "On Tides and Waves," Encycl. Metropolitana (reprinted in a separate form).

Scott Russell, Report to British Association for 1844. Also, 'Modern Naval Architecture.'

Stokes, 'Cambridge Transactions,' 1842 and 1850.

Earnshaw, 'Cambridge Transactions,' 1845.

Froude, 'Transactions of the Institution of Naval Architects,' 1862, p. 48, and (incidentally) in his papers "On Rolling." Also, "Remarks on the Differential Wave in a Stratified Fluid," Trans. I. N. A. vol. iv. for 1863, p. 216.

Rankine, 'Philosophical Transactions,' for 1863; 'Phil. Mag.,' Nov. 1864; 'Proceedings of the Royal Society,' 1868; also, 'Shipbuilding: Theoretical and Practical.'

Cialdi, 'Sul Moto ondoso del Mare.'

Caligny, papers in Liouville's Journal, 1866.

T. Stevenson, 'On Harbours.'

With regard to the rolling of ships in wave-water, we believe that almost the only exact investigations are to be found in the 'Transactions of the Institution of Naval Architects,' some of which have been reproduced in 'Shipbuilding: Theoretical and Practical,' and reprinted in the 'Engineer' and in 'Engineering.' They are as follows:—

Froude, "On the Rolling of Ships," vol. ii. for 1861, p. 180, with Appendices, vol. iii. pp. 45 & 48.

Woolley, "On the Rolling of Ships," vol. iii. for 1864, p. 1.

Crossland, "On Mr. Froude's Theory of Rolling," vol. iii. p. 7.

Rankine, on the same, vol. iii. p. 22; "On the Comparative Straining Action of different kinds of Vertical Oscillations upon a Ship," vol. iv. for 1863, p. 205.

Scott Russell, "On the Rolling of Ships," vol. iv. p. 219.

Froude, "Remarks on Mr. Scott Russell's Paper," vol. iv. p. 232.

Scott Russell, rejoinder, vol. iv. p. 276.

Woolley, Mem. on same subject, vol. iv. p. 284.

Rankine, "On the Action of Waves upon a Ship's Keel," vol. v. for 1864, p. 20. "On the Uneasy Rolling of Ships," vol. v. p. 38.

Lamport, "On the Problem of a Ship's Form," vol. vi. for 1865, p. 101.

Froude, "On the Practical Limits of the Rolling of a Ship in a Sea-way," vol. vi. p. 175.

Reed, "On the Stability of Monitors under Canvas," vol. ix. for 1868, p. 198.

An abstract of the leading principles will be found, as already stated, in 'Shipbuilding: Theoretical and Practical,' edited by Mr. Rankine.

Some valuable practical observations on the rolling of ships in waves will also be found in a pamphlet, 'Du Roulis,' by Captain Mottez, of the French Imperial Navy.

Measurement of Waves at Sea.

This is a thing which has seldom been done with any degree of accuracy. Not only is the vessel moving, but the apparent direction of gravity is not the true one. The result is, that the difference of direction between the tangents to two waves from a point a little behind the spectator is generally taken for the apparent angular height. This may evidently be far in excess of the true apparent height *.

* See Mr. Rankine's "Remarks," Trans. I. N. A. vol. iii. p. 27.

Admiral Paris has invented a self-recording instrument for the purpose of measuring both the height and form of waves. A description of this will be found in the Trans. I. N. A. vol. viii. 1867, p. 279. It is unfortunately a differential instrument, without any means of getting a good datum line. It appears to be much better adapted for getting approximate profiles of complex waves than for obtaining accurate measurements of simple ones.

Observations on the lengths of waves present much less difficulty: a float, sunk so as not to catch the wind (such as a bottle), and observed from a considerable height, will give the periodic time with a fair degree of accuracy, and the length may be inferred from the period.

General observations upon waves * are not in point. The object in the present case is to ascertain what the particular waves are in which the ship's rolling is being observed.

Measurement of Rolling.

It is very well known that a pendulum at sea does not give a vertical line, but a direction due to the joint effect of gravity, of its own free oscillation, and of the forced oscillation due to the motion of its point of suspension. A suspended clinometer is thus perfectly useless for this purpose. Barometers, cuddy-lamps, and chandeliers generally oscillate through larger angles than the ship.

Mr. Froude (Trans. I. N. A. for 1862, p. 41) suggests watching the rattlins of the rigging come down to the horizon, as a ready and fairly correct way of measuring the roll. The motion of the mast-heads relatively to the stars may be used in the same way.

M. Normand, jun., of Havre, has invented a very ingenious clinometer suspended on gymbals, like a chronometer, in such a way as to be as little as possible influenced by the ship's motion †. We do not consider that any instrument depending upon gravitation is to be relied upon at sea, and we have been informed that M. Normand himself is not quite satisfied with his instrument.

Apart from observations depending on the stars, or actual sea-horizon, the only instrument that can be relied upon as giving an invariable plane is of the gyroscope class. A modification of Foucault's gyroscope was tried in the North Sea in 1859, by Professor C. Piazzi Smyth, who gave an account of the instrument and its performance in the Trans. I. N. A. for 1863, p. 118.

An instrument upon the same rotatory principle, but self-recording, has been invented by Admiral Paris, Hydrographer of the French Imperial Navy. It consists of a spinning top, with its point of support above its centre of gravity. It spins in an agate cup, and the top of the spindle carries a camel's-hair pencil which marks a paper band, driven by clockwork, and passing through bent guides so as to keep close to the pencil. It is described, and some of its curves copied, in the Trans. I. N. A. vol. viii. for 1867.

What these instruments really give is the deviation from an undetermined direction. They therefore give the time of rolling or pitching, and of any intermediate oscillation of a periodic character, and the amplitude of

* Although very desirable for other reasons.

† See Trans. I. N. A. for 1866, p. 187.

deviation from the mean line; but they evidently would not disclose any steady inclination to which the rolling might be superadded.

The gyroscope or top will, of course, have its own proper oscillatory revolution, which, however, soon spins out, on the same principle that a peg-top "sleeps."

On the whole, there does not seem to be much room for improvement in Admiral Paris's instrument, unless, perhaps, in diminishing the atmospheric resistance. Possibly also provision might be made for adjusting the point of support to the centre of gravity.

Recommendation of Experiments on Rolling.

The mathematical theory of rolling is very far from easy, and leads to equations of which there is no known solution. The time of a common pendulum, for instance, depends upon an elliptic integral, and, beyond the degree of complexity involved in such a function, mathematics are in the condition of uncleared ground. Accordingly, while it is possible to give a rational account of the immediate gross results of a compound oscillation, these results cannot be expressed or measured with the requisite combination of generality and accuracy. In order to treat them, we are obliged to introduce simplifying suppositions, which do not necessarily belong to our problem—as, for instance, isochronism, or the neglect of certain elements of resistance, or the grouping of others.

Now, when this occurs with any branch of practical knowledge, the proper mode of applying mathematical investigation is to start, not from the known principles of general mechanics, but from an advanced base of observations peculiar to the science itself. In hydrodynamics, between minuteness and number, the ultimate molecular unit escapes our notice, and we are only able to observe effects in the gross; being thereby driven to a certain want of detail, both of observation and of reasoning, which allows us to trust our conclusions only when they have been made to rest on a broad experimental foundation. Whether we regard the theory of the propulsion of ships, or that of their rolling, our analysis has assuredly been pushed quite to the extreme verge to which general reasoning can be trusted; and a largely increased extent of exact observation ought to precede further attempts at inductive reasoning on these subjects. We have many exact experiments on propulsion, although, from the complicated character of the phenomena involved, it is difficult to separate the issues; and this will probably not be set right without further special investigation. With regard to rolling, however, we have much vague observation, and but little exact knowledge derived from experiment.

We are not aware of any one published experiment on the rolling of ships in waves in which the details necessary to make any mathematical use of the results are supplied. The data required are, as a minimum for each case,—

1. A draught of the ship, and her calculated elements.
2. The position of her centre of gravity.
3. Her periodic time in still water.
4. The condition of her wet surface.
5. The extent and period of her roll.
6. Was the rolling simple, or mixed with pitching?
7. The height, length, and period of the waves in which she was rolling.
8. Were these waves simple?
9. What alterations have been made in her displacement, her trim, and

the position of her weights, as regards both centre of gravity and moment of inertia, previously to the trial?

10. Force and direction of wind, and condition of ship as regards resistance to it.

11. Full details as to manner in which, and the instruments or calculations by which, these data have been ascertained.

There is no doubt that for a comprehensive view of the subject, it would be necessary that these things should be ascertained with care for a large number of ships, of various classes, and under very varied conditions. But this is too much to expect to get done, although we think it would be a good thing for the Government, and other large shipowners, to keep in view as an ultimate object. Meanwhile we think it would be a very great experimental aid to science if these things could be accurately settled for even two or three ships, under different circumstances of weather and different arrangements of weight, both in amount and distribution.

Similar experiments should also be made with reference to pitching.

The trials should be made with sails furled, and as little disturbance from headway as possible. We have every wish to have parallel experiments tried under any possible conditions of sail and propulsion, and, if it may be done, on the same ships, consecutively with the simpler experiments; but it will be seen that the data are already sufficiently complex at the best, and that they must be used clear of headway and leeway before they can be discussed with reference to these.

No experiments are of use for the purpose of inductive reasoning in which any one of the data mentioned above are wanting.

We think that the Government might fairly be asked to institute such a set of calculations and experiments. We cannot find that the exact information which we have suggested is in existence anywhere. We are certain that it has not been published in any available form; and we have reason to believe that the knowledge is quite as much needed and desired by the gentlemen responsible for the construction of the navy as by merchant builders or by students of theory.

We therefore recommend that the deputation previously mentioned with reference to the experiments on resistance be also instructed to urge upon the Admiralty the importance, both practical and theoretical, of instituting such a set of experiments, of providing suitable instruments for recording exact observations, and of publishing the results. We also recommend the appointment by the Council of the Association of a committee of *three* members to confer with the officers of the Admiralty as to the drawing up of detailed instructions for conducting these experiments; and that the Lords of the Admiralty, in the event of their assenting to the proposals, be requested to nominate a committee to confer with the committee named by the Association.

In conclusion, we beg leave to recommend that this Report be officially communicated to the Councils of the Institution of Naval Architects, the Institution of Civil Engineers, and the Institution of Engineers in Scotland, and the cooperation of those bodies sought, both in applying to the Government and in making known among shipbuilders, and other persons connected with Naval Architecture, as well what is the state of our existing knowledge as what are the immediate desiderata for its extension.

CHARLES W. MERRIFIELD.
GEORGE P. BIDDER.
DOUGLAS GALTON.
W. J. MACQUORN RANKINE.
W. FROUDE (*subject to the following explanations*).

Mr. Froude's Explanations.

The subject of a ship's resistance is one which I have for many years been independently investigating, both theoretically and experimentally; and I have been thus led to conclusions which are in very material respects at variance with those which Mr. Merrifield has placed on record for the Committee as representing the existing state of knowledge respecting it, and specially at variance with the consequent recommendations which he has drawn up, as indicating the experiments for the performance of which the assistance of Her Majesty's Government is to be sought: I thus find myself somewhat abruptly placed in a position in which I must ask permission to present, as part of our proceedings, a supplementary report explaining the reasons which oblige me to dissent from the recommendations to which I refer. Until the Draft Report was in my hands, I was unaware that "Resistance" was regarded as included in the list of subjects submitted to the Committee; for I understood the terms "Stability" and "Sea-going qualities" as having reference to the theory of "Rolling motion," and "Propulsion" to the theory of the Action of Propellers. The subject of Resistance appeared to belong already to the "Steamship Performance Committee."

Let me say at the outset that Mr. Merrifield's very full discussion of this subject appears to me to set forth most lucidly what must be called "the existing state of knowledge" respecting it; it has evidently involved much laborious research and deep consideration.

And, on the other hand, the results at which I have arrived are in many respects so far from complete that I have hitherto hesitated to bring them before the public. But I believe I have so fully established those conclusions, to which I shall now refer, and the difference in the line of action to which they point is so serious that, under the present circumstances, I feel bound to press them on the notice of the Committee.

The Report specially recommends, as the experiment which it is important to try, the dynamometric determination of the scale of resistances for a full-sized ship.

Now, without impugning, or rather, while fully asserting that any scale of resistance, in terms of velocity, accurately determined for a full-sized ship, would be of real value and of great interest, I shall nevertheless contend (1) that experiments on the resistances of models of rational size, when rationally dealt with, by no means deserve the mistrust with which they are usually regarded, but, on the contrary, can be relied on as truly representing the resistances of the ships of which they are the models; and (2) that in order properly to open up the question, so great a variety of forms ought to be tried that it would be impossible, alike on the score of time and expenditure, to perform the experiments with full-sized ships. Both these propositions require to be drawn out at some length. The kindred proposition, that as accurate results can be obtained far more easily and rapidly in experimenting with a model than with a ship, though of great importance, is so obviously true as to require no elucidation.

The natural expectation that the ascertained resistance of a model will furnish a measure of the resistance of a ship similar to the model, depends on the *primâ facie* probability that the resistance for a given body will vary as the square of its velocity; and that in comparing similar bodies of different dimension at a given velocity, the resistance will be as the square of the dimension, since that function expresses alike the proportion of the respective midship sections and of the respective friction-bearing surfaces. Were these propositions true, the ascertained resistance of a model, at given velocity, would supply a complete scale of resistance for all velocities, both for the model and for any ship similar to the model.

Since, however, the resistance of a model or ship deviates from the law of the square of the velocity, as under certain circumstances it is known to do, in a manner dependent on its actual dimensions, it is obvious that the simple scale of comparison, which seemed *primâ facie* probable, can be no longer accepted, and it has hence been hastily concluded that no assignable scale of comparison can be found instead.

Now it appears to me to be pretty well established, and it is scarcely questioned, that, for deeply submerged bodies of tolerable size and fair shape, the resistance does follow the law of the squares with a high degree of approximation. Such deviations from this law as appear in Beaufoy's experiments are, I think, explicable by the angularity of the shapes tried and by the mode of trying the experiments, under which the considerable distance between the bodies tried and the conducting float by which they were carried involved some deviation of the body from true axial motion, when the velocity and the consequent resistance became considerable.

That surface-friction, in particular, follows the law of the squares of the velocity very closely, is well established by the experience of the flow of water through pipes, in reference to which, I may observe, I have myself experimentally verified on a five-mile length of 9-inch pipe, the law that the delivery is almost exactly as the square root of the steepness of the hydraulic gradient. The experiments were tried with very great variations in the steepness*. Now Professor Rankine's admirable stream-line investigations have definitely established the conclusion that for symmetrically shaped bodies of "fair" lines, not excluding by that description certain very blunt-ended ovals, when wholly submerged, the entire resistance depends on the conditions of imperfect fluidity, of which surface-friction is the only one so considerable that we need take account of if we deal with bodies of rational dimensions; and this, as I have pointed out, does follow the law of the squares. I set aside the condition of "viscosity"; for though this defect, even as it exists in water, is certainly sufficient to affect differently the resistances of bodies of different dimensions, this is not sensibly the case unless the bodies are very minute; and having regard to the great vitality of such small surface-waves as (say) one foot in length, and to the fact that discharge of water through pipes and orifices exhibits no results indicative of this special action, unless the diameters are very small indeed, it seems extremely improbable that the resistances of bodies five or six feet in length will be affected by it. If, therefore, we were dealing with submerged bodies, we should have no reason to mistrust the *primâ facie* deductions founded on experiments with models.

When, however, we deal with a body moving at the surface, we at once meet with a *vera causa*, which alters those simple relations that exist between the resistances of differently dimensioned submerged bodies. This *vera causa* is the generation of surface-waves, which accompanies the transit of the body along the surface; and it is, I believe, not merely the only known cause, but a sufficient one.

What absolute conformation and magnitude of waves a given vessel moving with a given velocity may create, and what excess of resistance may thus be

* Though I regard these experiments as sufficiently conclusive in reference to the point to which they were directed, I am inclined to think that the theory of surface-friction in its application to a ship's resistance requires considerable revision.

developed in any individual instance, it is not necessary for the present purpose to determine; for it will appear that, whatever the excess may be, however abnormally, in virtue of it, the law of resistance for any given ship may vary in terms of her velocity, a very simple scale of comparison will express the relation between the excess as developed in a model and as developed in a ship similar to the model when moving at a corresponding velocity. I shall show, in fact, that if the velocities of the ship and the model are as the square roots, these excesses of resistance thus arising will be as the cubes of their respective dimensions, a law which, as is easily seen, expresses also the relation founded on those elements of resistance which vary as the square of the velocity and as the squares of the respective dimensions.

The principles on which Professor Rankine's stream-line investigations are founded establish generally, in relation to all wholly submerged symmetrical bodies moving in a fluid infinitely extended on all sides, that the stream-line displacements which the motion of the body imposes on the surrounding volumes of fluid are, for a given body, identical in configuration for all velocities (an identity which assigns to them always a velocity proportional to that of the body itself), and that the configuration is similar for all similar bodies.

If we now suppose that the body is moving along the surface of the fluid, and if we imagine the surface to be not under the influence of gravity or any such force, it is obvious that here also the configurations of the stream-line displacements will be identical at all velocities for the same body, and will be similar for similar bodies, including those displacements which consist of upward disturbances of the surface.

When we impose the further condition appropriate to an existing water-surface, that the replacements of the surface, when disturbed, are governed jointly by gravity and by the volumes and velocities of the original impulses of disturbance, it follows that those impulses of disturbance, being similar for all similar bodies at all velocities, will retain their similarity wherever and in the manner which the operation of gravity permits: and this will be when the similar bodies are moved with velocities proportioned to the square roots of their respective dimensions; in these a similar wave-configuration will, in each case, similarly dispose of the originally similar volume of displacement, since similar waves have their velocities so related.

These waves (as is explained by Professor Rankine), when the velocity proper to their length along the line of motion is exceeded by that of the ship, so that they cannot squarely travel with her, satisfy the conditions of their motion by travelling obliquely, and diverging into the surrounding fluid, the angle of divergence and their size forming a measure of the work constantly running away from the ship, and consequently of the resistance caused by their generation.

Now the similarity of the configuration which has been asserted involves the condition that when the velocities of similar ships are as the square roots of their respective dimensions, the angles of divergence will be equal, and therefore equal lengths of similar wave-crest will be "run off" for equal distances travelled by the respective ships; and hence the energy abstracted in each case by these equal lengths of similar wave-crest is clearly as the cube of the dimension (since the mass elevated is as the sectional area, and the elevation is simply as the dimension); and since the forces which supply proportionate amounts of energy while travelling a given distance must be as the energy, it follows that the excesses of resistance thus called into existence are also as the cube of the dimension, agreeing in this respect, as has already been pointed out, with the resistances derived from the surface-friction. In fact, we are thus brought to the scale of comparison which was just now enunciated, that the entire resistances of a ship, and similar model, are as the cubes of their respective dimensions, if their velocities are as the square roots of their dimensions.

In verification and illustration of the foregoing views, I tried, in the autumn of 1867, a large number of resistance-experiments with a pair of models of contrasted forms, six feet long, by towing them simultaneously from the ends of a pair of ten-foot scale-beams connected with self-recording dynamometric apparatus, and mounted on booms projecting sideways from the nose of a steam-launch, lent me for the purpose by Mr. Bidder. The water-lines of the models are shown in Plate I. fig. 1. One was of the wave-line type, the other, having the same length, form of midship-section, and displacement, had large rounded ends. I also tried similar experiments with a pair of very nearly similar models of twice the dimensions and eight times the displacement. I had already obtained a series of experimental results of the same kind, but with less successful apparatus, from a similar pair of models, three feet long. These data enabled me to compile for each model a diagram of resistance in terms of velocity.

The three pairs of such diagrams, proper to the three pairs of models, were laid down to scales corresponding to the dimensions of the models, according to the system of comparison I have enunciated; thus the velocity-scale for the six-foot models is $\sqrt{2}$ times, and that for the three-foot models twice as open as that for the twelve-foot models; and the resistance-scales for the six-foot and three-foot are respectively 8 and 64 times as open as that for the twelve-foot. According to my proposition, were the three sets of models exactly similar the three sets of diagrams should be identical.

Reduced copies of these diagrams are shown in Plate I. figs. 2, 3, 4. Their general agreement, especially as to the position occupied in the velocity-scale by the several salient features of the curves and as to the relative resistances of the contrasted forms, is very striking. It is true that on comparing the absolute resistances, the correspondence is not so close as it at first sight appears. Thus the three-foot models exhibit throughout a decided excess of resistance as compared with the six-foot; but I think this is probably attributable to their being small enough to be within the range of viscosity. On comparing the diagrams of the twelve-foot and six-foot models, however, we find that it is the larger model that has an excess of resistance. This excess, which is slight, may be partly due to certain minor differences of form which had been introduced in the larger models, It may also have partly arisen from the fact that the twelve-foot models, owing to their greater dimensions, swam relatively nearer to the towing-boat, a circumstance which may naturally have tended to enhance their resistances.

On the whole, I think that series of diagrams supplies a very fair verification of the alleged scale of comparison.

Besides thus throwing light on the question of comparison of the performance of similar vessels of different dimensions, these experiments show very clearly that strange forms may possess merits that are entirely unknown and unexpected before experiment is made upon them; for here we find that an abnormal form (suggested simply by the appearance of water-birds when swimming), if moving with a high though not excessive velocity, experiences considerably less resistance than the wave-line form, the accredited representative of the form of least resistance, particularly at high

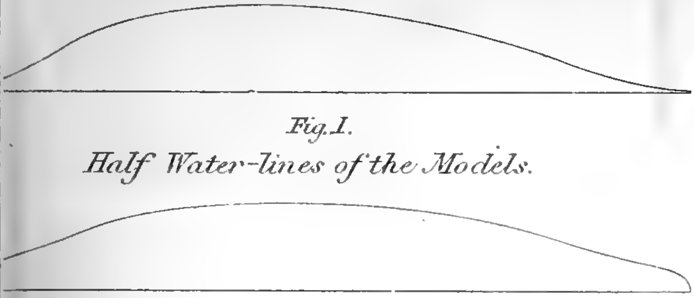

Fig. 1.
Half Water-lines of the Models.

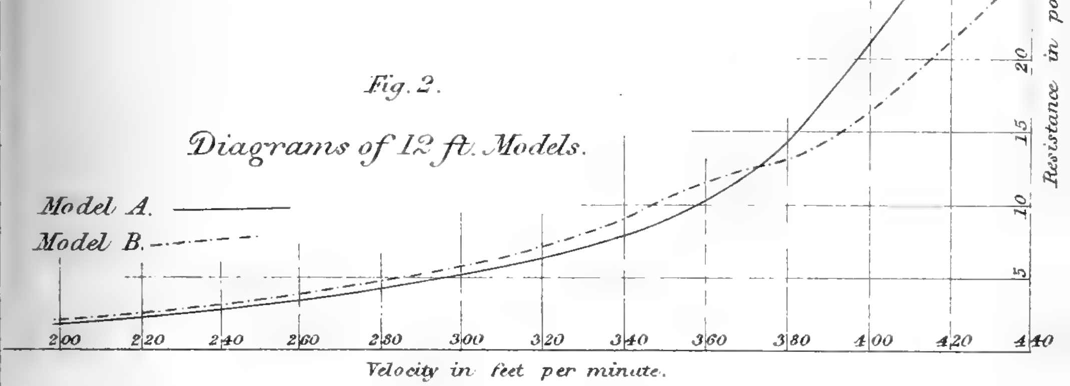

Fig. 2.
Diagrams of 12 ft. Models.

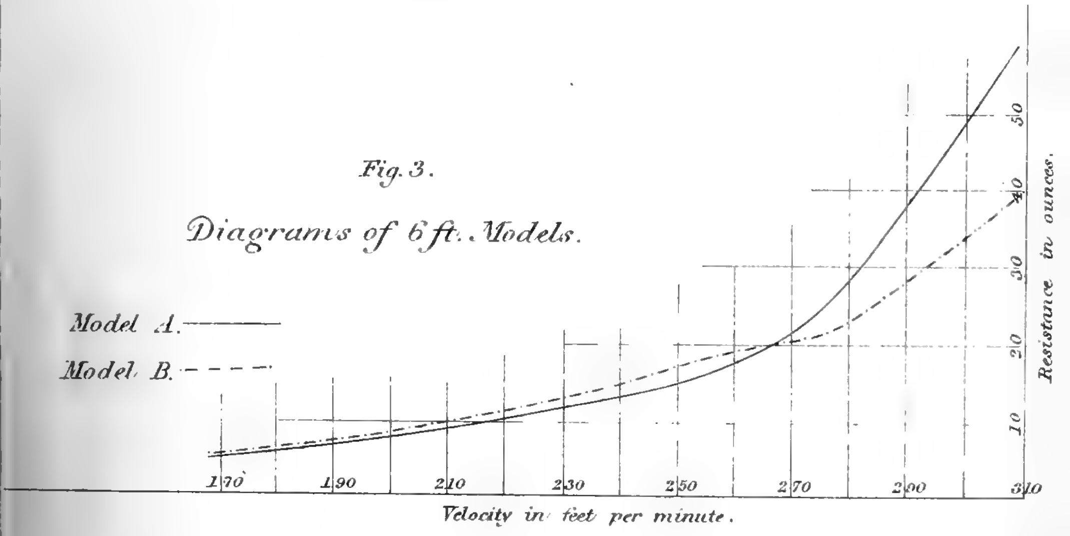

Fig. 3.
Diagrams of 6 ft. Models.

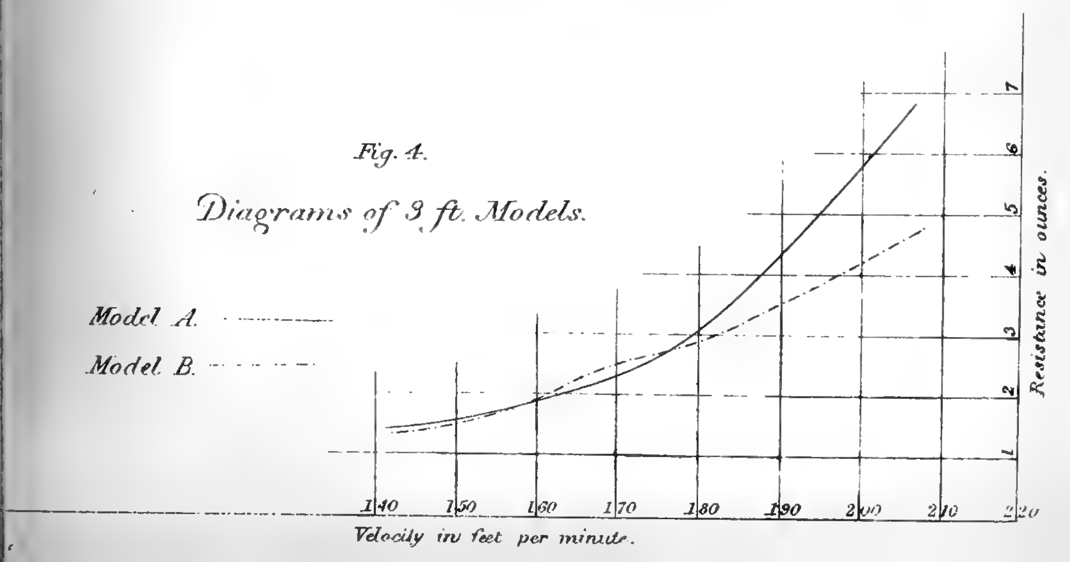

Fig. 4.
Diagrams of 3 ft. Models.

speeds. This proves that we can have no ground for certainty that we have found even an approximation to the best form, unless we have gone experimentally over almost the whole ground and tested a very wide variety of shape. But, independently of this aspect of the question, it is, I think, certain that on very many important questions, such as, for instance, the proper ratio of length to breadth, there is no really established principle of judgment on which reliance can be placed. Yet most weighty considerations affecting economy and efficiency are involved in the settlement of even that single question. But unless we build mere experimental ship-sized models, there seems no possibility of determining the question by full-scale experiments.

It is true that the circumstances under which my experiments were tried did not admit of such exactness as to render them absolutely conclusive as the sole basis of the theory of comparative resistance in terms of dimension. Nor do I by any means pretend to be certain that there are no elements of resistance other than I have taken account of in my theoretical justification of it; but if any such do exist, they can be detected, and the laws of their operation discovered with far greater facility and completeness by small-scale than by full-size experiments. And I contend that unless the reliability of small-scale experiments is emphatically disproved, it is useless to spend vast sums of money upon full-size trials, which, after all, may be misdirected, unless the ground is thoroughly cleared beforehand by an exhaustive investigation on small scale.

Report of the Committee appointed to consider and report how far Coroners' Inquisitions are satisfactory Tribunals for the Investigation of Boiler Explosions, and how these Tribunals may be improved, the Committee consisting of William Fairbairn, *C.E., F.R.S., LL.D., &c.,* Joseph Whitworth, *C.E., F.R.S.,* John Penn, *C.E., F.R.S.,* John Hick, *C.E., M.P.,* Frederick J. Bramwell, *C.E.,* Thomas Webster, *Q.C.,* Hugh Mason, Samuel Rigby, William Richardson, *C.E., and* E. Lavington Fletcher, *C.E.*

I. Boiler explosions continue to occur with their accustomed frequency and fatality. Since the Meeting of the British Association held last year in Norwich not less than 46 explosions have occurred, by which 78 persons have been killed, in addition to 114 others having been injured; and as these catastrophes take place with considerable regularity, there is every reason to apprehend that a similar number of explosions, causing the loss of a similar number of lives and a similar amount of bodily injury, will transpire before the next Meeting of the British Association, unless some very immediate measures are adopted for arresting these sad disasters.

The fearful explosion which occurred on the 9th of June last, at Bingley, by which as many as fifteen persons were killed and thirty-three others injured, some of them very seriously, will be fresh in the remembrance of every one; more especially from the fact that amongst those killed and injured were a number of women, having no connexion whatever with the works at which the explosion occurred, as well as a number of little children. These children were exercising in an adjoining playground, when just as they were passing close to the wall of a two-storied building on the premises at which the explosion occurred, the boiler burst, demolishing the building, burying the children in the ruins, and crushing eight of them to death, in addition to seriously injuring seventeen others.

Sad as it is when those connected with boilers and who gain their livelihood from working them are injured, it is even more so when outsiders, who have no interest in their use or control over their management, are victimized by their explosion, more especially when these victims are women and children. Such, however, is by no means an infrequent occurrence. In one case, a child asleep in its bed, unconscious of all danger, was killed on the spot by a fragment of an exploded boiler sent through the roof like a thunderbolt. In a second case, a young woman working at her needle in an upstairs room in her own dwelling, was struck by a boiler which was hurled from its seat, and dashed against the window at which she sat. The injury she received was serious; her leg had to be amputated, and death shortly after ensued. In a third case, just as an infant was making its first assay at walking across the kitchen-floor in a collier's cottage, a fragment of an exploded boiler came crashing through the roof, and striking down the child, killed it on the spot. In a fourth case, a woman was standing at her own cottage-door with an infant in her arms, when one of the bricks sent flying by the bursting of a boiler struck her little one on the head, and killed it in its mother's arms. In a fifth case, a group of boys were sporting in a meadow, when the boiler of a locomotive engine, just drawn up at an adjoining railway-station, burst, and scattering one of its fragments among the group, killed one of the boys on the spot, and injured another. In a sixth case, a house in which an infirm old woman lived, confined to her bed in an upstairs room, was demolished by a boiler explosion, so that the poor woman, with the bed on which she lay, was rudely brought to the ground. In a seventh case, a man passing through a public thoroughfare on horseback was struck by the débris showered around by a boiler that happened to explode at the moment; so that even those casually passing by the premises at which steam-power is employed are not safe from the attacks of bad boilers. It is no uncommon thing for dwelling-houses in the vicinity of boilers to be invaded on the occurrence of an explosion with huge fragments, and to have their windows and roofs riddled as if they had been bombarded, while in some cases they are altogether demolished. Many other cases similar to the above might be added; but the facts already given are, it is thought, sufficient to show that those who use steam-boilers are not the only parties who suffer from their explosion. Thus the subject acquires a wider interest, and becomes not only important to steam-users, but also to the public at large.

It is therefore desirable that public attention should be thoroughly aroused on the subject of steam-boiler explosions, while it is clearly well worthy of the consideration of the Members of the British Association.

II. The Committee pass on, in the second place, to state that the attention of its Members has for years been directed to the cause of these sad catastrophes, and that they have invariably found that steam-boiler explosions, though so complicated and disastrous in their results, have sprung from causes of the simplest character.

In some cases explosions arise from the boilers having been originally malconstructed, the furnace-tubes, for instance, not having been strengthened, as experience has shown to be necessary, by encircling rings or flanged seams, or other approved and suitable means; and, in consequence of the neglect of these simple precautions, which may readily be adopted by any one, a considerable number of furnace-tubes have collapsed and ruptured, when the rush of steam and hot water resulting therefrom has been attended with the most disastrous consequences both to life and property. Explosions of this character are particularly prevalent in Cornwall, where it seems especially difficult to persuade steam-users that a furnace-tube can collapse from any other cause than that of overheating through shortness of water. This simple but obstinate prejudice makes Cornwall one of the most prolific counties for steam-boiler explosions; and the Cornish boiler, which, when well constructed and strengthened in the furnace-tube as just described, is one of the safest and most reliable of any, has been raised to the undesirable notoriety of being the most explosive, simply through the obstinate prejudice just referred to, so that the very county that gave this boiler birth and name is doing more than any other to damage its reputation.

Other explosions arise simply through defective staying, as in the case of the boiler that exploded at Aberaman on the 31st of May last, killing four persons and injuring four others. In this case the front end of the boiler was blown out, consequent on the removal of the furnace-tube in order to metamorphose the boiler (most unwisely) from one fired internally to one fired externally. When the furnace-tube, which formed a most valuable longitudinal stay, had been removed, no adequate provision was made for repairing its loss, and the consequence was that the end blew out from sheer weakness. This explosion is by no means singular; and many similar cases have been met with in which the flat ends of boilers have been blown out through unwisely removing the furnace-tube in Cornish boilers in order to exchange internal firing for external. One other explosion, resulting from imperfect staying, may be referred to, which occurred on the 28th of July, 1866, at Tunstall, and resulted in the death of two persons and in injury to seven others. This boiler was of considerable size, being as much as 36 feet long by 9 feet diameter, while it was worked at a pressure of from 35 lbs. to 40 lbs. on the square inch. This boiler, which contained an internal horseshoe-shaped flue, was constructed with a hemispherical end at the back, and a flat one at the front. The flat end was insufficiently stayed, in consequence of which it was blown out with the horseshoe-shaped tube attached to it, and thrown to a distance of about 50 yards in one direction, while the shell of the boiler recoiled to about the same distance in another. Alongside this boiler was another, in process of completion, with two boiler-makers and a boy at work inside it. On the occurrence of the explosion, not only was the boiler first referred to torn from its seat, as just explained, but the sister one alongside was thrown on to a public road, and as this road happened to be on an incline, the boiler went rolling down, with the men, the boy, and their tools inside it, so that their predicament was somewhat similar to that of poor Regulus in his spiked cask.

Other explosions occur from defective material and workmanship, in illustration of which, the explosion may be referred to which occurred at Norwich on the 25th of September, 1866, by which the works were laid in ruins, seven persons killed, and two others injured.

Other explosions, again, arise from defective equipments, the manholes not being guarded by substantial mouth-pieces, or the boilers not being mounted with suitable safety-valves, glass water-gauges, or other necessary fittings.

Many explosions occur from the worn-out state of the boilers, the boilers being worked on till the plates are so reduced as to be no thicker than a sheet of brown paper. One such case occurred on the 24th of April, 1865, at Wigan, and resulted in the death of one person, and in injury to four others. Another took place at Leeds on the 27th of March, 1866, by which two persons were killed, and six others injured. A third happened at Collyhurst, Manchester, on the 23rd of December, 1867, by which six persons were killed and four others injured. Cases of this class are so numerous that they defy enumeration, and the working on of old worn-out boilers, that should long since have been discarded altogether, is a prolific source of explosions.

Some explosions arise from neglect of the attendants, who have ignorantly tampered with the safety-valves, or neglected the proper supply of water. The number of explosions from this cause, however, is not by any means so great in proportion to those that arise from malconstructed or worn-out boilers, as is generally supposed; and many more explosions arise from bad boilers than from bad attendants, though it is often much to the convenience of the steam-user to have the blame of an explosion thrown upon the attendant rather than on the boiler.

Such are some of the leading causes of steam-boiler explosions, all of which, it will be seen, are extremely simple; and the Committee consider that, as a rule, boilers burst simply because they are bad—bad either from original malconstruction, or from the condition into which they have been allowed to fall; while they wish to record their opinion that these lamentable catastrophes, by which so many persons are annually killed, are not accidental, but that they might be prevented by the exercise of *common knowledge and common care.*

III. The next point the Committee have to consider is, how far the present inquiries conducted by coroners as to the cause of boiler-explosions are satisfactory.

On referring to the verdicts returned by coroners' juries on deaths occasioned by boiler-explosions, it appears that the usual verdict is one of "accidental death;" in fact this seems to be returned on nearly every occasion, whatever the cause of the explosion may be, and even when it has resulted from the use of an old worn-out boiler, reduced to the thickness of a sixpence. Added to this, the evidence commonly given at these inquiries is anything but of a reliable and instructive character. The most visionary theories are advanced, and the attempt is frequently made to show that explosions are unaccountable and inevitable. Thus no suitable information is given to the public as to the cause of these sad disasters, and the consequence is that boiler-makers can palm off on the public bad boilers, and steam-users employ them with the certainty that if they explode with fatal consequences, they will, by the help of a coroner and his jury, be publicly absolved from all responsibility, and the event proclaimed to be accidental. After the conclusion the Committee have arrived at, that explosions are not accidental, but may be prevented by the exercise of "*common knowledge and common care,*" they cannot but consider that such evidence and such verdicts are eminently unsatisfactory, and that they call for immediate attention.

IV. In the fourth place, the Committee have to consider how far the present unsatisfactory character of coroners' investigations can be corrected.

It has been proposed by the Manchester Steam-users' Association that every coroner, when holding an inquiry on a steam-boiler explosion, should be both *empowered* and *instructed* to avail himself of the assistance of two competent engineers having no connexion with the works at which the explosion occurred, and that these engineers should visit the scene of the catastrophe, investigate the cause of the explosion, and attend the inquest in order to assist the coroner in his examination of witnesses, as well as to give evidence themselves before the jury, and report on the cause of the explosion, their reports (which might either be joint or several, as found most convenient in each case) being accompanied with explanatory scaled drawings, showing the original construction of the boiler, and as far as possible the lines of rent, as well as the direction in which the parts were thrown, and the distances at which they fell; while, in order to secure to the public the full advantage of the investigation, it is further proposed that the engineers' reports, with the accompanying drawings, along with the verdict of the jury, should be printed and deposited in the Patent Office, and lie there for inspection and purchase, as in the case of specifications of inventions; and also that copies of these Reports should be forwarded to the members of both Houses of Parliament, as in the case of reports on railway catastrophes, as well as to the various free libraries and scientific societies throughout the country.

The Committee consider that the adoption of this proposition would very much raise the character of the present inquiries conducted by coroners, and that the measure is well calculated to secure the truth being fully arrived at and plainly spoken, to which they attach the greatest importance.

The fact of two engineers being appointed to investigate and report, those engineers being altogether independent of the works at which the explosion occurred, would, it is thought, secure an unbiassed opinion, while from the publicity given to the verdict, the coroner and jury would be stimulated to make a searching investigation. It is possible that in some cases, more especially in the early adoption of this plan, some coroners might not select the most competent engineers to assist them in their inquiry; but this, it is thought, is an error that would soon be corrected from the publicity it is proposed to give to the whole proceedings, which would make the coroners careful to make a wise selection for the sake of their own reputation, while, as they would not be limited in their choice to a special locality, but might take the range of the whole country, there would be no difficulty in their finding thoroughly competent men. Were two competent engineers selected, the Committee consider there would never, or at all events but very seldom, be any practical difference in their views as to the cause of an explosion; but presuming that in a few instances such might be the case, the Committee would not recommend that, as a rule, a third party should be called in to decide the point, since such a question should not be decided simply by a majority of opinions. The better plan would be to record the facts and the conclusions arrived at, and to leave to public discussion and time to show how far the opinions advanced were correct or not.

One of the results of searching investigations and plain-speaking verdicts would be, that when a steam-user has killed some half dozen people by the use of a crazy old boiler, the widows and children of the deceased would be able to claim from him compensation for the loss of their bread-winners. This, it is thought, would operate as a most wholesome check both upon boiler-makers and boiler-users, as the one party would be exposed if he sold a bad boiler, and the other if he bought it. Some timid steam-users object to this measure, lest they should ever be brought in for heavy damages; but such fears may be altogether dismissed by all those who are working honest boilers. Good boilers, as already stated in this Report, do not burst. Explosions are not mysterious, inexplicable, or unavoidable. They do not happen by caprice, alike to the careful and the careless. They may all be prevented by the exercise of common knowledge and common care, so that timid steam-users may dismiss their apprehensions as long as they are doing their duty by

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their boilers and boiler-attendants. These improved investigations would at the same time have a most wholesome effect upon the operations of boiler-inspection associations and boiler-insurance companies, as in the event of the explosion of an enrolled boiler, the case would be fully investigated by impartial parties, and the facts brought to light. Such a course would clearly promote sound inspection.

Thus the Committee consider that the adoption of this measure would have so wholesome an influence upon boiler-makers and boiler-users, as well as upon boiler-attendants and boiler-inspectors, and indeed upon all those connected with the use of steam, that it would, without any further Governmental interference, do much to prevent the recurrence of steam-boiler explosions, and they warmly concur with the proposition.

With regard to the manner in which the expense of these investigations should be defrayed, the Committee recommend that this should be met from the same source that coroners' inquiries are met at present, viz. either from the county or city rates, as the case may be. This course is deemed better than that of throwing the cost of the inquiry upon the owner of the exploded boiler by way of penalty, as in many cases his resources would be so drained by the catastrophe as to be insufficient to meet the charges; while, in addition, it is thought that scientific witnesses, called upon to discharge so important a public duty as that now proposed, should not be dependent on so uncertain and invidious a source for remuneration.

It has been proposed that the Crown should levy a heavy deodand on the owners of all boilers that explode, unless it could be shown that the explosion arose from causes entirely beyond their own control, the onus of the proof being thrown on the boiler-owners, and not on the Crown. Such a measure has, at first sight, much to recommend it. It would doubtless act as a powerful stimulant to care; but inasmuch as the relatives of those killed by boiler explosions are deprived thereby of their means of support, it is thought that all payment should go to them in the way of compensation rather than to the Crown. In many cases the owner of a boiler is so impoverished by its explosion that, had he to pay a deodand, he would have nothing left to compensate those who were rendered widows and orphans by the catastrophe, so that the Crown would be robbing them of their legitimate compensation. It is thought therefore it would be better not to impose any deodand, fine, or penalty, but to leave the steam-user, in the event of explosion, simply to the exposure of full investigation and plain speaking, combined with the liability to an action for damages, which the improved verdicts would give increased facilities for setting in motion.

The Committee would wish to add a few remarks upon the misapprehension that arises from the use of the word "*accidental*" in the verdicts returned by coroners' juries, and the advantage they think would be derived from the substitution of the expression "*not due to malice aforethought.*" The Committee apprehend that the fundamental object of a coroner's inquiry, in the case of a sudden or violent death, is to determine whether that death was occasioned by personal malice or not. Thus it may be legally correct for the jury to return a verdict of "accidental death" from a steam-boiler explosion, though the boiler may have been so worn out that, in an engineering and common sense view, the explosion was no accident at all. Thus the jury use the word in one sense, but the public accept it in another, and the term is taken to be an exoneration of the owner of the boiler. It is thought that the obligations of the jury would be fulfilled, at the same time that the prevention of steam-boiler explosions would be promoted, if juries, instead of returning a verdict of "*accidental death,*" would state that they consider there had been no "*malice aforethought,*" and the following verdict is given by way of illustration:—

"The jury find that X., X., X., &c. were killed by a steam-boiler explosion that occurred at —— street, in —— town, on —— day of the week, month, and year, on the premises occupied by ——; and while they consider that these deaths were not occasioned by any '*malice aforethought,*' either on the part of the owner of the boiler or others connected with it, they wish to record the fact that the boiler was a bad one, its plates being considerably reduced by corrosion, and that it was to this cause that the explosion was due."

The Committee do not overlook the fact that juries have a third course open to them, which lies between the announcement of "accidental death" or "wilful murder," and that they have the power of committing owners of boilers for "manslaughter," a power which in many cases they are bound in the discharge of their duty to exercise, and in the opinion of the Committee much more frequently than they do. The task, however, of committing a boiler-owner for manslaughter is frequently an invidious one for a coroner's jury, and in practice verdicts of manslaughter are very seldom brought in by them. Were the suggestion thus made carried out, coroners' juries would be extricated from an unpleasant position, and the truth with regard to explosions would be more fully and freely spoken.

The following is a recapitulation of the conclusions to which the Committee have arrived:—First, that a lamentable loss of life is annually caused by steam-boiler explosions, which urgently calls for public attention. Secondly, that these explosions, as a rule, are not accidental, but may be prevented by the exercise of "*common knowledge and common care.*" Thirdly, that the present investigations conducted by coroners with regard to steam-boiler explosions are eminently unsatisfactory, and call for immediate improvement. Fourthly, that coroners should, when conducting inquiries on boiler explosions, be *instructed* and *empowered* to avail themselves of competent engineering advice, so that the cause of every boiler explosion may be fully investigated, while the information acquired should be widely circulated. Fifthly, the Committee entertain a sanguine hope that this course alone would do much towards the prevention of the present recurrence of steam-boiler explosions, without any further Governmental action.

Before concluding this Report, the Committee feel it incumbent upon them to allude to the general movement that has taken place within the last year with regard to the adoption of some system of compulsory inspection.

During the past session a Bill was introduced to Parliament, and carried through an early stage, for placing all steam-boilers under Government inspection, by the agency of the Board of Trade. By others it has been proposed that every steam-user should be compelled to have his boiler examined and certified by some private association or company instituted for that object, and authorized by the Government. Others propose that insurance should be an essential accompaniment to this arrangement, and that, to secure the integrity of the service, the boiler-inspectors should themselves be inspected by the Government.

With regard to these propositions, the Committee would wish to express a strong and, as they think, a wholesome dread of any Government interference with the management of private concerns; and they cannot but consider that the plan proposed of handing over all the boilers in the country to the supervision of the Board of Trade would prove harassing to the steam-user, and a barrier to progress. Such a system, it is thought, must soon prove a system of limitation. Inspectors armed with Governmental powers must be guided by a code of rules laid down by some higher and central authority. They must be instructed what diameter of boiler and what thickness of plate to allow for certain pressures of steam, also what area and description of safety-valves, and what number and description of fittings generally. Thus the responsibility of construction would be removed from the boiler-makers to the Government, and the Board of Trade would become the national boiler constructors. However wisely and liberally such a system might be worked, and however carefully its code of rules might be devised, it is feared it would shortly prove an irksome limitation, and that serious embarrassment would result. Whether any milder measures could be introduced to extend the operations of private associations, is a question on which the Committee are not in a position to pronounce an opinion at present; but the subject appears to them to be one of considerable importance, and the more public attention is called to it, and the more it is ventilated and discussed, the better.

The Committee would venture, however, to submit to consideration, whether it would not be worth while to try the effect of more searching coroners' investigations, and plain-speaking verdicts, before any other steps are taken. Were the course recommended herein with regard to coroners adopted, such a mass of well-authenticated information would soon be accumulated that it would be shortly apparent whether this measure were of itself sufficient to arrest the course of boiler explosions, or whether the recklessness of steam-users was so great that more stringent measures were absolutely necessary; while, supposing that the latter unfortunately proved to be the case, the amount of authentic information obtained would form a sure basis for legislative enactment. The Committee therefore venture to urge that the plan proposed in this Report be fairly tried before any further steps be taken, and they recommend this subject to the best consideration of this Meeting of the British Association.

It should not be omitted to mention that since the subject was brought under the consideration of the Mechanical Section of the British Association last year, the Manchester Steam-users' Association memorialized the Home Secretary with regard to the improvement of coroners' inquiries in the manner referred to in this Report. The deputation was favourably received, and the Home Secretary stated, in his place in the House of Commons, only a few days since, that he should endeavour, during the Recess, to prepare a measure for the prevention of steam-boiler explosions. Thus considerable attention has been drawn to this subject during the past year, and considerable progress has been made in educating public opinion with regard to it. The Committee think that this affords ground for congratulation, and that, from the interest now aroused in connexion with this subject, the attainment of the prevention of steam-boiler explosions is not far distant.

(Signed on behalf of the Committee)

WILLIAM FAIRBAIRN, *Chairman*.

August 18, 1869.

Preliminary Report of the Committee appointed for the determination of the Gases existing in Solution in Well-waters. *By* Dr. E. Frankland, *F.R.S., and* Herbert M'Leod, *F.C.S.* (Reporter, Herbert M'Leod.)

In consequence of the investigation being far from complete, this Report must be considered as merely a preliminary one; a more detailed account of the results obtained, and the inferences to be drawn from them, must be postponed till a future occasion.

The apparatus employed in these and other experiments was described at the last meeting of the Chemical Society, and has been published in the Journal *.

In collecting the waters it is, of course, of the greatest importance that they should be prevented from coming in contact with the air, otherwise serious errors might be produced in the determination of the gases dissolved. In order to avoid these errors, the tap delivering the water from the pumps is connected by means of a caoutchouc tube with a tubulure at the bottom of a tin cylinder, about 10 inches high and 7 in diameter. The water is turned on and allowed to flow over the edge of the vessel; thus only the surface of the water is exposed to the action of the air, and the liquid at the lower part of the vessel is protected by the upward current and continual overflow.

The bottles used for collecting the waters hold a little more than 100 cubic centimetres, and a separate quantity is used for each experiment. Into each bottle a piece of glass tube, bent in the form of a U, is introduced; one end of the tube is sealed, and in the closed limb a bubble of air is confined by mercury which fills the open limb and the bend. In the collection of each water, four of these bottles are lowered by means of pieces of string into the tin vessel, while the water is flowing over its edge. After being filled each bottle is carefully examined, and if any bubbles of gas adhere to the sides they must be removed. The bottles are then again lowered into the vessel and the temperature observed. A siphon is now passed to the bottom of one of the bottles, and after it has drawn two or three hundred cubic centimetres of water through the bottle, it is placed into the second. The first bottle is now raised, and while its neck is still under the water, a slightly greased stopper is put into the neck and carefully pressed down. This force compresses the air contained in the glass tube, and if the pressure is sufficient, it prevents the escape of gas from the water, a precaution which in some cases is very necessary. The siphon is then transferred from the second into the third bottle, and the second is closed and removed. When the four bottles have been filled, the stoppers are covered with ground caps. The caps are next filled with mercury through small holes at their tops, which are afterwards closed with glass stoppers.

The gases should be removed from the waters as soon after collection as possible. In the following cases, the greatest length of time which was allowed to elapse between these operations was five days, but usually the removal of the gases was effected the day after the collection.

With so few results as have been obtained up to the present, it will be impossible to do more than point out the small quantity of oxygen in the waters from deep wells as compared with those from shallow ones, and with rain- and river-waters. The quantity of nitrogen is also very remarkable, as being in all the cases, except the river- and rain-water, in excess of the

* Journ. Chem. Soc. ser. 2, vol. vii. p. 307.

	I. Rain-water.	II. Water from cistern of Royal College of Chemistry. Supplied by Grand Junction Company.	III. Water from well in chalk, 367 feet deep, at Messrs. Barclay and Perkins's Brewery, Southwark.	IV. Water from well not down to chalk, in course of construction, 143½ feet deep, at Messrs. Barclay and Perkins's Brewery, Southwark.	V. Water from chalk well at Worthing.	VI. Water from surface well to face of the chalk, 27–30 feet deep, at Mr. Hills's Brewery, Deal. In the town. Influenced by tide.	VII. Water from chalk well, 115 feet deep, Waterworks, Deal, surrounded by cultivated fields. Not influenced by tide.	VIII. Water from waterworks, Deal, drawn from main about a mile from the reservoir.
Temperature at time of collection	15°·5 C.	14°·8	12°·1	12°	?	11°·9	14°·8	17°·2
Mean of	2 experiments.	2 experiments.	2 experiments.	4 experiments.	2 expers.	2 experiments.	2 experiments.	2 experiments.
Volumes of gases in 100 volumes of water. Nitrogen ...	1·382	1·397	2·030	1·973	1·552	1·704	1·548	2·241
Oxygen ...	0·673	0·620	0·029	0·018	0·446	0·023	0·580	0·796
Carbonic anhydride	0·135	4·239	5·765	3·814	5·452	10·252	5·055	4·413
Total ...	2·190	6·256	7·824	5·805	7·450	11·979	7·183	7·450
Solubility of nitrogen in 100 volumes of distilled water (Bunsen)............	1·468 at 15·5°	1·478 at 15°	1·549 at 12°	1·549 at 12°	......	1·549 at 12°	1·478 at 15°	1·44 at 17°

The experimental results of which the above numbers are the means were tolerably concordant; the greatest differences between the results of different experiments are the following:—In water No. IV. exp. 3 gave 0·140 part more nitrogen than exp. 2. In water No. VII. the oxygen obtained in the second experiment was 0·045 in excess of the quantity obtained in the first. In water No. III. the second experiment gave 0·760 part more carbonic anhydride than the other. Since this last was done the modes of collection and removal of the gases have been improved.

amount absorbable by distilled water. To show this there is introduced into the foregoing Table numbers taken from Bunsen's 'Gasometry,' indicating the quantities of nitrogen absorbable by 100 volumes of distilled water at the temperatures which are nearest to those at which the waters were collected. The reasons of this apparent anomaly will be investigated during the course of the ensuing year, and it is hoped that, by the next Meeting of the Association, a much larger amount of information will have been obtained. The prosecution of the experiments has been much hindered by the necessity of perfecting the apparatus for the removal of the gases, and the means of collection, so that it was not until after the beginning of July that any systematic work could be commenced. Although the investigation will be continued, it is not intended to ask for any additional grant, as the amount voted last year will probably be sufficient.

The Pressure of Taxation on Real Property. By FREDERICK PURDY, *Principal of the Statistical Department, Poor Law Board, and one of the Honorary Secretaries of the Statistical Society.*

[A Communication ordered to be printed *in extenso* among the Reports.]

I. THE PRESSURE.

THE question of the fiscal pressure caused by the incidence of imperial and local taxation on real property is no new topic in this country. In 1846 the House of Lords appointed a select committee to inquire into the "Burdens affecting real property." This committee, of which Lord Beaumont was the chairman, gathered from various sources a large body of information, and made in the same session a rather brief report to the House upon the voluminous evidence which was subsequently published. A draft report which Lord Monteagle, one of the members, had drawn up was not accepted; it was, however, printed as a separate paper by the House of Commons in the same year.

Both documents have rather an historical than practical interest for us in the present day. Our imperial financial policy has materially changed since 1846, and the local burdens of that time are quite dwarfed in absolute amount by recent growths in the same field. It therefore appeared a useful task to ascertain the taxation laid on real property at this moment with the greatest precision that authentic records render possible. I propose to do this *statistically*; an *economic* treatment of the subject would be, no doubt, as touching the pockets of a large number of people, a more exciting theme. But admitting that the aggregate of imperial and local expenses must be provided for, throwing a tax off one description of property means, in the sphere of financial policy, placing it on another. The correlation of the parts would be disturbed; the wide and intricate field of taxation must then be entirely reviewed and readjusted, a task of no mean difficulty which may be fittingly omitted on this occasion.

The nearest approach, at present, to the annual value of real property in England and Wales is expressed by some figures supplied to me by the courtesy of Mr. Frederick Gripper, Accountant and Comptroller-General to the Board of Inland Revenue.

They show the gross sum to be upwards of £145,000,000 for the financial year 1867–68, thus assessed:—

	£
Under Schedule A	116,341,387
Sum formerly charged under A, but since 1865 transferred to Schedule D as profits	29,057,991
Total..........................	145,399,378

The assessment upon which the Crown actually gathered the tax was upwards of £9,000,000 short of this gross sum, the statement of the amounts "charged" standing, for the same year, thus:—

	£
Under Schedule A	107,092,692
Sum formerly charged under A, but since 1865 transferred to D as profits....................................	29,041,932
Total..........................	136,134,624

A difference between gross and net value of £9,000,000 and more, arising upon those properties which are still retained in Schedule A.

What originally stood in Schedule A before any transfer was effected can be shown in detail for the last year of the old series thus:—

Gross Annual Value of Property in England and Wales, Assessed under Schedule A of Income-Tax Acts, Year ended 5th April, 1865.

		£
1. Lands, including tithe-rent charge		46,403,000
2. Messuages		59,286,000
3. Tithes (not commuted)		58,000
4. Manors		189,000
5. Fines		166,000
6. Quarries	D	526,000
7. Mines	D	4,277,000
8. Iron-works	D	1,248,000
9. Fisheries..................	D	31,000
10. Canals	D	786,000
11. Railways..................	D	13,882,000
12. Gas-works	D	1,618,000
13. Other property *		2,486,000
14. General profits †..................		387,000
Total		131,343,000

The principal items now placed under Schedule D have that letter marked against the sum in the list above; probably considerable transfers have also been made from "other property" and "general profits;" but this is certain, quarries, mines, iron-works, canals, fisheries, railways, and gas-works heretofore under Schedule A are now accounted for under Schedule D.

In the British fiscal system real property suffers an exceptional liability to taxation. It bears fully *three-fourths* of our heavy and fast-increasing local rates, and then in a variety of ways it is made to supplement the imperial budgets. Here I may be permitted to remark that in this country we are too much in the habit of discussing our imperial and local systems of rates and taxes as things apart, yet their conjoint bearing on the interests of the holders of real property is obvious and practical. This opinion I had the honour of indicating to Section F, in a brief paper, when the British Association last met at Cambridge‡.

The amount of local taxation incident upon real property is now known

* Salt-springs or works, alum-mines or works, docks, drains and levels; rights of markets and fairs, tolls, bridges, and ferries.

† All other profits arising from lands, tenements, and hereditaments or heritages not in the actual possession of the party to be charged, and not before enumerated.

‡ See the Transactions of the British Association for 1862, p. 162.

with great fullness: much is also known of the imperial burden; but, for the reasons hereafter stated, approximate completeness is alone attainable in this section of our taxes. As the heaviest in amount the local taxes are first shown by the subjoined list:—

Local Taxation in England and Wales falling on Real Property in 1867–68, *according to Mr. Ward Hunt's Return, Nos.* 497 *and* 497—I. *Sess.* 1868.

	£
1. Amount levied under the name of poor-rate	11,061,000
2. County, hundred, borough police, *not* paid out of poor-rate	307,000
3. Highway-rate, *not* paid out of poor-rate	917,000
4. Church-rates	217,000
5. Lighting- and watching-rate	77,000
6. Improvement-commission rates	445,000
7. General district-rates, levied under the provision of Public Health and Local Government Acts	1,797,000
8. Rates under Courts of Commissioners of Sewers, including drainage and embankment rates	709,000
9. Rates of other kinds, and inclusive of £981,000 levied in the metropolitan district as general and lighting-rates..	1,203,000
Total.........................	16,733,000

*** Taken in round numbers and corrected by the most recent returns in possession of the Poor-Law Board.

It may be well to remember that nearly half of this heavy sum is entailed upon the ratepayers by the absolute right to relief which the legislation of England has given to the poor. The expenditure last year for "relief to the poor" was £7,498,000; but law charges to the amount of £29,000, the cost of making valuations £50,000, and "money expended for all other purposes" £532,000, a large portion of which latter sum is solely contingent on pauperism, are all items that are excluded from what, in official language, is termed "relief;" though it is patent that if pauperism ceased out of the land, most of these expenses would be determined. Add a due proportion of the excluded items and we may fairly say that, in round numbers, English pauperism last year cost little short of £8,000,000 sterling.

The imperial taxes that are incident upon realty certainly exceed £6,000,000; they probably approach to £7,000,000. So far as their respective amounts can be discovered, they are exhibited in the following statement:—

Imperial Taxation in England and Wales falling on Real Property in 1867–68, *or thereabouts, according to Returns in possession of the Commissioners of Inland Revenue.*

	£
1. Property-tax, 1867..................................	2,354,000
2. Land-tax, 1868	1,058,000
3. House-duty, 1868	1,003,000
4. Succession-duty, average of 1867-68-69	562,000
5. Stamps on deeds and other instruments, not otherwise specified, 1868 (*a*)	1,405,000?
6. Fire insurance?	....
7. Stamp-duty on wills and letters of administration?	....
8. Probate Court fees?	....
Approximate total	6,382,000

(*a*) Stamps on sales, conveyances, leases, mortgages, &c. will be included in this sum, but what portion is not incident on real estate it is impossible to discover. The stamp-duties on wills and letters of administration, some of which will be paid on leaseholds for years, and therefore indirectly from real property, are excluded from the above, and that exclusion may possibly balance the excess under the head of stamps on deeds. The duty on wills &c. in England and Wales in 1867–68 was £1,493,000. Probate Court fee stamps, which in 1868 amounted to £124,000, are also excluded.

The succession-duty experiences considerable variations; according to particulars furnished by Mr. Gripper, the sums collected in England and Wales for the financial years 1867, 1868, 1869 were respectively £507,081, £608,297, and £571,831. For the purposes of this paper the average of the three years has been taken. Fire-insurance duty has ceased; it is noted above as a reminder; very recently it was a tax that largely bore on certain descriptions of real property. After trial it is found impossible to unravel the stamp-duties so as to exhibit that portion of the impost with which alone this paper is concerned.

Allowing for possible defects in the imperial tax table, the aggregate burden is this:—

	£
Taken by local taxation	16,733,000
„ imperial taxation	6,382,000
Grand total	23,115,000

upon the gross value assessed under Schedule A—£145,399,000. This is equivalent to 3*s.* 2¼*d.* in the pound; on the net value (the amount "charged," £136,135,000) it equals 3*s.* 4¾*d.* in the pound. Here, however, it should be remembered that the standards of comparison are themselves averages of a comprehensive sort; it is not every pound of gross or of "charged" value that is taxable. For example, on many estates the land-tax is redeemed*; the inhabited-house tax is not paid by more than *one-sixth* of all the householders of the kingdom; though measured on *value* alone, more than half the house-rental pays. The assessment of houses &c. (other than farm-houses) to the property-tax in 1864–65 was, as already stated, £59,286,000; but for the purposes of the house-tax, the levy was made upon £30,405,000. Again, many small proprietors, being outside the statutable limit of the income-tax, altogether escape it. In a word, as a taxable *corpus*, the valuations here cited must not be invested with an homogeneity they do not possess.

Though the Crown valuations under Schedule A be a much truer exponent of the country's wealth in real property than any assessment yet made for the purpose of local ratings, it is nevertheless advisable to give, in a theme of this kind, some attention to the latter.

There is no information in existence as to the "rateable value" of England and Wales previous to the year 1840–41. This "rateable," or, as it is sometimes termed, "annual value," when discovered from returns obtained by the Poor Law Commissioners from the overseers of that time, was found to be £62,540,000. The parish officers' valuations were notoriously defective. The annual value of real property was ascertained by the Commissioners of the Income- and Property-Tax Acts to be £85,803,000 in the subsequent year 1841–42. The whole excess of £23,000,000 or so must not, however, be ascribed to under valuation in the poor-rate assessment. Some few things are in Schedule A that are exempt from poor's rate. The Parochial Assessment Act of 1837 does not appear to have mended matters much†. The increase of assessable property, and, latterly, the application of sounder principles, introduced by the assessment committees in the practice of valuation, though yet very short of attainable completeness, make themselves visible in the next statement:—

* The annual tax redeemed up to 1856 was £770,000.—*Statistical Journal*, vol. xx.
† See 'Statistical Journal,' vol. xxiii. p. 292 *et seq.*

Parochial Years.	Poor-Rate Valuation.		
	Gross Estimated Rental.	Net Annual or Rateable Value.	Clear Interval between the Successive Returns.
	£	£	
1840–41	Not known.	62,540,030	—
1846–47	"	67,320,587	6 years.
1849–50	"	67,700,153	2 "
1855–56	86,077,676	71,840,271	5 "
1865–66	110,079,308	93,638,403	9 "
1867–68	118,334,081	100,612,734	1 year.

A Parliamentary Return of some interest to the discussion of the incidence of taxation was in 1853 obtained upon the motion of Mr. Moffatt. The growth of the last fifteen or sixteen years has materially changed the relative proportion of some of the data selected from the paper and placed hereunder. Historically they have value now; hereafter, when we wish to ascertain whither political and economic forces are in this matter of taxation carrying us, their worth may be greater. The amounts payable in England and Wales out of each sort of rateable property was, in the language of the return, "ascertained by the rule of proportion applicable to the poor's rate."

Different Descriptions of Property upon which the Rates were Incident.	Poor's Rate (including County, Borough, and Police Rates).	Highway Rate.	Land-Tax.	Proportion paid by each Description of Property.	
				Amount.	Per cent.
	£	£	£	£	
1. Land, including farm-houses	2,707,627	607,546	533,112	3,848,285	41·2
2. Tithe-rent charge	295,056	59,123	60,563	414,742	4·4
	3,002,683	666,669	593,675	4,263,027	45·6
3. Houses, including warehouses, factories, &c.	3,124,526	889,574	478,816	4,492,916	48·1
4. Coal-mines	61,191	14,082	5,981	81,254	0·9
5. Saleable underwoods	28,524	6,236	5,581	40,341	0·4
6. Canals	28,471	7,596	3,756	39,823	0·4
7. Railways	204,871	52,537	30,171	287,579	3·1
8. All other descriptions of property	102,032	25,881	12,937	140,850	1·5
Totals	6,552,293	1,662,575	1,130,917	9,345,790	100·0

Note.—The poor-rate and highway-rate levy are for the year 1851–52; the land-tax for the previous year.

Here it is seen that sixteen years ago landed property, including the tithe-rent charge, bore 45·6 per cent. of the aggregate amount of the rates and tax mentioned above, and the residual property 54·4 per cent. There is not, I believe, any subsequent return to show what changes may have taken place in these ratios when measured on the basis of the poor-rate valuations; though, from the comparatively slow growth of one and the rapid growth of the other portion of assessable property, the differences must be considerable.

In the absence of a means of comparison similar in each particular with the table of 1851–52, we may, bearing in mind the necessary qualification, take the property-tax assessment for 1864–65 as a guide, especially as the mere ratios are much less open to doubt, from the diversity of practice between Crown valuers and local valuers, than the absolute amounts.

Amount and Ratio of Gross Assessment in 1864–65, *of Lands and of other Real Property under Schedule A, in England and Wales.*

	£	Per cent.
Of lands, including tithe-rent charge	46,403,437	35·3
Of all other descriptions of real property assessed in this schedule	84,938,062	64·7
Total	131,341,499	100·0

As against 1851–52, we may say that 10·3 per cent. has passed from the land and gone upon other assessable property. Land would appear now liable to bear rather more than *one-third* of any burden laid upon real property generally, and real property, other than land, rather less than *two-thirds.*

II. The Growth of the Property under Pressure.

It has thus been shown, I may submit, that the imposts upon real property are in appearance exceptionally severe, taxed as it is both by the imperial and the local assessor. Have these burdens in any wise injured or retarded the growth of this species of wealth? is the next question. During the past fifty years England has increased largely in numbers, and more largely in material prosperity. Under such conditions, it is inconceivable of any community that a great impetus should not have been given to the development of what English lawyers mean by the term "realty" or real estate. Authentic records afford the means of instituting a comparison between the years 1815 and 1868; or, roughly speaking, after the lapse of half a century. In the first-named year the population of England and Wales was 11,004,000; in 1865 it was 21,590,000, the increase being 96·2 per cent. In 1814–15, the real property assessed under Schedule A was £53,495,000, and in 1867–68 it was £145,399,000, or 171·8 per cent., and thus surpassing the rate of development in the population by 75·6 per cent.

This increase of real property is the more remarkable when the circumstances of what was formerly its most eminent constituent (land) are considered. This natural agent, in a country like England of the present century, is within very narrow limits restricted in quantity. Houses, mills, factories, railroads, &c. may and do increase indefinitely; arable land cannot. It is impossible to say what was the area under cultivation in 1815; and it is, I believe, a matter of conjecture which way the balance would incline if the loss by the expansion of our towns and by the introduction of railways was measured against the acquisitions by enclosures, which, reckoning only from 1845 to 1867, amounted to 506,502 acres, a surface much larger than the area now under cultivation in Dorset or in Cornwall. The estimated quantity of land occupied by a lineal mile of railway, according to a Parliamentary Paper of last Session, was 12·97 acres; the total extent 133,430 acres, or rather more than *one-fourth* of the quantity brought under culture by the Enclosure Commissioners in twenty-two years.

The Government has published no return of the gross valuation in each county, under Schedule A, for a period later than the financial year 1864–65; but since a comparison of the value of land and of the other descriptions of real property in that year, in the different parts of the kingdom, with the official account in 1814–15, may be of some interest to the Section, the details have been worked out and placed in an Appendix *.

* See 'Statistical Journal' for September 1869.

Taken divisionally, the results are these, for the aggregate of real property other than land:—

Divisions.	Annual Value of Real Property other than Lands*.			Increase per cent.
	1814–15.	1864–65.	Increase in 1864–65.	
	£	£	£	
I. The Metropolis *and the extra metropolitan parts of* Middlesex, Surrey, and Kent ..	6,914,492	31,336,856	24,422,364	353·2
II. South-Eastern, *less the extra metropolitan parts of* Surrey and Kent	921,408	3,215,947	2,294,539	249·1
III. South Midland, *less the extra metropolitan part of* Middlesex	664,948	2,475,068	1,810,120	272·2
IV. Eastern	1,032,175	2,453,107	1,420,932	137·6
V. South-Western	1,782,524	4,695,384	2,912,860	163·4
VI. West Midland	1,429,248	7,852,049	6,422,801	449·5
VII. North Midland..............	473,185	4,248,121	3,774,936	798·1
VIII. North-Western	1,856,841	13,138,535	11,281,694	607·6
IX. York	996,986	7,924,120	6,927,134	694·8
X. Northern	712,777	4,013,925	3,301,148	462·9
XI. Welsh..	450,791	3,584,534	3,133,743	694·9
England and Wales	17,235,375	84,937,646	67,702,271	392·8

Under the house-tax the farmer's dwelling is separately assessed, but for property-tax purposes it is treated as an integral part of the land.

Divisions.	Annual Value of Lands (inclusive of Tithes).			Increase per cent.
	1814–15.	1864–65.	Increase in 1864–65.	
	£	£	£	
I. The Metropolis *and the extra metropolitan parts of* Middlesex, Surrey, and Kent ..	2,018,000	2,582,315	564,315	27·9
II. South-Eastern, *less the extra metropolitan parts of* Surrey and Kent	1,956,000	2,697,641	741,641	37·9
III. South Midland, *less the extra metropolitan parts of* Middlesex	3,716,000	4,935,099	1,219,099	32·8
IV. Eastern	3,209,000	4,908,096	1,699,096	52·9
V. South-Western	5,294,000	6,313,853	1,019,853	19·2
VI. West Midland	4,893,000	6,189,576	1,296,576	26·4
VII. North Midland	4,339,000	5,755,138	1,416,138	32·6
VIII. North-Western..............	2,397,000	2,826,389	429,389	17·9
IX. York	3,764,000	4,431,864	667,864	17·7
X. Northern	2,498,000	2,628,592	130,592	5·2
XI. Welsh	2,176,000	3,135,290	959,290	44·1
England and Wales	36,260,000	46,403,853	10,143,853	27·9

* With "lands," wherever mentioned in this paper, tithes in the earlier years, and tithe-rent charge in the later ones, are always included.

In these comparisons no adjustment for the depreciation of the currency in the earlier part of the century has been attempted. Professor Jevons has given a table in the 'Statistical Journal'*, showing that, in 1814, gold was above the standard price of £3 17*s.* 10½*d.* by 34 per cent., and in the next year 20 per cent.; at the latter ratio *one-fifth* must be deducted from all values in 1814–15.

From the absence of any authentic record of the land under cultivation in 1814–15, the means of computing the farm rental per acre are wanting. We are in a better position now: the rent for the whole kingdom, as well as for individual counties, can be worked out with, I believe, a useful approach to accuracy. The rent for all England and Wales was, in 1866, £1 17*s.* 9*d.* per acre. The statistics for this, as well as for the counties of the south-western division, are displayed below.

	Total Area in Acres.	Acreage under all kinds of Crops, Bare Fallow, and Grass in 1866.	Annual Rental, Schedule B, in 1864-65.	Rent per Acre.
			£	£ s. d.
All England and Wales †	37,324,883	24,546,607	46,403,853	1 17 9
South-Western Counties:—				
Wilts	865,092	636,786	1,161,656	1 16 6
Dorset	632,025	398,599	744,047	1 18 10
Devon	1,657,180	919,336	1,780,976	1 18 9
Cornwall	873,600	436,071	744,652	1 15 6
Somerset	1,047,220	735,604	1,852,522	2 10 4

Note.—The agricultural statistics do not include the area of hill-pastures; holdings under five acres are also excluded. In 1861, according to the census, there were 7656 holdings in England and Wales under five acres each; their aggregate area was, however, only 19,140.

These figures have, perhaps, no very immediate bearing on the subject of the paper; but it seemed of possible utility to record them here for future guidance.

While land and other kinds of real property have made, in the past half century, the highly satisfactory progress already mentioned, it is certain that trades, manufactures, and professions have enormously distanced agricultural industry in the race for wealth.

The assessment "for all profits or gains arising from any profession, trade, employment, or vocation," under Schedule D, is notoriously, and perhaps irremediably defective. In their last Report, the Commissioners of Inland Revenue estimate, from circumstances within their knowledge, that the return of income under this schedule is £57,250,000 short of the true amount; no exaggeration can, therefore, be charged against the figures which represent profits and gains in the annexed Table (p. 65).

The land rental in respect of which the farmer's profits are assessed has, during the fifty years ended with 1865, increased by £12,375,000, or 36 per cent.; the profits of trades and professions have, in the same interval, augmented by £72,611,000, or 212 per cent., irrespective of the correction due for depreciated currency in 1814–15. Two factors enter into the increased assessments returned under Schedules A and B since 1864—real

* Vol. xxviii. 1865.

† The rent per acre for land, *i. e.* for 25,542,427 acres, under cultivation, in all England and Wales, according to the Returns of 1867-68, is £1 17*s.* 4*d.*

advance in quantity and in market value, and an apparent advance by better assessment *.

England and Wales under	Annual Value Assessed in	
	1814–15.	1864–65.
	£	£
Schedule B— Farmers' profits †	34,028,655	46,403,853
Schedule D— Profits of trades and professions	34,287,685	106,808,319

There is, I fear, no possibility of assigning the true value to each factor. The Union Assessment Committees' valuation of 408 unions, embracing about half the rateable property of the kingdom, in 1863 amounted to £43,298,000; in the following year, when it may be supposed these bodies had obtained greater knowledge of their work, the assessment of the same unions was raised £5,384,000, or 12·4 per cent.

III. Conclusion.

Though in the preceding pages the taxes incident upon real property have been termed a burden, this language requires some qualification when we examine the objects to which a large portion of our local rates are devoted. The charges entailed on the ratepayers by crime and pauperism might be dispensed with, to the great advantage of the property now defraying the cost, though English poor-rates largely supplement wages, and consumers thereby gain some temporary, but in its consequences more than doubtful, benefit. Expenditure upon the maintenance and repair of roads and bridges, upon the drainage and embankment of marsh lands, upon the sewerage, paving and lighting of towns, and upon many other services performed by improvement commissioners, as well as the sanitary measures undertaken by boards of health, are operations signally beneficial to rateable property.

So far, therefore, as the property is judiciously assessed, and the proceeds honestly and intelligently administered for these purposes, the local rate is a good investment, for which no enlightened owner will manifest an ignorant impatience of taxation. The imperial taxes and the other part of the local rates stand in a very different category.

[*Note.*—An Appendix, consisting of detailed Tables, will be found in the 'Journal of the Statistical Society' for September 1869.]

* Alluding, in 1864, to a new valuation of property then in progress, under the orders of the Inland Revenue Office, the Commissioners mention that in many districts the amount of duty was greater at 6*d.* than formerly at 7*d.* They state that, "so far as Schedules A and B are concerned, this result is attributable in no small degree to the care and judgment with which the assessments were made upon this occasion by our surveyors, acting under special instructions from this office. We have also been much assisted by the valuations under the Union Assessment Act, especially in the case of land in the occupation of the owner, where the former unsatisfactory parochial rating to the relief of the poor was the guide upon which our officers chiefly relied."—*Ninth Report of Commissioners*, 1865.

† Farmers' profits were estimated as equal to three-fourths of their rental in 1814–15, and one-half rental under the Act of 1842. The full rental of both years is given above.

On the Chemical Reactions of Light discovered by Professor Tyndall. *By* Professor Morren, *of Marseilles.*

[A communication ordered to be printed *in extenso* among the Reports.]

Since the last session of the British Association, Mr. Tyndall has published, in several papers, highly interesting researches on a particular species of luminous reactions, thus providing physicists and chemists with a new instrument, both of synthesis and analysis, to which he invites the attention and investigation of all whom it may concern. In obedience to this scientific challenge, I have repeated, with the utmost care, all the learned gentleman's experiments. I have found them all as rigorously exact as they are ably described. They refer to atomical evolutions in which we almost seem to detect Nature in her most mysterious operations. The molecules of bodies, when powerfully lighted, the observer himself being in absolute darkness, may be easily perceived in their infinitely minute motions; in following which, Mr. Tyndall, and every one who is passionately desirous of penetrating the secrets of the constitution of bodies, cannot but feel the most exciting curiosity. Mr. Tyndall has made use principally of electric light, and has caused it to act mostly on organic bodies. I have followed in this respect quite a different method and object.

Most favourably situated with respect to solar light, in Provence, where for months together we enjoy a cloudless sky, I proposed to limit myself to the use of solar rays only, and confine myself to those conditions which the atmosphere affords us. I have carefully avoided organic bodies, the molecules of which are highly complicated and most difficult to follow in their multifarious evolutions. I have even preferred the simpler bodies of mineral chemistry, as offering an easier field of observation to the physicist desirous of arriving at clear and precise results.

In this exposition I shall follow, step by step, the order which, without any preconceived or systematical ideas, directed my successive experiments. It is, so to say, a journey in an unknown land. I shall thus the better show the deceptions I met with, the incessantly supervening difficulties, the necessities of modifying the apparatus, and the various incidents of the route. I hope by this means the better to illustrate the object I had in view.

At the outset I made use of an experimental apparatus entirely similar to Mr. Tyndall's—a glass tube 8 to 9 centimetres in diameter and 1 metre long, fitted at each extremity into a broad brass ring luted with cement, and carefully ground in the anterior part; two plain pieces of plate glass, perfectly transparent, resting on the rings, and slightly lubricated on the edges with a fatty substance, constituted an air-tight cavity when a vacuum was formed. A glass cock, fitted on each extremity, and let into the cylindrical rings, allowed me to make the vacuum at one end, and to introduce at the other the gas or vapour on which the experiments were to be made. Extreme, if not absolute cleanness and perfectly dry tubes are indispensable requisites.

The light arrives in the tube after condensation by a lens which everything induces me to believe was not achromatic in Mr. Tyndall's experiments. In his apparatus, as in mine, two cones are formed joined at the apices, the first, the converging cone, with an orange-red periphery, the other, the diverging one, with a violet-blue periphery, circumstances which I notice here, because the white molecules which are about to appear will often assume, in passing through them, the hues of the luminous bands in which they circulate. When a vacuum has been produced in the tube, the light passes through it without the cones being in the least perceived; the tube is optically vacuous; but when the gas or vapour is introduced, a blue cloud, or blue precipitate, of an incomparable delicacy appears after a varying lapse of time, first at the summit of the cones, then in the converging cone. As long as the precipitate is of that beautiful blue colour, the light which it sends to the eye is perfectly polarized as Mr. Tyndall has described it. Then by slow degrees the precipitate increases, and slowly becomes white, the light emitted still remaining polarized; but as the sides of the tube lighted by the cones send to the eye light which is also polarized, and as it were the product of a polarizer, the whitish vapour of the cones then behaves like a thin polarizing lamina under inspection through the Nicol held by the observer; and when the two polarization planes are perpendicular to one another, the whitish cones assume a magnificent blue colour, exactly as a thin lamina of selenite of the required thickness would do; but in proportion as the white precipitate increases, all polarization disappears. The precipitated molecules become heated, both at the summits of the cones and against the entrance glass plate, and there arises a motion, slow at first, which brings to the cones other particles of the body under experimentation, not yet acted on by the light; and as these particles, owing to transparency, appear dark, their intermingling with the white particles produces a series of the most beautiful, varying, and often most regular images, such as have been described with expressions of genuine admiration by Mr. Tyndall.

The precipitated molecules seem to increase in diameter, and the two cones are then resplendent with reflected light. But there are, for the eye, certain points where the cone takes a fine rosy colour; and the position of these points varies in the course of the same experiment. They are sometimes on a line which forms an angle of 45° with the axis of the converging cone, sometimes on a line forming an angle of $90°+45°$ with the same axis. There is, as in the rainbow, a line of position, and for the precipitated molecules a zone of efficacious rays, which demand special and ulterior inquiries.

Let me resume the exposition of facts already so well described by the English physicist.

It will be easily seen that either a synthesis or a decomposition of a body has taken place, *i. e.* a new grouping of the atoms, when under the influence of concentrated solar light the blue cloud invades the cones.

The first body of which I have attempted the synthesis is that which I have so often and so easily obtained by electricity, by causing the induction spark to pass through a gaseous mixture, formed of one of oxygen, two of nitrogen, and three of sulphurous acid *. It is the compound which is formed in the leaden chambers in the preparation of sulphuric acid.

I submitted the gaseous mixture to the solar action immediately the compound was produced. The same gaseous mixture enabled me to recognize, like Mr. Tyndall, that the special rays which produce these reactions are neither the less refrangible calorific rays, nor the red rays even when highly concentrated. I have for this object made use of the greatest variety of screens—smoky quartz, iodine dissolved in bisulphide of carbon, CS^2, then coloured glasses, red, orange, yellow, green; but I dislike and distrust the glass screens; I prefer by far liquid ones. The action produced was insignificant. It became, on the contrary, extremely energetic with blue and violet glasses.

It is therefore under the shock of the more rapid oscillations of the chemi-

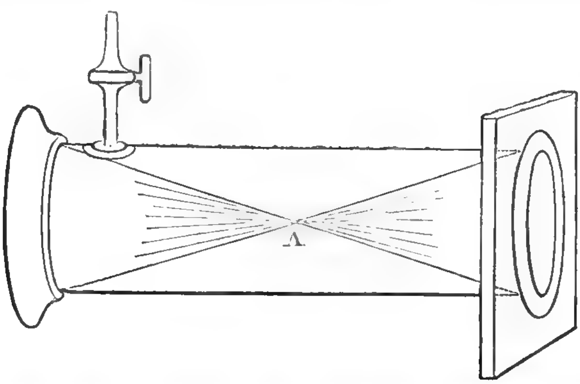
* *Vide* Annales de Chimie et de Physique, vol. vi. series 4.

cal rays that these reactions are produced. And here I wish to notice, in passing, an interesting fact, important especially for photographers—I mean the power of intercepting only the chemical rays of solar light, without stopping the luminous rays, possessed by a solution of bisulphate of quinine, well filtered and confined, by means of gutta percha, between two glass plates. This screen, 5 millimetres in thickness, is of an extreme transparency to light; but the chemical rays are intercepted. It might be advantageously used instead of the yellow glass, which, in photographic operations, casts on all objects such peculiar hues as to require a special education of the eye which has to judge of the reactions. This screen proved inestimable to me, as it allowed of my disposing and regulating the apparatus suitably beforehand, while it enabled me to permit the chemical rays, which the screen had intercepted, to act at the proper moment only.

After the experiments on $NO^3 2(SO^3)$ (O=8), I tried to unite the most resistant bodies. I introduced into the tube hydrogen and nitrogen perfectly pure and dry, and my surprise was extreme when I beheld the formation of a white cloud. This unexpected result, and one which I had considered as utterly impossible, obliged me to look still more closely into the matter, and to proceed with still greater caution.

The brass rings at the extremities of the tube were luted with the usual resinous cement. Against this cement my first scruples were now directed; it might still contain some volatile essence (spirits of turpentine for instance) which might have penetrated into the tube when a good vacuum was formed; and so small a quantity of matter sufficed perhaps to produce an appreciable result; this might have given rise to the unexpected cloud. It became necessary to suppress these rings and simplify the apparatus, which I effected in the following manner.

I took a cylindrical glass tube (a glass with a foot, Fr. *éprouvette*) 29 to 30 centimetres long and 8 to 9 in diameter, and 1200 to 2000 cubic centims. in capacity. The upper edge, somewhat bell-mouthed and carefully ground, of above 8 millims. thickness, was slightly lubricated with a little tallow, wax, and oil melted together. A flat square of plate glass, very transparent, was placed on the oil and sharply pressed down upon it, and some wax was melted all round the contact surface with a hot iron. At the bottom of the cylinder, on the side, a glass stop-cock was carefully fitted in. With this apparatus the vacuum may be preserved during a long time, even for months together. The



vacuum is produced, and the gases are introduced by the stopcock solely. But there is another method, very important to notice, for introducing into the tube the body to be examined, when it is solid or liquid and volatile. A very small quantity of the substance is put into a very fine thin cylindrical tube, which is closed with the lamp at both ends after the introduction of the body, and can be, when necessary, easily broken to pieces by a slight shock against the tube. The mercury gas-holders which receive and conduct the gases are glass, carefully divided, so as to measure the volume of the gases experimented on. In lieu of an air-pump I have always made use of a mercury exhauster, the only apparatus which can be absolutely relied on, and which enables the operator, when the reaction is completed, to withdraw the gases from the tube for analysis; the mercury exhauster likewise enables us to measure the elastic force of the gases before and after the reaction, and thus indicates the variations of volume of the gas employed.

What therefore gives these experiments a peculiar character is the complete elimination of all gaseous vehicles employed to convey the vapour. The conditions of my experiments differ in this respect from Mr. Tyndall's.

The tubes, of smaller dimensions, which I have employed do not give indeed the splendid results which Mr. Tyndall presented to his delighted audience; but these tubes are easier to set up and to clean: the mercury exhauster possesses moreover another advantage; it allowed me to ascertain whether the gases were perfectly dry—a most essential point.

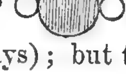
As to the means of conveying the solar light, the process was the following. A broad mirror receives and reflects horizontally a voluminous pencil of rays which is refracted by a lens 22 centimetres in diameter and of 40 centimetres focal length. The luminous cone is enclosed in a metallic box, whence it issues to penetrate into the tube through the glass plate. The summits of the two cones, the converging and the diverging, are situated pretty nearly in the centre of the tube (A); the two cones are therefore easily visible when the modifications of the bodies contained in the tube are produced. It must not be forgotten that the periphery of the two cones is coloured, as we said before, in consequence of the non-achromatism of the large condensing lens.

Under these circumstances I was very much surprised to see that a mixture of hydrogen and nitrogen, perfectly pure and dry, produced the reaction cloud. They had been dried by a very slow passage through pounded glass which had been calcined and moistened with sulphuric acid, pure and highly concentrated. I changed the desiccating substance, and successively made use of potash, chloride of calcium, phosphoric acid, all recently melted. In the three latter cases the cloud did not appear; the action was null, and the solar light passed unperceived. What could the *sulphuric* acid, then, convey? evidently some little *sulphurous* acid; for *sulphuric* acid is in fact a real emitter of it, and always adds a certain quantity of it to any pure gas which passes through it in minute and successive quantities; and this acts in fact as an absorbent of the dissolved gas. Therefore hydrogen and nitrogen cannot be united by solar influence when perfectly freed from other gases. But, in truth, what could the action of the sulphurous gas be?

I applied myself to a special study of sulphurous acid, and have ascertained how easy the decomposition of this gas is. As soon as the light passes through it, the white cloud appears; and if its manifestation is followed with care, it will easily be seen that it is produced not only at the summit of the cones, but likewise on the blue periphery of the first part of the diverging cone, and in the interior of the converging cone. I know of no body more sensible to luminous action; and the use of condensed light seems hardly necessary for the purpose, since the cloud is formed at other points than the summit of the cones. With this body it is certainly both easy and admirable to behold the coloured bands which form the outline of the cones; and then even the violet rays (scarcely perceptible under ordinary circumstances) can be easily seen in the interior of the first cone. One may thus easily follow and account for the varied hues which the whitish vapour assumes when the variations of temperature waft it about the cones, intermingled with the black streaks arising from such portions of the gas as have not yet been acted on.

But to return to the sulphurous acid: What was the substance, blue at first, then whitish, thus obtained? The two hues so different were merely the consequence of a difference in diameter—the first hue belonging to the bodies (perhaps atoms) precipitated in the minutest state of division. The white and pearly colours appear when the diameter has sufficiently increased, and goes on still increasing. These circumstances induced me to endeavour to measure this diameter, a thing feasible by different means, but not with ease and facility by microscopic inspection, however; for the small spark-like bodies move too rapidly through the field of the microscope. But there were other methods. It may be first observed that if you expose sulphurous acid for a sufficient length of time to solar action, the precipitated substance becomes sufficiently abundant for a sort of haze to become perceptible in the tube. A part of the gas has been acted on; and the two luminous cones, when moved about in the tube, find everywhere reflecting precipitated molecules. If the tube is left long enough in repose and darkness, the cloud collapses, forms a deposit, and the gas is restored to its primitive transparency. If at this point the tube be again placed under solar action, the same successive phenomena of haze and return to transparency may be repeated indefinitely, till there remains no more gas to be decomposed, which is a very long process, for the very formation of the precipitate intercepts itself the chemical rays which form it.

But since transparency has been produced, a deposit of molecules must have taken place; and in this case, if the tube remains in a horizontal position and a broad slip of glass be placed inside it, it is on this slip that the molecules will be found. Their diameter might then be measured, either directly or by the rings of diffraction; but unfortunately it became impossible to use this expedient: the sulphur was dissolved by sulphuric acid; and instead of the molecules which I expected to find, very small drops only were perceived. But nevertheless it was possible to obtain the molecules of sulphur in large quantities, and to submit it to all requisite reactions so as to recognize it completely. It is sufficient to place in the tube after the sulphurous acid three or five cubic centimetres of distilled water; and after the solar rays have sufficiently acted on the gas, the tube is then shaken; the water dissolves the sulphuric acid and renders it powerless for dissolving the precipitated sulphur; the water then becomes milky and the sulphur is collected. It is then boiled in a small glass vessel (to drive out the sulphurous gas) and filtered in order to collect the sulphur; the water then gives abundant proof of the presence of sulphuric acid.

The atoms of the molecules of sulphurous acid are therefore not able to support the shock of the undulations of the chemical rays; they divide into sulphur and sulphuric acid, $3\,SO^2 = S + 2\,SO^3$ (and from the form  they change to , in which state they are able to resist the shock of the chemical rays); but they exhibit other phenomena, to which I shall return a little further on. During sixteen days of uninterrupted sunshine, from the 14th to the 31st of July, I exposed to solar light 1900 cubic centimetres of sulphurous acid in a tube of 2000 cubic centimetres capacity; and the decomposing action was, after that lapse of time, being still carried on in an always sensible and wonderful manner. It was evident that every day the solar action was only partial; it stopped as soon as the precipitated molecules of sulphur in motion in the tube were abundant enough to intercept all the chemical rays as an opaque screen.

The action of light on sulphuric acid was interesting to study; it is one of the most beautiful and instructive experiments which can be executed. It smokes abundantly on exposure to air; and this effect is attributed to the absorption of aqueous vapour by this substance. This is not a correct explanation, since in a perfectly dry vacuum the same phenomenon takes place. In the tube with a dry vacuum of $\frac{1}{2}$ to $\frac{1}{10}$ of a millimetre I had introduced a very fine thin tube containing anhydrous sulphuric acid. When I broke the tube, the little explosion, and certainly the great and sudden expansion of the substance, scattered about the vapour of the sulphuric acid, which, owing to the cold generated, was condensed into a white cloud, and appeared with a dazzling resplendency in the luminous cones. Here the chemical rays are powerless, they cannot destroy what they have produced. There is no more decomposition, but sulphuric acid is, if I may use the comparison, like water in the vesicular state in a cooled medium through which heat is about to penetrate. Insensible to the chemical rays, the sulphuric acid absorbs the calorific rays, on the contrary, with prodigious energy. This absorption is so perfect that all molecular motion ceases instantly. The molecules remain motionless, as if busy in absorbing the heat; and, as aqueous vapour does when heated, they pass into the state of a transparent gas, assuming previously to their apparent annihilation all the most magnificent hues. If during the operation the cock is rapidly opened and immediately closed, the great movement of molecules so rapidly and so energetically produced ceases at once, by the absorption of the heat.

This invisible vapour, when still further and sufficiently heated, will have its component atoms so shaken by the amplitude of their new oscillatory vibrations that they will be removed beyond the radius of their sphere of action, and the molecular edifice of sulphuric acid is (in its turn) destroyed.

I am afraid of fatiguing the attention of my hearers if I develope at a greater length the details of various experiments made with a large number of gases and vapours. We must stop here. Yet what results are to be noted!

Thus, for instance, in the most natural, perhaps, of all the groups that constitute the family of metalloids (that which comprises chlorine, bromine, iodine, fluorine) strange anomalies are observed. Chlorine and hydrogen unite under the action of chemical rays and form hydrochloric acid. The latter, either dry or humid, and prepared with pure crystals of mineral salt of chloride of sodium, cannot be decomposed by chemical rays of solar light; whereas hydriodic acid, on the contrary, can be decomposed; it is true (and this circumstance must not be overlooked) it is very difficult to procure this gas free from atmospheric air. A curious circumstance in the examination of hydriodic acid is, that the first shock of light frees part of the iodine, which appears with its peculiar violet hue at the summit of the cones, amidst the movements which destroy the molecular edifices—movements, perhaps, produced by the calorific rays only.

Bromine presents the peculiarity, that (as in the case of hydrogen with chlorine) if pure and dry hydrogen is introduced with a small quantity of bromine into the little tube which is placed inside the cylinder previously to the experiment, and which is broken before it is submitted to solar action, after a few seconds the brownish colour of the bromine disappears and hydrobromic acid is formed, smoking abundantly on contact with atmospheric air.

I could increase still further the list of bodies submitted to this interesting means of investigation and experiment. I shall limit myself to a summary of the theoretical considerations which these facts have impressed on my mind.

We know that the calorific, luminous, and chemical rays are placed side by side and are even intermingled in the solar spectrum, with undulatory lengths successively decreasing.

Now all chemical bodies may be classed in two series: the first (having sulphurous acid for prototype) comprises all bodies formed under the action of calorific rays; the second (having hydrochloric acid for prototype) comprises all bodies formed by the chemical rays.

The following are the conclusions which the foregoing facts induce me to admit:—

If a body is formed and maintained under certain oscillatory conditions, the peculiar oscillations of the atoms which constitute its molecules must differ from those of the medium in which the body has been produced. But if this body is transferred into another medium in which it meets with oscillations isochronous to those of its own atoms, these oscillations increase, and the *vis viva* which the atoms acquire may become so great as to drive the atoms beyond the radius of their sphere of action; the atomic edifice is demolished; and as the constitutive atoms preserve, nevertheless, their peculiar affinities, they form a new edifice adapted to the oscillatory conditions in which they are now situated. Thus they escape the shocks of the generating medium, by ceasing to vibrate synchronously with it, exactly as an elastic sonorous body does not vibrate and gives no sound when the aërial vibrations which strike it are not synchronous with those which it is capable of reproducing. But if the new edifice is again submitted to the action of other synchronous rays it is again demolished.

Most curious evolutions! They seem to ask of the chemist:—

1°. Under what peculiar circumstances and influences are bodies formed?

2°. Under what vibrations precisely do their atoms oscillate?

3°. Finally, under the action of what other vibrations may the molecular edifice be destroyed?

Ozone, and all bodies capable of uniting themselves with other bodies, would be simply molecules whose atoms are possessed of a *vis viva* sufficient to animate and set in motion the atoms of the other bodies with which they unite themselves.

Will a *simple body*, even, always remain such to us, if it become possible to discover what oscillations have assembled the atoms of its constitutive molecule, and what can destroy it?

Such is the question which future lovers of nature and science may be one day enabled to solve.

One word more, upon a probable conjecture.

I have often seen that, under some circumstances not yet determined by me, the concentrated action of solar light is not without effect upon atmospheric air. In such case an appreciable whitish-blue colour is produced; might it not, then, be presumed that the fine whitish-blue vapour which in Alpine valleys bathes the foot of a mountain is produced by the action of a brightly luminous sky under favourable and unknown circumstances of heat, light, and aqueous vapour?

On Fossils obtained at Kiltorkan Quarry, Co. Kilkenny. *By* WM. HELLIER BAILY, *F.L.S., F.G.S.*

THIS celebrated fossil locality, in the Upper Old Red Sandstone, is situated between Kilkenny and Waterford, about six miles south of Thomastown and a mile south-east of Ballyhale, on a ridge of Old-Red-Sandstone hills rising gently from beneath the Carboniferous Limestone plain to heights of from 400 to 500 feet above the sea-level, and sometimes to even 800 feet, as near the boundary of the parishes of Derrynahinch and Jerpoint West.

This quarry has been visited from time to time by private individuals, by the representatives of scientific societies in Dublin, and by the officers of the Geological Survey of Ireland, on all which occasions it has furnished some most interesting fossils, remarkable for their preservation and beauty, each time yielding specimens either new to science or such as would assist in elucidating those already collected.

At the meeting of this Association in Norwich last year, I advocated the importance of further excavations at this place, and applied for a grant of £40 towards that object; £20 was, however, the only amount voted. I felt some hesitation in accepting this sum in consequence of its insufficiency to carry out the extent of excavation I had intended; and had I not been aided by the Geological Survey, it would have been comparatively useless to attempt reopening this quarry with the sum placed at my disposal.

I did, however, proceed there last month, accompanied by an efficient and zealous assistant, Mr. A. M'Henry, and provided with tools, such as bars and picks, for excavating with vigour. We were engaged for a fortnight, working most laboriously; and fortunately we had very favourable weather, except that it was extremely hot in this exposed situation for the heavy work we were occupied upon.

We engaged the services of two men, who ably assisted in removing the superficial soil and unproductive strata to the depth of about four or five feet, which was carted away at once; and we calculated that the total quantity removed in this manner and excavated by us amounted to at least 200 loads of stone and rubbish.

The character of the beds beneath this superficial covering, a fine-grained greenish sandstone, admitted of great facility in working, splitting up into layers, sometimes of large size; occasionally, however, it is much cut up by joints and small dislocations, which prevents its being worked so readily. Some of the surfaces of these layers are covered by plant-remains; and when first opened the fossils are most beautifully exhibited, as, from the dampness of the stone, their darker colour makes them appear very conspicuously.

The following is an enumeration of the fossil plants observed:—

Palæopteris Hibernica, originally named by Prof. Edward Forbes *Cyclopteris Hibernica*, then referred to *Adiantites* by Brongniart, and now placed by Prof. Schimper in his genus *Palæopteris*, the name signifying *ancient fern*, in allusion to the antiquity of its type and its first appearance with the most ancient terrestrial vegetables known, before the commencement of the Coal period *, that celebrated author on fossil plants observing that it differs from *Cyclopteris* in the arrangement of its leaflets &c., and from *Adiantides* (Adiantites) in its mode of fructification.

Two other ferns have been collected from this place; they are, however, of less frequent occurrence. One of these has already been brought before the notice of the members of this Association, and described by me as *Sphenopteris Hookeri*; the other, an undescribed species, I propose to name

* Traité de Paléontologie Végétale &c., par W. Ph. Schimper. Paris, 1869.

Sphenopteris Humphresiana, after a gentleman (Mr. H. T. Humphreys) who worked most indefatigably at this quarry, from which he obtained a large collection of valuable specimens.

On our late visit we were fortunate enough to procure perhaps the finest specimen extant of *Palæopteris Hibernica*, measuring about four feet in length, with its base of attachment and fertile pinnules shown at the lower portion.

A few fragments only of *Sphenopteris Hookeri* were collected; but we obtained a finer example of *S. Humphresiana* than any that had been before met with, being a branch or stem with several alternating pinnules arranged upon it.

Large closely fluted stems, which I had formerly regarded as being identical with *Sagenaria Veltheimiana*, and which, with others of a somewhat similar character, Dr. Haughton has described under the name of *Cyclostigma*, are also of frequent occurrence at this quarry: one of these stems measured six feet in length, with a diameter of six inches at its lower portion, and even then its commencement or termination could not be ascertained; the upper portion of this plant having divergent branches, was considered to be a distinct species, and referred to *Lepidodendron minutum*. Its fruit, of which we obtained remarkably fine specimens, is a cone-like body, formed of elongated scales, some of the detached ones showing very large and distinct sporules at their base; to these are appended long grass-like or linear leaves; it is remarkable, as Dr. Schimper observes, from the fact that no other species of *Lepidodendron* of which the fruits are known have such large sporules. That gentleman, through whom we sent a small collection of these fossils to the Museum d'Histoire Naturelle of Strasbourg, of which he is the Director, has done me the honour to name this remarkable plant after me, as he considers it distinct from *Sagenaria Veltheimiana*, especially in the form of the scales of the fruit, a part which I had not the opportunity of examining in the latter species.

Masses of roots with rootlets attached, such as I had observed in Mr. Humphreys's collection, and which he assured me were connected with the last-mentioned stem, were obtained by us from a bed which was permeated by fossils of this character.

The only example of mollusca found associated with these fossils, and of which we obtained good specimens, is the large bivalve named *Anodonta Jukesii* by Prof. Edw. Forbes, after the Director of our Survey in Ireland, whose loss, by death, we have had so lately to deplore. This shell is not unfrequent, and is so closely allied to the recent Swan Muscle, *Anodonta cygnæa*, of our freshwater rivers, that it becomes a valuable auxiliary towards the presumption as to the freshwater origin of this deposit. It is, however, amongst the class Crustacea, especially that of the Eurypteridæ and Phyllopodæ, that the most important additions have been made to the list of organic remains from this locality by our late visit.

In one of the earliest collections of fossils made by the Geological Survey at this place, a specimen was obtained, portion of a thoracic or body-segment, ornamented with the peculiar scale-like markings characteristic of these crustacea: this specimen was labelled by the late Mr. Salter *Eurypterus? Forbesii*, with a query as to the genus. In the Journal of the Geological Society, vol. xv. p. 229, the same palæontologist, in a paper on some species of *Eurypterus*, alludes to this specimen, which he figures as being probably identical with *Eurypterus? Scouleri* (Hibbert), a Coal-measure species from near Glasgow.

We have since met with other portions which favours the belief that this specimen belongs to *Pterygotus* and not *Eurypterus*. Amongst the collection just made are two which appear to be heads, although they are not clearly defined; also a more definite but small example of the basal joint of a swimming-foot (*ectognath*), showing very clearly the toothed edges of this masticatory and locomotive organ, another specimen being apparently the lower portion of a similar appendage. In a previous collection made by the Geological Survey are specimens showing the pincers or chelæ: in one of these the curved points of both rami are preserved; the upper one is seen to be armed with two large tooth-like projections; the lower one being imperfect does not show the corresponding parts.

It is possible all these fragments may belong to one species, which I propose to name *Pterygotus Hibernicus*. Another and distinct crustacean is shown in a well-marked head (or carapace), to which is attached portions of two of the thoracic segments. This specimen I fortunately picked up amongst the *débris* of the quarry immediately after visiting it. The form of this head, with its central arched divisions, to which the eyes are attached, is not very unlike that of a species of *Belinurus* from the Coal-measures; it is also provided with a border, and its posterior portion terminates on each side in a short spine. I have provisionally named this species *Belinurus? Kiltorkensis*.

Some detached body-segments, which were also procured at the same time in the progress of excavation (one of the specimens showing two entire segments, with portions of two others united), may possibly have belonged to the above species.

In a former collection from this place made by the Geological Survey, there are three well-defined examples of the detached carapace of a shrimp-like crustacean, which in shape approaches more nearly to that of the Silurian than to any of the Carboniferous species, and most nearly to *Hymenocaris* of the Lingula-beds. The anterior margin is broad and produced, giving it a curved outline, having a sinus running somewhat parallel and near to it, which is marked near the centre by a small elongated depression; the surfaces of these fossils are covered by fine labyrinthine markings. One of the fossils recently collected, although differing in shape (which may have arisen from pressure), is probably a carapace of the same species, it being also marked by a similar sculpturing. Some of the detached segments may also belong to this species, which, from its peculiar prow-shaped carapace, I propose to name *Proricaris MacHenrici*.

Of fish-remains we were not successful in obtaining many examples on this visit, a few detached scales only having been met with; those formerly collected are of great interest, and we had hoped to have met with specimens which might have thrown a better light upon some before collected; in this we were disappointed, but do not despair if another opportunity offers for a more extensive excavation. The fish-remains already obtained consist of large conical teeth, resembling those of *Dendrodus* or *Bothriolepis*, detached scales, and a large portion of a fish which appears to be identical with *Glyptolepis elegans*. The majority, however, appear to be referable to *Coccosteus*, some of them very closely resembling *C. decipiens*, Ag., especially a mass of plates in juxtaposition, showing the under sides; they consist, for the most part, of detached plates and jaws with teeth, which also resemble very much corresponding parts figured by Professor Agassiz in his Old-Red-Sandstone fish. There are also many detached smaller plates, and others with several plates united, which may possibly belong to *Pterichthys*: as some of the latter are in Prof. Huxley's hands, we may expect some valuable information about them.

With respect to the disposal of the specimens, a large number of which were collected, I would beg to suggest that the new species and those required for working out details, should be retained for the Geological Survey's collection in Ireland, and the duplicates distributed to such public institutions as it may be thought desirable to present them to.

Report of the Lunar Committee for Mapping the Surface of the Moon. Drawn up by W. R. Birt, *at the request of the Committee, consisting of* James Glaisher, *F.R.S.*, Lord Rosse, *F.R.S.*, Sir J. Herschel, *Bart.*, *F.R.S.*, Professor Phillips, *F.R.S.*, Rev. C. Pritchard, *F.R.S.*, W. Huggins, *F.R.S.*, W. R. Grove, *F.R.S.*, Warren De La Rue, *F.R.S.*, C. Brooke, *F.R.S.*, Rev. T. W. Webb, *F.R.A.S.*, Herr Schmidt, Admiral Manners, *President of the Royal Astronomical Society*, Lieut.-Col. Strange, *F.R.S.*, *and* W. R. Birt, *F.R.A.S.*

In presenting the Report of the proceedings of the Lunar Committee reappointed at Norwich, it is desirable to refer as briefly as possible to the progress of selenographical research during the entire existence of the Committee. Since the Meeting of the British Association at Birmingham four areas of the moon's surface, each of 5° in extent both of longitude and latitude, have been carefully and critically surveyed, not so much by the determinations of positions (the means at the disposal of the Committee being inadequate for instrumental and computative labour, which could only be carried on in an establishment exclusively devoted to such an object, the cost of which would far exceed the grants with which the Association has aided the work) as in an examination of the physical aspects of 100 square degrees of the moon's surface by means of the comparison and measurement of photograms, combined with observation at the telescope, by several observers in concert. Outlines of the objects thus surveyed have been laid down on the orthographical projection on a scale of 200 inches to the moon's diameter. The area thus surveyed includes 443 objects; a catalogue of these objects has been prepared containing numerous selenographical and selenological notices, those of the three areas completed previous to the reappointment of the Committee having appeared in the Appendices to the Reports of 1866 and 1868.

One of the principal objects which has been kept steadily in view is such a description of lunar features that at any future time the similarity of the description with the state of any particular crater, mountain, &c., or a departure therefrom, may be readily ascertained. The great question of continued lunar change, either transient or permanent, as contrasted with apparent change dependent upon illuminating and visual angles, is one more likely for posterity to settle. If, in geological science, a region undergoing a series of changes (during the progress of which, through a long period of geological time, lakes have been drained, volcanos have burst forth, extensive plateaus of igneous ejections formed, and vast denudations of softer materials effected) has retained its grander and more imposing features in their integrity, so in selenological science we may look for small, and in many cases to us almost inappreciable changes in and around well-recognized and imposing lunar forms, than expect to witness the obliteration of some very striking object as an evidence of change. The following are extracts from the catalogue of the area completed during the past year.

"The boundaries of *Hipparchus* differ materially from those of ordinary walled plains, and the cliffs on the S.W. are very unlike those of a circular form, inclosing large circular plains, as may be seen in the neighbouring formation *Ptolemæus*. They present the appearance of having suffered *erosion*, the character of the S.W. side of these cliffs being remarkably different from the exteriors of large rings, craters, and plains. These features, combined with the gradations of level observable in the floors of

Hipparchus, IV $A^{\alpha\,11}$, and the *Sinus Medii,* tend to invest them with peculiar interest. The apparent cutting away of the higher ground forming the E. slope of *Hind,* the projection beyond the general line of cliffs of the N.E. border of *Halley,* the indentations of the cliffs N.W. of *Halley* by the ravines scoring the E. slope of *Hind,* the general integrity of the cliffs S.E. of *Halley,* and the absence of similar indentations (these cliffs being cut through in one instance by a fault and in another scored by an apparent lava-channel) are phenomena which do not generally characterize walled plains. It is extremely difficult in the present state of our knowledge even to conjecture the kind of agencies which have operated in the production of a line of cliffs analogous in many respects to a terrestrial coast-line. One thing, however, appears to be certain, viz. the anterior existence of the E. slope of *Hind* as regards both *Halley* and the line of cliffs, while the fault and lava-channel on the S.E. are apparently more recent than the cliffs in which they occur."

"HIND is situated just W. of the fault IV $A^{\eta\,23}$, IV $A^{\beta\,62}$, and occupies the highest point of the mountain-range IV $A^{\eta\,7}$. The slopes around it are of very different characters. On the S.E., E., and N.E. the exterior slope is grooved or furrowed with well-marked radiating valleys, while on the S.W. and N. the slope is uninterrupted and destitute of any radiating markings. The more recent production of *Hind,* as compared with the fault on the E., is indicated by the valleys on its flank cutting through the fault. The posteriority of the formation of *Halley,* as well as the production of the depression IV $A^{\eta\,24}$ and the low floor of *Hipparchus,* is strongly suggested by the land on which the grooved valleys occur being penetrated by *Halley* on the one hand, and abruptly terminated on the other by the depression IV $A^{\eta\,24}$ and the valley IV $A^{\eta\,17}$ on the S.E., and the cliff IV $A^{\eta\,16}$ forming the S.W. border of *Hipparchus* on the N.E. The remarkable *smoothness* of the floor of *Hipparchus* in close proximity with the cliffs is very significant."

"The slope of *Hind* on the S.E., E., and N.E., with its valley-like furrows and interrupted continuity by *Halley,* and the cliffs on the S.W. of *Hipparchus* before mentioned, may be advantageously compared with the crater *Aristillus* on the *Palus Nebularum,* which to all appearance now exists in its primeval state surrounded by its furrowed flanks, extending far on the surfaces both of the *Palus Nebularum* and the *Palus Putredinis.* Only a small portion of the flank of *Hind* remains, the outer portions having been cut off by the more recent formations. It is not a little remarkable that the cliff IV $A^{\eta\,16}$ should be so distinct and precipitous in the neighbourhood of a crater partly surrounded by the remnant of a furrowed slope; and it is difficult to conceive with such phenomena, that ejecta from a volcano such as *Hind* appears to be, should extend no further than so precipitous a cliff as the S.W. border of *Hipparchus.* The order of production appears to be as follows:—the fault on the ray from *Tycho, Hind, Halley.* It is probable that the production of the floor of *Hipparchus* occurred at a still later epoch. * * * The highest portion of the region in which *Hind* and *Halley* have been opened bears some resemblance to the granitic plateau of central France."

"A very strong indication of the protrusion of *Halley,* subsequent to the formation of the valley IV $A^{\zeta\,27}$, IV $A^{\eta\,17}$, and IV $A^{\mu\,13}$, supposing the three portions were once connected, is afforded by the valley being completely *blocked* on the N.N.E. and S.S.W. by the E.S.E. rim of *Halley.* Mr. Ingall, on June 26, 1866, pointed out to me the connexion of the valleys N.N.E. and S.S.W. of *Halley.* At first sight this connexion might appear to be in *direction only.* The valley IV $A^{\zeta\,27}$ is certainly closed, as appears on the photograms, at the S.W. end by the angle formed by the N.E. border of *Halley*. The posteriority of the epoch of the valley IV $A\zeta^{27}$, IV $A^{\eta\ 17}$, and IV $A^{\mu\ 13}$ to that of *Hind* is strongly indicated by the continuity of the S.E. slope of *Hind* being interrupted by the valley, much in the same way as the N.E. is by the cliff IV $A^{\eta\ 16}$. We may trace here with great probability the following sequences of formations:—1°, that of the high land IV $A^{\eta\ 7}$; 2°, the fault IV $A^{\eta\ 23}$, IV $A^{\beta\ 62}$; 3°, the protrusion of *Hind*; 4°, the formation of the valley IV $A\zeta^{27}$, IV $A^{\eta\ 17}$, IV $A^{\mu\ 13}$ (several valleys hereabout are nearly parallel with this); 5°, the formation of the cliff IV $A^{\eta\ 16}$; 6°, the protrusion of *Halley*; and 7°, the cleft or wall on the E. of IV $A^{\eta\ 2}$, which is the highest in the locality."

"The exactitude of direction of certain lines of valleys and mountains on opposite sides of *Hipparchus* indicate a more recent epoch for the formation of the floor of *Hipparchus* than for the production of the valleys and mountains on the lines specified. In connexion with these circumstances the following questions suggest themselves. Does the general parallelism of the lines of mountains and valleys in the neighbourhood of *Hipparchus* point to contemporaneity of origin? Has the present floor of *Hipparchus* resulted from a *subsidence*, by which the former surface was depressed below the surrounding levels? There are some indications that, prior to the production of the fault IV $A^{\eta\ 11}$, IV $A^{\beta\ 20}$, $IV^{\alpha\ 72}$, the surfaces E. and W. of it were at the same level. Was this the level at which the valleys and mountains above alluded to were continuous? and has the surface between them, as well as the floor of *Hipparchus*, generally become depressed below its former level? If so, it would appear that *Horrox* was opened upon this former irregular surface; and it may be interesting to inquire further as to what may have become of the portions of the mountains and valleys which have disappeared. This question may be very difficult to answer, especially in the very imperfect state of our selenographical knowledge."

"There is some reason to believe that *Horrox* was not the only crater opened on this part of *Hipparchus* previous to the supposed epoch of depression. The curved mountain-chain IV $A\zeta^{58}$ presents all the characters of an ancient and nearly filled crater, slightly exceeding *Horrox* in size. Nearly half the ring is left, two craterlets are opened in the line of wall, and the surface which is traversed by a cleft is slightly depressed below the level of the surrounding floor of *Hipparchus*. It is one of those instances which Webb, in his paper on the Moon (Fraser's Magazine, Sept. 1868), refers to 'of cavities in proximity to the grey plains having interiors so flat, so grey, so identical in appearance and level with the plain, that hardly a doubt remains of their having been subsequently filled up by intrusive matter of the same origin and under the same pressure as that around them.' If IV $A\zeta^{58}$ be a nearly submerged crater, and the lines of mountains and valleys on opposite sides of *Hipparchus* were once continuous, the intermediate portions having also been submerged, the question to be resolved is—Whence came the material which has effected the submergence? The whole of the floor of *Hipparchus*, as compared with the surrounding formations, strongly exhibits indications of change of level; it is comparatively smooth, and of different reflective powers. The most striking difference of level occurs near the cliff IV $A^{\eta\ 16}$ and the mountains IV $A^{\beta\ 38}$ and IV $A^{\beta\ 47}$. Does this at all point to a subsidence of the floor of *Hipparchus*, accompanied by an invasion of intrusive matter? Instances of subsidence may be found on the moon; *Straight wall* may be quoted, the surface on the E. being at a *lower* level (about 1000 feet) than that on the W. The plain of *Dionysius* (Report Brit.

Assoc. 1865, p. 304) appears to be a *depressed* surface S. of the *cleft of Ariadæus*, the N. side being at a higher level. In like manner a portion of the surface N.E. of the line of cliffs from *Ptolemæus* to *Ritter* and *Sabine* may have subsided and produced the depressed region known as *Hipparchus*."

"While areas of depression, if not of subsidence, can be traced on the surface of the moon, and also the presence of a material which has invaded such regions and in many instances nearly buried preexisting craters and other objects, it is not so easy to ascertain whence this material came; still closer scrutiny is indispensable to throw further light upon it."

"In numerous portions of the moon's surface, as on that of the earth, we behold the results of the operation of two opposing forces,—one by which the features are moulded and, as it were, built up, imparting to the objects so produced an aspect of freshness that it is impossible to question their comparative recent production; the other by which objects once possessing all the characteristics of a recent formation have yielded, it may have been gradually, to surrounding influences, whatever they may have been, so that at the present time they exhibit the semblance of vast ruins, which in some localities are unrelieved by even the slightest indication of the operation of a force of an opposite character."

"Webb, in his very masterly paper on the Moon, in 'Fraser's Magazine' for September 1868, speaks of the possibility that the colossal lunar formations may have been the result of forces acting in a more gradual manner and with less temporary vehemence than may seem to comport with the term *explosion*. It may be that astronomers may have paid much more attention to those lunar features which are clearly the results of explosive action than to those which manifest the presence of a degrading agency. It has been considered that many of the larger forms have been produced by rapid, violent, and tumultuary processes; and, however true this view may be, it is certainly inadequate to account for the present appearances of still larger tracts in which no explosive outburst of an epoch which may in any sense be called recent occurs. Nearly filled as well as broken rings, interrupted mountain-chains, and comparatively smooth tracts without any well-defined boundaries are characteristic of such regions; and it may be asked in what manner and by what agency have they attained their present condition? Has the 'erosion' of Chacornac destroyed the missing portions of the broken rings? and has this 'erosion' acted suddenly or *gradually*? Has the 'diluvial,' restricted by Webb to the expression of comparative fluidity, independent of the nature of the material, invaded and nearly filled previously *deep* craters, so as to furnish a connected series of well-known forms, from the smooth, floored, walled plain to the just perceptible ring above the surface? Has this same 'diluvial' buried the lower portions and the lateral spurs of continuous mountain-chains, so that now the higher portions alone remain as short and detached ranges in the original line? One cannot help contrasting the continental region, to use a terrestrial analogy, in which this area IV A^{n} occurs, with the magnificent chains of the *Apennines* and *Hæmus*, and the lower and smooth levels of the *Mare Imbrium* and *Mare Serenitatis*, as exhibiting in a very marked degree the results of the forces already mentioned. In the latter we see the effects of comparative *recent* action in the production of vast mountain-chains and the neighbouring extensive level plains. In the former these grand features are wanting; the surface, although far from being smooth as that of the *Maria*, is roughened only with the remains of former mountains, rings, and craters; the degrading agency, whatever it may have been, appears to have operated almost unchecked in this region, and it is a subject of interesting inquiry as to how this state of things has been effected. Has the filling up, has the wearing down, if such is the case, been gradual? and what forces have been concerned in producing the mutilated forms we now observe?"

"Brightness and colour may ultimately become keys by means of which a better acquaintance may be obtained with the chronological sequence of lunar formations. Chacornac refers the great continental formations to an epoch anterior to that of the production of the great plains, this, again, being anterior to the period of explosive energy, contributing to the existence of numerous objects, such as bowl-shaped craters and smaller blow-holes, within the interior of which no intrusive matter is found. Reference, however, is not prominently made to objects in mountainous regions similar to those which we find in various portions of the great plains, viz. partly buried craters and partially destroyed rings, of which we have evidence in this and adjoining areas to the W. The contrast of the general colour of the surface hereabout, as compared with that of the grey plains, its mottled and rugged aspect, arising probably from its altered character from that which it possessed at a still earlier epoch, the absence of that sharpness of outline in its remaining mountain-peaks or ranges so characteristic of those which we find nearer to and often on the grey plains, together testify to a much earlier epoch than even that of the production of the partly filled rings on the grey plains. Bright, white, glistening surfaces, more or less in the neighbourhood of bowl-shaped craters, and dark patches of deep grey approaching black, appear alike to indicate the most recent formations—the first, it may be, from loose fragmentary incoherent materials ejected from adjacent craters; the last from substances in a state at least of comparative fluidity, which have escaped from the interior reservoirs at the times of eruption. Phillips compares the bright glistening region of *Aristarchus* to one in which *white* trachyte abounds; and many of the basalts in terrestrial volcanic regions present a dark colour. Between the brightest and darkest of such limited areas on the moon's surface every gradation of intermediate tint occurs; and from a careful consideration of the physical aspect of those regions which, on the one hand, reflect considerably less light than the brighter, and on the other considerably more than the darker, it may be inferred that such regions are amongst the most ancient of lunar formations."

A very ancient formation has been traced on area IV A^7, the earliest state of which is considered to have been very similar to many of the more recent districts, such as those in which perfect craters and mountainous regions intermingle. The first change which appears to have taken place on this formation is that of the production of a grey plain, traces of which still exist. The material of this plain appears to have invaded certain craters, breaking down the walls of those immediately facing the plain, and partially filling others. The next change appears to have been of an elevatory character, the evidences consisting of a line of low mountains which has in a great measure obliterated the characteristics of a grey plain and introduced those more in accordance with an ancient district, which are strikingly in contrast with the features of the more recent craters to the E. The only instance of volcanic outburst on this ancient district consists of a chain of craterlets of quite an insignificant character.

The determination of the successive changes before alluded to rests on the strong indications, afforded by the careful study of photograms, of the priority and posteriority of well-marked features, which can only be realized by contemplating the lunar picture in the seclusion of the study. While the telescopic view is far superior to the photographic, the continual changes of illuminating and visual angle prevent that appreciation of the relations of different features to certain epochs of production which can be so well studied in the photogram; the detail thus seized upon by the aid of photography is vividly realized by the eye at the telescope when the surface of the moon is suitably illuminated.

While engaged upon area IV A^{η} I have met with a remarkable instance of difference between De La Rue's photogram, Feb. 22, 1858, and Rutherford's, March 6, 1865. Lohrmann figures a plain, bounded on the W. by a mountain-chain on which he gives a little crater, which he numbers 51. In De La Rue's photogram the crater, which appears to be shallow, is *exactly* in the position given by Lohrmann. *Not a vestige of this crater is to be discerned on Rutherford's photogram seven years later*! Both photograms are under nearly the same illumination.

I have also met with a few instances of apparent variations of tint and brightness. The floor of the crater *Hind*, on the S.W. of *Hipparchus*, appears to have undergone a variability of tint during a period of eleven years according to the following numbers:—

$$1858{\cdot}14 = 5^{\circ}{\cdot}9, \qquad 1865{\cdot}18 = 7^{\circ}{\cdot}0, \qquad 1868{\cdot}98 = 3^{\circ}{\cdot}6$$

The slopes of two valleys, IV $A^{\eta\,6}$ and IV $A^{\eta\,11}$, which cut through the S.W. border of *Hipparchus*, manifest different degrees of brilliancy on the two photograms. They are much brighter on Rutherford's than on De La Rue's photogram, and IV $A^{\eta\,6}$ appears to have become brighter in a greater degree than IV $A^{\eta\,11}$.

		IV A^{η} 6.	IV $A^{\eta\,11}$.
De La Rue	1858·14	4·6	4·8
Rutherford	1865·18	7·4	7·0

A crater, IV $A^{\beta\,19}$, the middle of three conspicuous craters W. of *Hipparchus*, marked E Sec. I. Lohrmann and G by Beer and Mädler, appears to have become brighter since 1858. The gradations are exhibited below:—

Beer and Mädler..	1831–34	= $7^{\circ}{\cdot}00$	.. Full moon.
De La Rue	1858·14	= 6·30	.. Terminator just past Copernicus.
Rutherford	1865·18	= 7·14	.. ,, ,, ,,
Birt	1868·98	= 7·56	.. ,, ,, ,,
Birt	1868·99	= 8·00	.. $6^{h}\ 30^{m}$ past full moon.

The number of objects on the moon's surface, registered in accordance with the plan proposed in 1865 (see Report, 1865, pp. 294–299), is as follows:—

781	on	135	areas in Quadrant	I.
354	,,	86	,, ,,	II.
227	,,	59	,, ,,	III.
737	,,	63	,, ,,	IV.
Total 2099		343	,, on the moon's surface.	

Of these, 769 only have been published, viz. 492 in the Reports of this Committee, and 277 in Mr. Birt's Monogram of the 'Mare Serenitatis.'

Report of the Committee on the Chemical Nature of Cast Iron. The Committee consists of F. A. Abel, *F.R.S.*, D. Forbes, *F.R.S., and* A. Matthiessen, *F.R.S.*

The Committee have to report that, during the past year, some material progress has been made in this research. They entrusted the preparation of the pure iron to Mr. Matthiessen, who carried out this part of the investigation in conjunction with Mr. Prus Szczepanowski. From a series of experiments, which are detailed in the Appendix, pure iron appears to be obtainable in considerable quantities, and we hope, if the Committee be reappointed, that next year a great deal of valuable information will be obtained on the chemical nature and physical properties of pure iron and its alloys. The iron obtained by the process described in the Appendix is almost absolutely pure, containing only a minute trace of sulphur. According to an analysis made by Prof. Abel, the iron contained, in a hundred parts, only 0·00025 part of sulphur. In another analysis, the amount of sulphur found by Mr. Prus Szczepanowski amounted to 0·0007 per cent.* Phosphorus and silicon were carefully tested for by both analysts, and found to be entirely absent.

With regard to the physical properties of pure iron, owing to the want of time, nothing as yet has been accurately determined. It appears, however, that many of the physical properties of the pure metal differ considerably from those of the commercial.

APPENDIX.

On the Preparation of Pure Iron. By A. Matthiessen, *F.R.S., and* S. Prus Szczepanowski.

After numerous trials, the general outline of which was given in the Report of last year, the following method was found to yield nearly absolutely pure iron, in quantities sufficient for the purpose of this research. Pure dried ferrous sulphate and pure dried sodium sulphate are mixed in nearly equal proportions, and introduced gradually into a red-hot platinum crucible. The mass is kept in fusion until the evolution of sulphurous acid gas ceases. The crucible is then allowed to cool, and the fused mass extracted with water. If the heat be properly regulated, the whole of the iron is left as a very fine crystalline oxide. This oxide is thoroughly washed by decantation to remove every trace of the sodium sulphate, and, after being dried, is reduced by hydrogen in a platinum crucible; the spongy iron thus obtained is then pressed into solid buttons and melted in lime crucibles with the oxyhydrogen-blowpipe.

Before proceeding further, it will be as well to mention the precautions observed in obtaining the raw material in the purest state. The commercial pure ferrous sulphate was freed from every trace of copper by leading sulphuretted hydrogen through the warm acetic acid solution. After filtration, the ferrous sulphate was twice recrystallized and dried, first in a water-bath, then in an air-bath. The commercial crystallized sodium sulphate was recrystallized several times to get rid of the last traces of chloride of sodium, and then heated on a water-bath to melt the crystals. As is well known, anhydrous sodium sulphate separates out from this solution, which was scooped out from time to time, dried on an air-bath, and powdered. The purification of the sodium sulphate from chloride of sodium was found to be necessary, owing to the fact that, when fusions were made with sodium sul-

* The amount of substance taken for each analysis was about 30 grammes.

phate containing that salt, the resulting oxide of iron always contained platinum. The hydrogen used for the reduction of the iron, as well as for the blowpipe, was prepared by the action of sulphuric acid on zinc, and purified by leading the gas through two wash-bottles, the first containing nitrate of silver and strong nitric acid, and the second caustic soda and acetate of lead, both bottles being half filled with pieces of pumicestone. The oxygen was prepared by heating a mixture of chlorate of potassium with 15–20 per cent. of black oxide of manganese, and washed by leading through caustic soda. All wash-bottle &c. connexions were made of glass, lead, or pure india-rubber tubing.

The fusion took place in a large platinum crucible (the contents of which was rather more than half a litre), enclosed in the usual manner in a clay crucible. The dimensions were such that about a kilogramme and a half of the mixture could be fused at each operation. After fusion the crucible is allowed to cool, it is then boiled out with distilled water, and the accumulated product of 6–8 fusions washed by decantation with boiling distilled water. The crystalline oxide settles very quickly, and thus allows of a very rapid and thorough washing. The washing was in every case continued several times after the wash-waters ceased to give any turbidity with barium nitrate*. The reduction of the oxide thus formed was made in a covered platinum crucible, heated by means of a large Bunsen burner. The hydrogen was introduced by means of a platinum-tube, reaching through the cover to the bottom of the crucible. The gas, purified as described above and dried by chloride of calcium, was always kept slightly in excess, a constant stream of gas being obtained by not using a generator, but two large gas-holders joined together, the contents of each being about 600 litres (20 cubic feet), two other gas-holders of similar capacity being used for the storage of the oxygen, the one being used to collect the gas from the retort, the other to contain the gas purified by passing through a strong solution of caustic soda.

The resulting spongy iron was pressed into solid buttons by means of a strong coining-press and a diamond mortar, the cylinder of which being about 70 millimetres in height; the iron, when pressed, forms a cylinder of about 15 millimetres in height, and weighs about 20 grammes. The melting of the compressed iron took place in lime-crucibles, the lime having been previously burnt, slacked, and reburnt, thus forming a fine impalpable powder, which was compressed in the crucible mould.

The best method of fusion was found to be as follows:—The lime-crucible was placed in a slanting position on a piece of lime. One of the oxyhydrogen-blowpipes, used in the process, played on the outside of the crucible whilst the flame of the other was directed inside. When white-hot, a cylinder of the compressed iron was thrown into it. It quickly melts, but at the expense of a large quantity of the iron which is oxidized. The amount lost by oxidation varies between 25 and 50 per cent. In order to obtain a good solid button of melted iron, it is necessary to cool it in an atmosphere of hydrogen, which is easily obtained, simply by turning off the oxygen from the blowpipe playing inside the crucible. The button thus obtained weighs about 15 grammes. On analysis, it was found that these buttons were free from phosphorus, silicon, and calcium, but contained a minute trace of sulphur.

The preparation, on a large scale, of the pure ferrous sulphate and sodium

* It is worthy of mention that the above process to procure pure oxide from the mixture of mixed sulphates yields the purest oxide we have as yet obtained.

sulphate was kindly undertaken for us by Mr. J. Williams, who prepared for us more than a hundredweight of each of these substances. We are also indebted to Mr. W. G. Underhay for the use of his large coining-press for the pressing of the lime-crucibles and the iron buttons.

Report of the Committee appointed to explore the Marine Fauna and Flora of the South Coast of Devon and Cornwall.—No. 3. *Consisting of* SPENCE BATE, *F.R.S.*, T. CORNISH, JONATHAN COUCH, *F.L.S.*, J. GWYN JEFFREYS, *F.R.S.*, *and* J. BROOKING ROWE, *F.L.S.* *Reporter*, C. SPENCE BATE.

IN presenting to the Association the Third Report on the Fauna and Flora of the Southern Coast of Devon and Cornwall, I have to state that, independently of endeavouring to obtain a complete registration of all the more rare forms of life that exist upon the coast-line within dredging distance of the shore, the Committee have, as far as practicable, endeavoured to obtain information relative to the development, growth, and habits of those animals of which our knowledge has hitherto been imperfect.

CETACEA.

I think it desirable to put on record the Cetacea that have been taken within the last few years on the coast, specimens of most of which are preserved in the Museum of the Plymouth Institution.

Delphinus delphis. Dolphin.

Occasionally in the Channel: the last, January 1864. From the immense mass of fat underlying the skin, and from some unknown reason causing the skin to shrink, it was found impossible to preserve it.

D. tursio. Bottlenose Dolphin.

No record of any since the one described by Montagu in 1814.

Phocœna communis. Porpoise.

Common.

P. orca. Grampus.

Occasionally in the Channel. In Mr. Ross's collection, now in the Exeter Museum, I believe, was a young one driven on shore at Exmouth in 1844. The specimen in the Museum of the Plymouth Institution has been taken since.

P. melas. Round-headed Porpoise.

One captured off Plymouth in April 1839, and towed into the harbour.

Physeter macrocephalus. Spermaceti Whale.

One is stated by Bellamy to have been thrown on shore near Plymouth many years since.

Balænoptera boops.

This species has occurred several times. One in 1831 (the specimen now in the British Museum) was found floating off the Eddystone; a second was captured in a herring-net in Torbay, in 1846. In 1863 one was obtained off Plymouth, and the skeleton was purchased by the Alexandra Park Company, and is now, I suppose, at Muswell Hill.

Beluga albicans.

Mr. P. H. Gosse writes:—"On August 5th, 1832, I was returning from Newfoundland to England, and was sailing up the British Channel close to the land, when just off Berry Head I saw under the ship's bows a large

Cetacean of a milky-white hue, but appearing slightly tinged with green from the intervening stratum of clear water. It was about 16 feet long, with a round bluff head. It continued to swim along before the vessel's head, a few yards beneath the surface, for about ten minutes, maintaining our rate of speed, which was five knots an hour, all which time I enjoyed from the bowsprit a very good view of it. It could have been no other than the White Whale, the *B. borealis* of Lesson."

It frequently occurs on the Scottish coast.

Fish.

Of the Fish there have been but few novelties that I can add to the previous lists. The most interesting specimens are those of a Double-spined Ray and a variety of the Short-finned Tunny; the former is preserved in the Museum of the Plymouth Institution, and the latter in that of the Natural-History Society of Penzance. The Ray was taken off Plymouth, and appears to coincide nearly with that of *Raia aquila* (L.), except in being very much larger, and in the presence of two spines.

One point of interest that belongs to this specimen is the relation that it bears to *R. attavella* (L.). Of this Mr. J. Couch says :—" Consulting Artedi, and after him Linnæus, and comparing them with Lacépède, I find generally, as characters common to *R. aquila* and *R. attavella*, the body smooth and a slender tail. Linnæus says *R. attavella* has two spines often; but Lacépède makes the same remark of *R. aquila*. The material difference is that *R. aquila* has a very long tail, while *attavella* has it even less than the length of half the body. According to Lacépède (who says nothing of a Short-tailed Eagle Ray), the pectorals of his *aquila* are gradually slender, like the wing of an Eagle; but Artedi says that in *attavella* the pectorals are broad."

The dimensions of the recent specimen are 2 ft. 4 in. across the fins, 1 ft. 10 in. from the snout to the base of the spines, and 2 ft. 10 from the snout to the extremity of the tail; while those of *R. aquila*, in the Museum of the Plymouth Institution, are 14 in. across the fins, $11\frac{1}{2}$ in. to the base of spines, and 2 ft. 1 in. from the snout to the extremity of the tail.

Of the Tunny (*Thynnus brachypterus*), or Short-finned Tunny, Mr. Thomas Cornish of Penzance says that the specimen that he captured in Mount's Bay differs from that given, both in figure and letterpress, vol. iv. Appendix, by Mr. Couch, in his work on British Fishes, in having " more fin-rays in the first dorsal than my specimen had, and does not show two free soft fin-rays between the first and second dorsals, which were conspicuous in my fish."

Crustacea.

I am not aware that there are any novel forms or species to be recorded as the result of the dredging-operations of the Committee since the last reported list of Crustacea. In fact, the Committee have thought that they would be doing more to advance our knowledge of this class of animals, in pursuing the life-history of those that are already known to us, than by searching for the few stray specimens that have not hitherto been described as inhabitants of these seas.

Mr. Cornish informs me that he has very recently obtained in Mount's Bay several specimens of *Polybius Henslowii.*

Stenorynchus phalangium.

The young of *Stenorynchus* is a true Zoë, but differs from the typical form in the absence of the great rostral spine, and in the increased length of the great dorsal spine, by a series of latero-dorsal spines on the three posterior somites of the pleon, and in the enormous development of two deciduous spines on the base of second pair of antennæ.

Homarus marinus.

Common as the European Lobster is, it is very remarkable that a very young specimen has, as far as I know, never been met with. I have for several years offered a reward for a very small specimen, but have never received one less than 3 inches long from the rostrum to the telson. Many years since Erdl, in a memoir on the subject, described the young *Homarus* as being hatched in the form of the adult animal.

I have, during the last two summers that I have been engaged on this Report, endeavoured to hatch and develope this among other forms. Having specimens brought to me with ova, I have succeeded in hatching the same; but the mystery connected with the preservation of life, so as to enable us to watch the development of the animal from one stage to the next, has yet to be overcome.

Through the kindness of Mr. Alford Lloyd, curator of the aquarium in the Zoological Gardens at Hamburg, I have been enabled to obtain a specimen hatched under his knowledge about eight days old. This enables me to prove that not only is the young hatched in a form distinct from that of the parent, but, while it has continued to increase in size, and therefore cast more than a single moult, that it retains that form for some time after its birth. The ovum is about one-tenth of an inch in diameter, and contains a vitellus of a dark, almost black, green colour. In the earlier stages of the development of the embryo, the central or deciduous eye is distinctly seen, but appears to be lost at the time of the escape of the larva from the egg-case; at this period the young animal has a short pointed rostrum, that at first is bent back under the ventral surface of the cephalon; two large eyes, which at first are bent under the lateral margin of the cephalon; two pairs of short antennæ; a non-appendiculated mandible; two pairs of maxillæ, the third pair or maxilliped being not yet developed; seven pairs of pereiopoda, each of which carries attached to the third joint a long secondary multiarticulated ramus. The third pair is developed into a strong chelate organ, whilst the fourth and fifth pairs have rudimentary processes attached to the distal extremity of the fifth joint that demonstrates their chelate conditions at a very early stage. The pleon consists of six somites only, neither of which is furnished with a pair of appendages, or, as far as I could see, the rudiments of them. The posterior somite or telson is dorsally and ventrally flattened, evenly excavate at the posterior margin, which has the lateral extremities produced to a sharp point; while a large strong spine projects posteriorly from the centre, on each side of which, between it and the lateral point, are about twelve short stout pointed hairs.

Crangon vulgaris.

The young of the common Shrimp, although I have read of its resemblance to that of *A. mysis*, has not, I am convinced from that description, ever been described from the form in which it appears at the period when it leaves the egg-case.

At this stage it has a long straight anteriorly projecting rostrum on the carapace, a posteriorly projecting dorsal spine on the third somite of the pleon, and a lateral one on the posterior margin on each side of the fifth somite. The eyes are large, the antennæ short; the mandibles and two pairs of maxillæ, as well as the three anterior pairs of pereiopoda, are alone developed, of which the three last are furnished with secondary appendages: at a later stage in the development the posterior pairs of pereiopoda are developed with secondary appendages like the Lobster in its primary stage. At this time the resemblance to some of the *Mysidæ* is so great that it is highly probable that some of those *Mysidæ* that are distinguished by the development of their appendages in the form of true legs may be only the young of the several species of *Crangon*.

Palæmon.

The larva of the common Prawn differs but little from that of the Shrimp in the early stages of its development. The chief points of distinction are only such as could be called specific, and not improbably may be found in the young condition of the larva of various species in either genus. They chiefly exist in *Palæmon*, having a longer rostral spine and a dorsal spine being present on the posterior margin of the fifth somite of the pleon.

It would be interesting, should we have the opportunity, to compare the larva of the enormous freshwater Prawn of Guatemala, a crustacean as large as a half-grown Lobster, with that of our European species.

Palinurus marinus.

In my last Report are given figures of the young of the genus *Palinurus*, an animal that has excited considerable attention amongst carcinologists in consequence of its near resemblance to the form of *Phyllosoma*, a circumstance that has induced many zoologists to believe that they are but the same animal in different stages of growth. Since the presentation of the second Report, in which I gave certain reasons for not too readily accepting this conclusion, Dr. Anton Dohrn has given much time to the subject, and traced the development of the ovum from the commencement to the period when the young animal quits the egg-case. He writes to me from Messina, February 1869:—"I only assure you that the thing is finished. The *Phyllosoma* are the larvæ of the *Loricatæ*. I have followed the development of *Scyllarus* and *Palinurus* eggs, and both have brought out *Phyllosoma*. What is there so anomalous in *Phyllosoma*? It is nothing but a depressed *Megalops*. . . . I have followed the development of the interior organization as well, and there is no difference of real value between *Phyllosoma* and *Scyllarus*, or *Palinurus*."

This, which gives the author such confidence, is nothing more than has been known for the last twenty years. The question is not as to the forms of the larva of *Palinurus*, *Scyllarus*, &c., but whether certain animals that are like them, but five hundred times as large, that we find mostly in exotic seas, are the same but a little older specimens. If they are, as Dr. Dohrn and other naturalists affirm, then they establish the remarkable fact that the larvæ of these Crustacea grow from the one-tenth of an inch in length to that of one or two inches in length, without any material variation of form, a feature that is not consistent with the life-history of the development of the animals of this class.

If we examine the progressive growth of other Crustaceans, we find that with every increase in growth there is a fresh moult, and every moult developes the animal a stage nearer the type of the adult animal. If the *Phyllosoma* be, as contended, the young of *Palinurus*, then an arrest in progressive development takes place, while that of growth continues.

An argument in favour of this being the case (that *Phyllosoma* may be the young of *Palinurus*) may be found in a species described by De Haan in Siebold's 'Fauna Japonica' under the name of *Ph. Guerinii*, in which an intermediate progressive step exists, inasmuch as the carapace is developed so far posteriorly as to cover the pereion.

I think, therefore, that although step by step we may arrive at the true knowledge, yet the large amount of negative evidence, which is capable at any day of being overthrown, must make us hesitate in accepting as a thing proved the statement that *Phyllosoma* and the closely resembling larvæ of *Palinurus* are one and the same creature.

The genus *Scyllarus* has now been so frequently captured on our coast, that we must consider it not as a mere straggler, but as an old inhabitant of the British seas.

Mr. Cornish writes:—"Some years since I suggested to Prof. Bell, with the first specimen that I took, that it was identical with the little lobster described by Borlase (Nat. Hist. p. 274) as 'that fine Shrimp (*Squilla lata*, Rondeletii) I found in Careg-Killas, in Mount's Bay;' but he thought that *Squilla lata* was the other *Scyllarus*, and not mine. I now believe that I was right and he was wrong. Looking at the rarity of the species in Mount's Bay, it is more probable that Borlase's specimen and mine should be the same species, than that they should be distinct."

Borlase took his on Careg-Killas, in Mount's Bay. This name is lost; but it means "slate," or "killas-rock," and it was (*vide* Borlase, Nat. Hist. p. 254) "a ledge where loose stones could be turned over," near Penzance (p. 206).

There are but two places in Mount's Bay which satisfy this description, and the one nearest to the Doctor's residence is Long Rock, where the latest specimen of *Scyllarus* was taken.

Besides which, Pennant (vol. iv. p. 17, No. 23, Lobster) speaks of *Squilla lata*, Rondeletii, as the size of the *Spiny Lobster*. Dr. Borlase speaks of his specimen as "that fine shrimp."

The specimen of which Mr. Cornish writes was captured alive, and, being in full spawn, was sent on to me, with the hope that, should it arrive alive, I might be able to hatch the ova, and so make out the hitherto undetermined form of the young *Scyllarus*. Unfortunately the animal was dead when it reached me that same evening. The ova were very abundant in quantity, each being about $\frac{1}{50}$ of an inch in diameter, with an orange-coloured vitellus. The embryo was in a very immature stage, so that little could be learned from it as to the form or character of the larva when it quits the ovum. My friend Dr. Andrew Dohrn, however, who has on the coast of Sicily been giving his attention to this subject amongst others, informs me that the larva of *Scyllarus* is identical with that of *Palinurus*, and consequently assumes the form of *Phyllosoma*.

Squilla.

Several specimens of this genus have been recorded from the coasts of Devon and Cornwall; but the scarcity of their appearance induces us to consider them rather as stragglers drifted from the Channel Islands than inhabitants of our southern shores. Two other genera of closely allied animals are occasionally taken in the same locality. These have been described by Prof. Milne-Edwards, and figured under the respective names of *Alima* and *Squillerichthys*; specimens of both these have been taken during the last summer, the former by Mr. Ray Lankester, and the latter by Mrs. Collings of Serk. The former of these animals has much in its appearance that is suggestive of an undeveloped condition; but it was difficult to define the parent stock; it might be a young *Squillerichthys*, or it might be a young *Squilla*, from either of which it differs in having but two flagella to the anterior appendage, and in the absence of the five pairs of pereiopoda; while in *Squilla* and *Squillerichthys* there are three flagella to the anterior antennæ, and all the pereiopoda are present. The general form, however, of *Alima* is nearer to *Squillerichthys* than is *Squillerichthys* to *Squilla*. This separation appears to receive a wider demarcation from the circumstance that Mrs. Collings took attached to her specimen several small ova; two of these, with the specimen, she kindly forwarded to me for inspection. These, however, after due consideration, I came to the conclusion were only accidentally entangled, or else deposited by some parasitic animal, since they were attached to a large flexile membrane differing essentially from those that cover the ova of Crustacea generally.

Fortunately, however, Dr. Power, while staying in the Mauritius, hatched and forwarded to me a considerable number of the young of different Crustacea; among these were those of a *Squilla*. This, although the young of an exotic species, bears so close a relation to the genus *Alima* of Milne-Edwards, that we can have no hesitation in accepting them as different stages in the growth of animals of the same genus.

So with *Squillerichthys*, the features that distinguish it from *Squilla* being clearly expressed in the larva of *Squilla*, and repeated in the form of *Alima* in a condition that is a modification between it and *Squillerichthys*, conduces to the conviction that, like *Alima*, *Squillerichthys* is but a stage in the development of *Squilla*, a circumstance that enables us with much confidence to unite the three supposed genera as different stages in the progressive development of one and the same genus.

In the entrance to the channel, during the present spring, large quantities of the Crustacea named by Prof. Bell, in his 'History of the British Crustacea,' *Thysanopoda Couchii*, were taken in the stomachs of fish; of these a considerable number were sent to me by Mr. Loughrin, but they were not in a condition favourable for examination. The pendulous ovipouch, that affords such a peculiar feature to the animal, was generally of a bright orange-colour; but, generally speaking, the contents had been so acted upon by the digestive juices that little was determinable from them. This I think we may speak with certainty, that they are not of the genus *Thysanopoda*.

Ostracoda.

The following Ostracoda, which have been examined for us by G. S. Brady, F.L.S., were dredged off the Eddystone in 40 fathoms of water:—

Pontocypris mytiloides, *Norman*.
—— trigonella, *G. O. Sars*.
—— angusta, *Brady*.
Bairdia inflata, *Norman*.
—— acanthigera, *Brady*.
Cythere pellucida, *Baird*.
—— tenera, *Brady*.
—— badia, *Brady*.
—— convexa, *Baird*.
—— finmarchica, *Sars*.
—— villosa, *Sars*.
—— emaciata, *Brady*.
—— semipunctata, *Brady*.
—— cuneiformis, *Brady*.
—— antiquata, *Baird*.
—— Jonesii, *Baird*.
—— acerosa, *Brady*.
Eucythere parva, *Brady*.
Loxoconcha impressa, *Baird*.
Loxoconcha guttata, *Norman*.
—— tamarindus, *Jones*.
Xestoleberis aurantia, *Baird*.
Cytherura angulata, *Brady*.
—— cuneata, *Brady*.
—— striata, *Sars*.
—— similis, *Sars*.
—— acuticostata, *Sars*.
Cytheropteron punctatum, *Brady*.
—— nodosum, *Brady*.
—— multiforum, *Norman*.
—— subcircinatum, *Sars*.
Bathocythere constricta, *Sars*.
—— turgida, *Sars*.
Pseudocythere caudata, *Sars*.
Sclerochilus contortus, *Norman*.
Paradoxostoma ensiforme, *Brady*.
—— abbreviatum, *Sars*.
Polycope compressa, *Brady*.

Annelids.

Dr. M'Intosh, F.R.S.E., F.L.S., says a considerable collection of Annelids from the neighbourhood of Plymouth was sent to me for examination by Mr. Spence Bate and Mr. Brooking Rowe; the former likewise courteously gave me the use of some careful drawings, from which sources the following list is drawn up. As not unfrequently happens with such animals, the specimens were in an indifferent state of preservation, especially those which had been placed in glycerine. Although somewhat softened, however, they were of great interest, and much care had evidently been bestowed on their collection. As a series entirely from the southern shores of England, they form an advantageous contrast with the collections of Mr. Gwyn Jeffreys, which come from the opposite extremity of the British Islands, viz. from the Zetlandic seas.

The majority of the species are well-known forms, and with regard to these it is only necessary to refer to the list. Amongst the rarer forms, *Lepidonotus clava*, Mont., seems to be plentiful, whereas on most of our shores it is not commonly met with. Its speckled and adherent scales, swollen and ringed cirri, and stout yellow bristles render it an easily recognized species. The *Nereis Marionii*, Aud. & Ed., has not hitherto been recorded as British, and appears to be chiefly a southern form, for I have not yet found it elsewhere than in the Channel Islands and in this collection from Plymouth. It is characterized by the great development of the superior lobe of the foot towards the posterior end of the body. *Onuphis sicula*, De Quatref., is also comparatively common. The range of this species extends from the Shetland Islands to the Mediterranean. It has jointed bristles, as in *Eunice*, and the examples were in tubes of gravel and sand. The very large size of some of the specimens of *Cirratulus cirratus* calls for notice. I have not seen larger. The occurrence of *Terebella medusa*, Sav., a gigantic form, is likewise interesting; and it is probable that *Terebella gigantea* of Montagu refers to this species. The hooks correspond with that figured by Dr. Malmgren *, from a specimen procured in the Red Sea near Suez, and have five (rarely six) distinctly separated teeth. The *Terebella* (*Polymnia*) *Danielsseni* of Malmgren is a new British form, distinguished by the three comparatively short branchiæ and the shape of the hooks, which have a large fang and two or three small teeth above it.

List of Species.

Hermione hystrix, *Sav.*
Lepidonotus squamatus, *Linn.*
—— clava, *Mont.*
Harmothoë imbricata, *Linn.*
—— longisetis, *Grube.*
Polynoë asterina (squamosa, *Delle Chiaje*). Attached to Asterias aurantiaca.
Sigalion boa, *Johnst.*
Nephthys —— ?, softened fragment.
Notophyllum polynoides, *Œrst.*
Eulalia viridis, *Müll.*
Eteone pusilla, *Œrst.*
Syllis armillaris, *Müll.*
Gattiola spectabilis, *Johnst.*? (Drawing.)
Nereis zonata, *Malmgren*?
—— pelagica, *L.*
—— Marionii, *A. & Ed.*
—— cultrifera, *Grube.*
Nereilepas fucata, *Sav.*
Eunereis longissima, *Johnst.*
Lumbrinereis fragilis, *Müll.*
Eunice —— ?
Leodice norvegica, *L.*
Lysidice ninetta, *A. & Ed.*
Hyalinæcia tubicola, *Müll.*
Onuphis sicula, *Quatref.*
Notocirrus scoticus, *McI.*
Glycera capitata, *Œrst.*
—— Goësi, *Mgrn.*
Arenicola ecaudata, *Johnst.*
Chætopterus norvegicus, *Sars.* (Drawing.)
Nerine vulgaris, *Johnst.*
Scolecolepis cirrata, *Sars.*
Cirratulus cirratus, *Müll.*
Capitella capitata, *Fabr.*
Ammochares Ottonis, *Grube.*
Sabellaria alveolata, *L.*
Pectinaria belgica, *Pallas.*
Amphictene auricoma, *Müll.*
Amphicteis Gunneri, *Sars.*

* Nordiska Hafs-annulater, tab. 25. f. 80.

Terebella medusa, *Sav.*
—— nebulosa, *Mont.*
—— littoralis, *Dalyell*, &c.
—— Danielsseni, *Mgrn.*
Nicolea zostericola, *Œrst.*
Pista cristata, *Müll.*
Thelepus circinnatus, *Fabr.*
Leprea textrix, *Dalyell.*
Sabella penicillus, *L.* (pavonia, *Sav.*).
Dasychone Dalyelli (*Dal.*), *Kölliker.*
Protula protensa, *Lam. & Grube.*
Serpula vermicularis, *L.*
Serpula reversa, *Mont.*
—— triqueter, *L.*

Pontobdella muricata, *L.*
Borlasia olivacea, *Johnst.*
Lineus longissimus, *Simmons.*
Micrura fusca?
Ommatoplea. Several.
Sipunculus?
Thalassema Neptuni, *Gærtner.*

Foraminifera.

The Foraminifera, of which the following list was furnished me by Mr. David Robertson of Glasgow, were taken in about 40 fathoms seven miles south-east of the Eddystone, and some fourteen miles south-east of the Dudman, in about the same depth of water.

Cornuspira foliacea, *Phil.*
Biloculina depressa, *d'Orb.*
Spiroloculina limbata, *d'Orb.*
—— planulata, *Lamarck.*
Triloculina oblonga, *Mont.*
Quinqueloculina seminulina, *d'Orb.*
—— subrotunda, *Mont.*
Trochammina inflata, *Mont.*
Lituola canariensis, *d'Orb.*
Lagena lævis, *Mont.*
—— striata, *Mont.*
—— semistriata, *Will.*
—— globosa, *Mont.*
—— melo, *d'Orb.*
Dentalina communis, *d'Orb.*
Cristellaria rotulata, *Lamk.*
—— crepidula, *F. & M.*
Polymorphina lactea, *W. & J.*
Polymorphina oblonga, *Will.*
—— compressa, *d'Orb.*
—— myristiformis, *Will.*
Orbulina universa, *d'Orb.*
Spirillina vivipara, *Ehrenb.*
—— margaritifera, *d'Orb.*
Textularia sagittula, *Lamk.*
Bulimina pupoides, *d'Orb.*
—— ovata, *d'Orb.*
Bolivina punctata, *d'Orb.*
Discorbina globularis, *d'Orb.*
Planorbulina mediterraniensis, *d'Orb.*
Truncatulina lobatula, *Walker.*
Rotalia Beccarii, *L. & M.*
Patellina corrugata, *Will.*
Nonionina asterizans, *F. & W.*
—— turgida, *Will.*

Report on the practicability of establishing "A Close Time" for the protection of indigenous Animals. By a Committee, consisting of F. Buckland, Rev. H. B. Tristram, *F.R.S.*, Tegetmeier, *and* H. E. Dresser (Reporter).

In accordance with the resolution passed at the Meeting of the British Association at Norwich in August last, appointing Mr. Frank Buckland, Rev. H. B. Tristram, Mr. Tegetmeier, and Mr. H. E. Dresser as a Committee for the purpose of collecting evidence as to the practicability of establishing a close time for the protection of indigenous animals, this Committee met at the Zoological Society's rooms (which Dr. Sclater had kindly placed at their disposal) on the 13th of January last, the Rev. Dr. Tristram being in the chair; and on Professor A. Newton tendering in evidence the information published by the Yorkshire Association for the Protection of Sea-birds, respecting the utility of sea-birds, it was resolved, inasmuch as the said Association was working in the same direction as this Committee, that we should give every reasonable assistance in furthering the object for which the Association had been formed, viz. that of getting an Act of Parliament passed to protect the sea-birds during the breeding-season, the reasons given being that sea-birds are useful in destroying grubs and worms, in acting as scavengers in the harbours, in warning vessels off the rocks during fogs by their cries, and in hovering over and pointing out to the fishermen the locality of the shoals of fish.

At the above meeting Mr. J. E. Harting, F.L.S. &c. was proposed and elected as a member of this Committee.

Since then the members of your Committee have to the best of their power cooperated with the Association for the Protection of Sea-birds, and that Association has fully acknowledged the assistance rendered. The Bill for the protection of Sea-fowl was entrusted to the care of C. Sykes, Esq., M.P., in the Commons, and His Grace the Duke of Northumberland in the Lords, where it met with a most favourable reception.

Before the Bill passed into Committee a meeting of naturalists was held at the Hanover Square Rooms in order to consider and discuss the various clauses. However, as the progress of the Bill has been so fully reported in the newspapers, it is needless to enter into details here, and it will be sufficient to say that at first it was proposed to make it illegal, not only to kill the birds during the breeding-season, but also to take their eggs; and the close time was proposed to extend from the 1st of May to the 1st of August. However, it was found that so much injury would be inflicted on the poorer classes living on the coast if they were prevented from taking the eggs or young of the sea-birds, as they are often dependent on these for subsistence, that the egg clause was struck out, and the young, when unable to fly, were exempted. It was also considered that it would be expedient to exempt the island of St. Kilda, the inhabitants of that island being so entirely dependent on sea-birds for their subsistence.

With these modifications, and the close time being extended one month, or from the 1st of April to the 1st of August, the Bill became law in June last, and one conviction has already taken place. The person convicted under this Act had dead sea-gulls in his possession, and was heavily fined. The Bill for the protection of sea-birds having now become law, it has to be considered how far it will be advisable to press for its extension to other birds and mammals. That it will be well to afford protection to most, if not all, of our birds, at least during the breeding-season, your Committee are fully convinced; but it yet remains to convince the farmer that he will derive benefit from so doing.

Our British agriculturist is in general no naturalist, and takes it for granted that every grain-eating bird must do him harm. He accordingly does his best to exterminate sparrows and other small birds, little thinking of the *benefit they* render him in *destroying insects.* Nor will the *game-preserver,* we fear, countenance so sweeping a measure until he is fully convinced that it is necessary to put some limit to the ravages made by his gamekeeper amongst our feathered friends.

On the continent, and particularly where zoology forms a branch of study in the schools of agriculture (as in Germany, Sweden, &c.), the utility of many of our birds, which with us are persecuted as vermin, is fully recognized, and instead of forming sparrow clubs, the agriculturists there take steps to protect the feathered tribes.

In the grain-growing countries of Russia near and in every village small boxes and sections of hollow branches may be seen fixed on to trees, barns,

* We may here state that an Act protecting the sea-birds, not only during the breeding-season, but during the whole year, has been for some time in force in the Isle of Man, and has had the effect of almost entirely stopping the destruction of sea-fowl on that island.

houses, &c., in order to induce sparrows and starlings to take up their abode there, and assist in freeing the crops from destructive insects. Sparrows, starlings, and particularly jackdaws swarm near most of these villages, and, according to what the peasants say, are of infinite use in freeing the crops from insects.

In Sweden, also, the starling is an especial favourite with the agriculturist, and the Principal of the Böda Forest School, Jägmästare Boman, makes every one of his pupils prepare and hang up a certain number of these nesting-boxes, or "holkar," before leaving the school.

The late Mr. Charles Waterton also recommended the introduction into England of this plan of providing nesting-boxes for starlings.

In speaking of the starling, we may refer to a letter from Universitäts Forstmeister Wiese, published in the 'Journal für Ornithologie,' 1866, p. 422, in which he urges the necessity of putting up nesting-boxes for starlings, and states that at Elisenhain in the Griefswald the oak-forests were suffering severely from the devastations of *Tortrix viridana*, when, to destroy this insect, the starlings were protected, and these birds soon succeeded in keeping down the numbers of this insect.

Some agriculturists of New Zealand are at the present moment endeavouring, at considerable expense, to introduce into those islands the rook, the jackdaw, and the starling, for the purpose of protecting their crops from the ravages of caterpillars and locusts.

The best mode of judging of the good or harm done by birds is most certainly that of *studying the nature of their food*; and as almost all our smallest birds, even those which are chiefly graminivorous, feed their *nestlings on insects*, it would surely benefit the farmer and gardener were they protected during the time when the insects are most destructive to the crops. Even the *Raptores* should, we think, be protected; and in proof of this we may refer to Professor Newton's paper on the "Zoological aspect of Game-Laws," read at the last Meeting of the British Association, and the Rev. Dr. Tristram's theory propounded at the Meeting in 1867, viz. that the birds of prey are the sanitary police of nature, and that if they had existed in their original strength they would have stamped out the grouse-disease, inasmuch as hawks in preference make sickly birds their quarry.

Regarding the food of our birds we may make the following short remarks:—

The common Buzzard (*Buteo vulgaris*), which was once, it is true, common in Great Britain, but is now rapidly approaching the fate of the Great Bustard, owing chiefly to the mistaken zeal of the gamekeepers, is a bird by no means injurious to game. Its food consists chiefly of frogs, mice, snails, &c., and but seldom or never of birds.

The Kestrel (*Falco tinnunculus*) feeds almost entirely on field-mice, but also eats beetles and grasshoppers.

The Merlin (*Falco æsalon*) feeds chiefly on mice and small birds.

The Sparrowhawk (*Accipiter nisus*) is perhaps the only true enemy of the game-preserver; though at the same time it is probable that if the good and evil it does were justly weighed, the balance would be in favour of the hawk, its favourite quarry being the Woodpigeon, which is now increasing to an extent injurious to agriculture.

As far as owls are concerned, Professor Newton clearly showed, at the last Meeting of the British Association, that these birds are of the greatest use to the agriculturist in destroying the small mammals which injure his crops. Prof. Newton refers to the researches of Dr. Altum, the results of which were as follows:—In order to ascertain the nature of the food of the different owls, Dr. Altum collected pellets, or castings, at different seasons of the year, from different localities, which pellets he carefully examined.

Of the Barn-owl (*Strix flammea*) he examined 706 rejected pellets, which contained remains of the following, viz.:—

4	Plecotus auritus.
11	Vesperugo pipistrellus.
1	Vesperus serotinus.
3	Mus decumanus.
237	—— musculus, sylvaticus, and minutus.
34	Hypudæus glareolus.
23	—— amphibius.
588	Arvicola arvalis.
47	—— agrestis.
1	Arvicola campestris.
76	Crossopus fodiens.
349	Crocidura araneus (and leucodon).
1164	Sorex vulgaris.
1	—— pygmæus.
1	Talpa europæa.
19	Passer domesticus.
1	Fringilla chloris.
2	Cypselus apus.

Of the Wood-owl (*Strix aluco*) he examined 210 pellets, the contents of which he classifies as follows—

1	Mustela erminea.
6	Mus decumanus.
42	—— musculus, sylvaticus, minutus.
19	Hypudæus glareolus.
11	—— amphibius.
254	Arvicola arvalis.
12	—— agrestis.
1	Sciurus vulgaris.
5	Crossopus fodiens.
3	Crocidura araneus.
20	Sorex vulgaris.
5	—— pygmæus.
48	Talpa europea.
1	Certhia familiaris.
1	Emberiza citrinella.
1	Motacilla alba.
15	Small birds (sp.?).
15	Carabus granulatus.
4	Harpalus —— ?
9	Ditiscus marginalis.
14	Scarabeus stercorarius.
1	—— sylvaticus.
1	Elater —— ?
1	Silpha rugosa.

and large quantities of *Melolontha vulgaris*, some of the pellets consisting entirely of the remains of these insects.

Of the Short-eared Owl (*Strix brachyotus*) he examined a few pellets, which he found to contain only remains of *Hypudæus amphibius*; but as these were only obtained from one locality where this mouse is especially abundant, Dr. Altum reserves his remarks on the food of this owl until he can make further investigations.

Of the Long-eared Owl (*Strix otus*) he examined many pellets, which contained remains as follows:—

14	Mus sylvaticus.
1	Hypudæus amphibius.
12	—— glareolus.
193	Arvicola arvalis.
65	Arvicola agrestis.
2	Sorex vulgaris.
3	Birds, sp.?

The above proves most clearly that our owls should be protected, as in destroying mice &c. they are benefitting the agriculturist. Not only, however, do the owls, as is above shown, feed chiefly on mice, but the Wood-owl (*Strix aluco*) is often insectivorous; and Mr. Leopold Martin of Berlin (Journal für Ornithologie, 1854, p. 93) states that he found in the stomach of one of these birds the remains of no less than 75 *Sphinx pinastri*.

Many of our smaller birds are entirely insectivorous, and are undoubtedly useful at all seasons of the year; and of these we may in particular refer to the Woodpeckers and Titmice, the latter of which feed largely on the eggs of *Bombyx pini*, which is so *destructive to the pine forests*. Every female of this moth will lay from 600 to 700 eggs, and were it not that they are kept down in number by the tits they would increase enormously. Count C. Wodzicki, in a small work on the influence of birds in destroying injurious insects, published at Lemberg in 1851, calculates that a single tit will devour 1000 *insects' eggs in a single day*, and besides, the tits feed their young chiefly on insects' eggs and caterpillars. Count Wodzicki mentions in particular *Sitta europœa*, *Certhia familiaris*, and the *Regulidœ*, as being useful in destroying *Bombyx pini*. He also mentions that the Woodpeckers are of great utility in destroying the following insects, viz. *Noctua pinastri*, *Geometra piniaria*, *Sphinx pinastri*, *Tenthredo pini*, *T. septentrionalis*, *Bostrichus typographus*, and *B. chalcographus*. M. C. von Heyden also remarks (Journal für Ornithologie, 1859, pp. 316, 317) that in the winter *Sitta europœa* and *Parus major* feed on the larvæ of *Cecidomyia fagi*, the Beech-gall insect, and states as follows:—"The well-known conical gall of this insect is often found in large numbers on the upper side of the beech-leaves. In the autumn it becomes hard like wood, and falls off the leaf. These birds then search carefully on the ground under the trees for the galls, and after pecking a hole (generally in the side of the point of the gall), pick out and devour the insect. The hole is generally so small that the insect cannot be extracted with the beak, and the bird must use its tongue for that purpose. It is curious that the bird should bore a hole at the hard point of the gall when the base is merely closed by the thin paper-like web of the insect."

Professor Buckman has also recently observed that the Blue-tit (*Parus cœruleus*) destroys the flies which make the oak-galls, which in many parts of the country threaten to ruin the young oak-plantations.

Many of our seed-eating birds are useful, not only because they feed on the seeds of injurious weeds, but also on destructive insects; and our common Yellowhammer (*Emberiza citrinella*) feeds with avidity on the caterpillar of the white Butterfly (*Pieris rapœ*).

Mr. Mewes, the well-known Swedish naturalist, states (Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar, 1868, p. 256) that at Borgholm in Sweden he found the oak-woods near the castle almost stripped of their leaves by *Tortrix viridana*, and that numbers of birds were feeding on the larvæ of this insect, amongst which he names the common Crossbill (*Loxia curvirostra*), which, though in general a seed-eater, was in that instance doing good service in eating insects. He states that flocks of these birds were busily employed in destroying this insect.

The much-persecuted Sparrow (*Passer domesticus*) is also a good friend to the agriculturist, and amply repays him for the little corn he may take by destroying many injurious insects, and in eating the seeds of many rank weeds.

During the winter the Tree-sparrow (*Passer montanus*) feeds chiefly on the seeds of *Urtica divica*, *Chenopodium album*, and *Polygonum aviculare*, all of which are injurious weeds.

It is true that the House-sparrow is a grain-eating bird, but its nestlings are fed chiefly on insects. Mr. Berthold Wicke, of Göttingen (Henneberg's Journal für Landwirthschaft, 16 Jahrgang, 3 Heft) examined the contents of the stomachs of 118 sparrows procured between the 21st of April and 24th of June, and gives the following results of his investigations:—Of these birds, 45 were adults and 73 young, ranging from the small naked nestling to the full-fledged bird. In the stomachs of three of the adult birds he found only grain, in one nothing but the remains of a few beetles; one had the stomach and crop so full of grain that he counted 50 grains; one stomach contained the seed of weeds, pieces of peas and seeds of *Stellaria media*, and the rest contained corn with the remains of beetles; and in one was the entire skin of a *Melolontha vulgaris*.

Whereas, however, the stomachs of the adult birds contained chiefly grain and but a small proportion of insect-remains, it proved to be entirely the reverse as regards the young birds. Out of the 73 he examined, the stomachs of 46 contained insects, larvæ, caterpillars, &c., and only 9 contained vegetable matter alone. Of the remaining stomachs 10 contained the remains of insects mixed with a few seeds, 7 contained chiefly seeds with a small proportion of insect-remains, and 1 contained eggshells and small stones without trace of anything else.

Our American cousins have recognized the utility of the sparrow, and have introduced it into New York, where it is now found comparatively numerous, and has been most useful in keeping the trees free from caterpillars, which before its introduction threatened seriously to injure them.

Our thrushes and blackbirds are also most useful to the gardener from the quantities of slugs and snails they destroy, and our rook is universally acknowledged to be a most useful bird.

Much information as to the nature of the food of birds is, however, yet needed in order to judge correctly of the amount of good or harm they do; and it would be well if the question were fully ventilated in the newspapers, and naturalists resident in different parts of the country encouraged to make investigations as to the nature of the food of the different species of birds, and compare the results of such investigations.

Your Committee felt, however, sure that the good done by birds will be found largely to predominate over the harm, and that it will prove expedient to afford them protection during the breeding-season.

It is, however, a measure that will require considerable time to carry through, and we would suggest that the best mode of affording the necessary protection to birds would be to prohibit the carrying of a gun during the breeding-season, as is now done in several parts of the continent, as, for instance, in Switzerland, some parts of France, &c. In the United States of North America, where freedom of action exists more perhaps than anywhere else, the close-time system is to a large extent carried out, and has proved most beneficial, though, as may be supposed, it is most difficult to enforce in a thinly populated country.

Much information is, however, yet needed as to the practical working of the close-time system in those countries where it has been in force, and your Committee hope ere long to be able to procure reliable particulars on this point.

Generally it is said to work excellently, and, far from interfering with the game-preservers, it has been found to act in harmony with their views. Were it enforced here in England it would have the good effect of stopping the damage done by idle men and boys, who on Sundays are in the habit of going out in the neighbourhood of the towns to shoot small birds.

Experimental Researches on the Mechanical Properties of Steel. *By* W. FAIRBAIRN, *LL.D., F.R.S., &c.*

In my last Report I had the honour of submitting to the Association an experimental inquiry into the Mechanical properties of Steel, obtained from the different sources of manufacture in the United Kingdom. On that occasion several important experiments were recorded from specimens obtained from the best makers; and bars were received from others, the experiments on which were at that time incomplete. Since then I have had an opportunity of visiting the important works at Barrow-in-Furness, and from there I have received bars and plates of different qualities for the purpose of experiment, and such as would admit of comparison with those recorded in my last Report. I have also received specimens from Mr. Heaton for experiment, illustrative of the new process of conversion from crude pig iron (of different grades) to that of steel, as exhibited in the results contained in this Report.

In every experimental research connected with metals, it is necessary to ascertain, as nearly as possible, the properties of the ores, the quality of the material, and the processes by which they are produced. Generally this information is difficult to obtain, as in every new process of manufacture there is a natural inclination (where the parties are commercially interested) to keep it as long as possible to themselves, and hence the reluctance to furnish particulars. Of this, however, I can make no complaint, as Mr. Bessemer, the Barrow Company, and Mr. Heaton have unreservedly not only opened their works for inspection, but they have furnished every particular required (including chemical analysis) relative to the properties of the ores, and the processes by which they are reduced.

From this it will be seen that in some of the experiments I have had the privilege of recording the chemical as well as the mechanical properties of the specimens which have been forwarded for the purpose of experiment, and of ascertaining their respective and comparative values.

As regards the works at Barrow, I have, through the kindness of Mr. Ramsden and Mr. Smith the manager, received every facility for investigation, and they have kindly sent me the analyses of all the ores in use for the purpose of manufacturing both iron and steel. In these Works, it will be noticed that the manufacture is exclusively confined to the hæmatite ores, and that by the Bessemer process.

It is curious to trace the progressive development of the manufacture of steel from the earliest period down to the present time, and to ascertain how nearly the more premature and early stages of manufacture approaches to those of Bessemer and others in our own days. To show how closely they approximate in principle (the exception being in the vessels used and the power employed), I venture to quote from my own Report to the Barrow Company, in which the coincidence between the ancient and modern processes is exemplified.

In treating of the value of the hæmatite formation, I have stated that "we have no reliable accounts of the time when the hæmatite ores were first used for the purpose of manufacture. They must have existed contemporary with those in Sussex and the Forest of Dean; for the numerous cinder-heaps in those counties and at Furness bear evidence of the smelting-process having been carried on from an early period, until the forests became exhausted during the reign of Elizabeth and her successors. The process by which the ores were reduced in those days was extremely rude and simple, and was probably no better than what had been practised from time immemorial at the ancient bloomeries, to which were attached artificial blasts, first practised in this country after the Roman conquest. What was the nature of the apparatus for producing this blast we are unable to ascertain; but it is likely that two or more pairs of bellows may have been used, or the method, still practised by the natives of Madagascar, might have been adopted of fitting pistons loosely into the hollow trunks of trees. In whatever form the hæmatite ores were reduced, it is clear that the smelting-furnace was not in operation in those days; and assuming that the bloomery was the only process in use, the result would be a species of refined iron or steel, which, deprived of the greater part of its carbon, would become malleable under the hammer.

"It is interesting to observe how nearly our improved modern process of making steel approaches to that of those rude and early times. The Bessemer system is neither more nor less than the old process of the bloomery and the Catalan furnace, the former being adapted to smelt the ore, and the latter to decarbonize and refine it into the malleable state of iron or steel.

"That such was the state of the early manufacture of hæmatite iron can hardly be questioned, as the country around Ulverston was covered with forests; and the name given to Furness Abbey shows that its site was in the vicinity of furnaces, employed exclusively for the reduction of the ores with which the surrounding country abounds. The remains of these ancient furnaces have to some extent been carried down to our own times, and Messrs. Harrison and Co. still manufacture a fine quality of charcoal iron, the wood being obtained from the adjoining forests. The new works at Barrow have, however, entirely changed the nature of this process; and the system of manufacturing direct from the ore has become a question of such importance, as to induce an investigation of its value, and the improvements it is likely to effect both in the manufacture of iron and steel. For this object the following experiments have been instituted, in order to show the peculiar properties of this manufacture, and the extent to which it is applicable for the general purposes of trade and constructive art.

"The proprietors of the Barrow Works have confined themselves to certain descriptions of manufacture, on the Bessemer principle, these being chiefly steel rails, tyres, plates, and girders, manufactured at a comparatively low price. From the nature of the ore and fuel (the latter of which is chiefly brought by rail from the coal-fields of Durham and Northumberland) a description of highly refined homogeneous iron and steel is produced; and as this manufacture is intended for purposes where tenacity and flexibility are required, it would not be just to compare it with other descriptions of manufacture, where the object to be attained is hardness, such, for instance, as that employed for carriage-springs and tools. The description of steel or iron required for rails, beams, girders, &c. is of a different character; tenacity combined with flexibility is what is wanted, to which may be added powers to resist impact. The same may be said of wheel-tyres and other constructions, where the strains are severe, and where the material is sufficiently ductile to prevent accidents from vibration, or those shocks and blows to which it may be subjected. Keeping these objects in view, the Barrow Company's Works have, to a great extent, been limited to this description of manufacture; and, judging from the ductility of the material as exhibited in the experiments, there is little chance of accidents from brittleness when subjected to severe transverse strains, or to the force of impact.

"In calculating the value of the hæmatite steel, we have been guided by the same formulæ as adopted for comparison with similar productions from other works. Very few of them, however, will admit of comparison, as no two of them appear to be alike. The hæmatite steel is manufactured, at the Barrow Works, for totally different purposes from those of other makers, and having the command of a variety of ores for selection (as may be seen from the analysis of the ores given in the Table) the desired quality of steel can be obtained at pleasure. We have therefore submitted the different specimens to the same tests as those received from other makers, not only for the purpose of ascertaining wherein their powers of resistance differ, but also wherein consists their superiority as regards deflection, elongation, and compression, from all of which may be inferred their nature and properties, and the uses to which they may be applied. It is for this purpose we have applied the same formulæ of reduction to each particular class of experiments as in the former cases, and the results have been embodied in the summaries. If, for example, it were required to know the modulus of elasticity, the work of deflection, or the unit of working strength, these will be found in their respective columns, carefully deduced from the experiments as given in the Tables. The same principle for ascertaining the amount of work done to produce rupture from tension has been followed, and the force required to produce compression with a given load has also been calculated with the same degree of care and attention to facts.

"As the Bessemer principle of manufacturing direct from the ore is calculated to produce great improvements and important changes in the production of refined iron and steel, and as the homogeneous properties of the material thus produced are of the highest importance as regards security, &c., it is essential to construction that we should be familiar with the mechanical properties of the material in every form and condition to which it may be applied.

"For this purpose I have given all the various forms of strain, excepting only that of torsion, which is of less moment, as the strains already described involve considerations which apply with some extent to that of torsion, and from which may be inferred the fitness of the material for the construction of shafts and other similar articles to which a twisting strain applies.

"The great advantage to be derived from the Barrow manufacture of steel is its ductility combined with a tensile breaking strain of from 32 to 40 tons per square inch. With these qualities I am informed that the proprietors are able to meet all the requirements of a demand to the extent of 1000 to 1200 tons of steel per week, which, added to a weekly produce of 4500 tons of pig-iron, will enable us to form some idea of the extent of a manufacture destined in all probability to become one of the most important and one of the largest in Great Britain"*.

From the above statement it may be inferred that the description of manufacture practised at Barrow is carried on upon a large scale, and the products have reference to certain properties almost exclusively adapted to the formation of wheel-tyres, rails, and plates. To the attainment of these objects the greatest care and attention is devoted by the Company, as may be seen by comparing the reduction of the experiments in the summary of results.

In this extended inquiry I have endeavoured to deduce true and correct results from the specimens with which I have been favoured from the Barrow Steel Company. In the same manner I have now to direct attention to the products of an entirely new system of manufacture introduced by Mr. Heaton of the Langley Mills, near Nottingham. The experiments on this peculiar manufacture require a separate introductory notice, as the process of conversion is totally different to that of Bessemer, the Puddling-furnace, or that of the old system of the Charcoal-beds.

For the finer description of steel the old process of conversion is still practised at Sheffield, from a fortnight to three weeks being required for the conversion of wrought iron into steel; and, with the exception of Mr. Siemens's Reverberatory Gas-furnace, there no improvements had been made on it until

* In round numbers, it is stated that the produce of the Barrow Mines is 600,000 tons of ore per annum; of the Barrow Blast-furnaces 230,000 tons of pig-iron; and of the Rolling Mills 60,000 tons of steel rails, tyres, plates, &c.

Mr. Bessemer first announced his invention by means of which melted pig-iron was at once converted into steel.

This new process of forcing atmospheric air through the metal in a molten state took metallurgists by surprise; and when it was taken into consideration that the conversion was effected in twenty minutes and at one heat, the question became one of absorbing interest to the whole of the commercial population.

By the old process the metal was first deprived of its carbon and reduced to the malleable state, when it was rolled into bars and retained (as above described) from fourteen to twenty-one days in charcoal-beds until it had absorbed by cementation the necessary quantity of carbon. The new process of Mr. Heaton, unlike that either of Mr. Bessemer or of cementation, simply deals with the pig-iron, and, according to his own statement, eliminates the superfluous carbon, so that steel is in the first place produced and thence wrought iron by a still further elimination of the carbon. This is totally different to the puddling or the Bessemer process, which in the former was tedious and expensive, whilst in the latter the pig-iron was rendered malleable without any additional fuel and ready for the hammer or the rolls in a very short period of time.

It is unnecessary to notice in detail the subsequent mechanical processes of reheating, rolling, hammering, &c., which are common to all the systems of conversion; it is, however, important to mention that an admixture of *spiegeleïsen*, a description of cast iron containing an excess of carbon, is made into the molten mass, without which the conversion is not easily effected by the Bessemer process.

It is asserted by some writers on this subject, "that, whatever are the merits of the Bessemer process, the conversion cannot be effected without a destructive action upon the converters, and a rapid wear and tear of the tuyeres, that there is waste in filling the moulds, and that the heavy royalties attached to the patents &c. are serious drawbacks to the extension of the process." Mr. Hewitt, a writer on this subject, comes to the conclusion "that good steel can only be made from good material, no matter what process is employed;" and he further states " that the Bessemer process will not, as Mr. Bessemer originally supposed, supersede the puddling-process, which appears to be as yet the only method applicable to the conversion of by far the greater portion of pig-iron made into wrought iron, because by far the larger portion of pig-iron made is of a quality not good enough for the Bessemer process, which absolutely exacts the absence of sulphur and phosphorus."

There may be some truth in this statement, as it was found necessary, in the selection of the hæmatite ores at Barrow, to make use of the best quality, and only seven or eight out of twenty sorts were found suitable for the purpose. It is, however, evident from the rapid extension of the process and the estimation in which it is held by manufacturers and the general public, that whatever objections the process is subject to (on purely economical grounds) Mr. Bessemer has succeeded in carrying out the pneumatic principle of conversion to the highest degree of excellence at present attainable by that process.

In so important a branch of metallurgy it would be remarkable if Mr. Bessemer had hit upon the only feasible means of converting iron into steel. Other minds have been inspired by Mr. Bessemer's success in the same direction; and the admixture of metals to effect a transmutation has been assumed in many forms and proportions so as to increase our knowledge and lessen the cost of production. Amongst those is the new process of Mr. Heaton, a description of which we venture to transcribe from a pamphlet published by the proprietors of the Heaton process.

"The furnace (which is a common cupola) is charged with pig-iron and coke, and fired in the usual way, and the iron when melted is drawn off into a ladle, from which it is transferred to the converter.

"The converter is a wrought-iron pot lined with fire-brick. In the bottom is introduced a charge of crude nitrate of soda, usually in the proportion of 2 cwt. per ton of converted steel, usually but not invariably diluted with about 25 lb. of siliceous sand. This charge is protected or covered over with a close-fitting perforated iron plate weighing about 100 lb., the diameter of the plate being about 2 feet. The converter, with its contents, is then securely attached, by moveable iron clamps, to the open mouth of a sheet-iron chimney, also lined for 6 feet with fire-brick, and the melted iron taken in a crane ladle from the cupola is poured in. The subsequent part of the process is thus described by Professor Miller.

"'In about two minutes a reaction commenced. At first a moderate quantity of brown nitrous fumes escaped; these were followed by copious blackish, then grey, then whitish fumes, produced by the escape of steam, carrying with it in suspension a portion of the flux. After the lapse of five or six minutes, a violent deflagration occurred, attended with a loud roaring noise and a burst of brilliant yellow flame from the top of the chimney. This lasted for about a minute and a half, and then subsided as rapidly as it commenced. When all had become tranquil, the converter was detached from the chimney, and its contents were emptied on to the iron pavement of the foundry.

"'The crude steel was in a pasty state and the slag fluid; the cast-iron perforated plate, which was placed as a cover to the converter, had become melted up and incorporated with the charge of molten metal. The slag had a glassy or blebby appearance, and a dark or green colour in mass.' Professor Miller proceeds to detail the subsequent parts of the process, and the results of his analysis of some of the products.

"'A mass of crude steel from the converter was then subjected to the hammer.

"'About $4\frac{1}{2}$ cwt. of the crude steel was transferred to an empty but hot reverberatory furnace, where in about an hour's time it was converted into four blooms, each of which was hammered, rolled into square bars, cut up, passed through a heating-furnace, and rolled into rods varying in thickness from 1 inch to five-eighths of an inch.

"'Three or four cwt. of the crude steel from the converter was transferred to a reheating furnace, then hammered into flat cakes, which, when cold, were broken up and sorted by hand for the steel melter.

"'Two fireclay pots, charged with a little clean sand, were heated, and into each 42 lb. of the cake steel was charged; in about six hours the melted metal was cast into an ingot.

"'Two other similar pots were charged with 35 lb. of the same cake steel, 7 lb. of scrap steel, and 1 ounce of oxide of manganese. These also were poured into ingots.

"'The steel was subsequently tilted, but was softer than was anticipated.

"'These results are on the whole to be considered rather as experimental than as average working samples.

"'I have therefore made an examination of the following samples only:—

No. 4. Crude Cupola Pig.	No. 8. Rolled Steely Iron.
No. 7. Hammered Crude Steel.	No. 5. Slag from the converter.

"'I shall first give the results of my analysis of the three samples of metal:—

	Cupola Pig (4).	Crude Steel (7).	Steel Iron (8).
Carbon	2·830	1·800	0·993
Silicon, with a little Titanium	2·950	0·266	0·149
Sulphur	0·113	0·018	traces.
Phosphorus	1·455	0·298	0·292
Arsenic	0·041	0·039	0·024
Manganese	0·318	0·090	0·088
Calcium	..	0·319	0·310
Sodium	..	0·144	traces.
Iron (by difference)	92·293	97·026	98·144
	100·000	100·000	100·000

"'It will be obvious from a comparison of these results that the reaction with the nitrate of soda has removed a large proportion of the carbon, silicon, and phosphorus, as well as most of the sulphur. The quantity of phosphorus (0·298 per cent.) retained by the sample of crude steel from the converter which I analyzed is obviously not such as to injure the quality *.

"'The bar iron was in our presence subjected to many severe tests. It was bent and hammered sharply round without cracking. It was forged and subjected to a similar trial, both at dull red and a cherry-red heat without cracking; it also welded satisfactorily.

"'The removal of the silicon is also a marked result of the action of the nitrate.

"'It is obvious that the practical point to be attended to is to procure results which *shall be uniform* so as to give steel of uniform quality when pig of similar composition is subjected to the process. The experiments of Mr. Kirkaldy on the tensile strength of various specimens afford strong evidence that such uniformity is attainable.

"'I have not thought it necessary to make a *complete* analysis of the slag, but have determined the quantity of sand, silica, phosphoric and sulphuric acid, as well as the amount of iron which it contains. It was less soluble in water than I had been led to expect, and it has not deliquesced though left in a paper parcel.

"'I found that out of 100 parts of the finely powdered slag, 11·9 were soluble in water. The following was the result of my analysis:—

Sand	47·3
Silica, in combination	6·1
Phosphoric acid	6·8
Sulphuric acid	1·1
Iron (a good deal of it as metal)	12·6
Soda and lime †	26·1
	100·0

* It is important to point out that, as no analysis of the finished steel tested by Mr. Kirkaldy is given, it is not improbable that this small percentage of phosphorus might have been still further reduced before it arrived at its final state of manufacture.

† The use of lime was exceptional. Its use is now discontinued; but its use on that occasion no doubt accounted for the slag being less deliquescent and soluble than it is usually found to be.

"'This result shows that a large proportion of phosphorus is extracted by the oxidizing influence of the nitrate, and that a certain amount of the iron is mechanically diffused through the slag.

"'The proportion of slag to the yield of crude steel iron was not ascertained by direct experiment; but, calculating from the materials employed, its maximum amount could not have exceeded 23 per cent. of the weight of the charge of molten metal. Consequently the 12·6 per cent. of iron in the slag would not be more than 3 per cent. of the iron operated on.

"'In conclusion, I have no hesitation in stating that Heaton's process is based upon correct chemical principles; the mode of attaining the result is both simple and rapid. The nitric acid of the nitrate in this operation imparts oxygen to the impurities always present in cast iron, converting them into compounds which combine with the sodium; and these are removed with the sodium in the slag. This action of the sodium is one of the peculiar features of the process, and gives it an advantage over the oxidizing methods in common use.'

"The slag produced is already utilized at the works, and forms the subject of a new and valuable patent. There is every reason to believe that the products of combustion may, by the means of a mechanical arrangement, devised by Mr. Heaton, be further utilized and afford a large set-off on the original cost of the nitrate. It is also a great question whether the phosphorus may not be most profitably reduced from the slag for commercial purposes."

In addition to Mr. Miller's statement, Mr. Robert Mallet reported on the subject and expressed himself highly satisfied with the results, both as regards the chemical and physical properties of the metal; and having been present at the experiments made on Mr. Kirkaldy's testing machine, he states the results as under:—

	Rupturing strain, in tons, per square inch of section.	Extension at rupture, per cent. of original length.
Heaton's steel iron......	22·72	21·65 per inch.
Heaton's cast steel......	41·73	7·20 ,,

The results recorded in the above Table for cast steel are somewhat below the results obtained in my own experiments, being in the ratio (for the breaking strain) as 41·73 : 44·94, or as ·936 : 1.

The whole of these experiments appears to be correct; and assuming the statement of cost to be equally satisfactory, we arrive at the conclusion that "taking steel from the furnace in ingots, or made into steel rails, or bar iron, or in any other form of ordinary manufacture, the net cost of production, after adding 10 per cent. for management, including all cost of labour, fuel, and material, and making all allowances for wear and tear and the like, is *several pounds sterling per ton* under the present market prices of similar descriptions of the metal." And this will cease to be a matter of surprise when it is taken into consideration that, to repeat the words of Mr. Mallet, "steel can be produced from coarse, low-priced brands of crude pig-irons, rich in phosphorus and sulphur." "Thus," continues Mr. Mallet, "wrought iron and cast steel of very high quality have been produced from Cleveland and Northamptonshire pig-irons, rich in phosphorus and sulphur; and every ironmaster knows that first-class wrought iron has not previously been produced from pig-iron of either of these districts, nor marketable steel at all."

With these observations I have now to refer to the drawings of the furnaces and apparatus which I have attached in illustration as an Appendix. In conclusion I may state that, looking at this new process and its further development as a step in advance of what has already been done by Bessemer and others, we may reasonably look forward to a new and important epoch in the history of metallurgic science.

Before entering upon the experiments, it will be necessary to repeat the formulæ of reduction as given in my previous Report of 1867. This appears to be the more requisite, as it may be inconvenient to refer to the Transactions of 1867, where it was originally introduced.

Formulæ of Reduction.

For the reduction of the Experiments on Transverse Strain.—When a bar is supported at the extremities and loaded in the middle,

$$E=\frac{wl^3}{4\delta K d^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where l is the distance between the supports, K the area of the section of the bar, d its depth, w the weight laid on added to $\frac{5}{8}$ of the weight of the bar, δ the corresponding deflection, and E the modulus of elasticity.

$$E=\frac{wl^3}{4\delta d^4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

when the section of the bar is a square.

These formulæ show that the deflection, taken within the elastic limit, for unity of pressure is a constant, that is, $\frac{\delta}{w}=D$, a constant.

Let $\frac{\delta_1}{w_1}, \frac{\delta_2}{w_2}, \ldots, \frac{\delta_n}{w_n}$ be a series of values of D, determined by experiment in a given bar, then

$$D=\frac{1}{n}\left(\frac{\delta_1}{w_1}+\frac{\delta_2}{w_2}+\ldots+\frac{\delta_n}{w_n}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which gives the mean value of this constant for a given bar.

Now, for the same material and length,

$$\frac{\delta}{w}, \text{ or } D \propto \frac{1}{Kd^2}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and when the section of the bar is a square,

$$\frac{\delta}{w}, \text{ or } D \propto \frac{1}{d^4}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

If D_1 be put for the value of D when $d=1$, then

$$D_1=Dd^4$$
$$=\frac{1}{n}\left(\frac{\delta_1}{w_1}+\frac{\delta_2}{w_2}+\ldots+\frac{\delta_n}{w_n}\right)d^4, \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

which expresses the mean value of the deflection for unity of pressure and section. This mean value, therefore, may be taken as *the measure of the flexibility* of the bar, or as the *modulus of flexure,* since it measures the amount of deflection produced by a unit of pressure for a unit of section.

Substituting this value in equation (2), we get

$$E=\frac{l^3}{4D_1}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

which gives the mean value of the modulus of elasticity, where D_1 is determined from equation (6).

The work (U) of deflection is expressed by the formula

$$U=\frac{1}{2}\times w\times\frac{\delta}{12}=\frac{w\delta}{24}, \quad (8)$$

where δ is the deflection in inches corresponding to the pressure (w) in lbs. If w and δ be taken at, or near the elastic limit, then this formula gives the work, or resistance analogous to impact, which the bar may undergo, without suffering any injury in its material. This formula, reduced to unity of section, becomes

$$u=\frac{w\delta}{24K}. \quad (9)$$

If C be a constant, determined by experiment for the weight (W) straining the bar up to the limit of elasticity, so that the bar may be able to sustain the load without injury, then

$$\frac{Wl}{4}=CKd, \quad (10)$$

where $C=\frac{1}{6}S$, or $\frac{1}{6}$ of the corresponding resistance of the material per square inch at the upper and lower edges of the section,

$$\therefore C=\frac{Wl}{4Kd}. \quad (11)$$

When the section of the bar is a square,

$$C=\frac{Wl}{4d^3}, \quad (12)$$

which gives the value of C, *the modulus of strength,* or *the unit of working strength,* W being the load, determined by experiment, which strains the bar up to the elastic limit. This value of C gives the comparative permanent or working strength of the bar.

Up to the elastic limit the deflections are proportional to their corresponding strains, but beyond this point the deflections increase in a much higher ratio. Hence the deflection corresponding to the elastic limit is the greatest deflection which is found to follow the law just explained.

For the reduction of the Experiments on Tension and Compression.—The work u expended in the elongation of a uniform bar, 1 foot in length and 1 inch in section, is expressed by

$$U=\frac{1}{2}\cdot\frac{P}{K}\cdot\frac{l}{L}=\frac{1}{2}P_1 l_1, \quad (13)$$

where $P_1=\frac{P}{K}$=strain in lbs. reduced to unity of section, and $l_1=\frac{l}{L}$=the corresponding elongation reduced to unity of length.

The value of u, determined for the different bars subjected to experiment, gives a comparative measure of their powers of resistance to a strain analogous to that of impact.

By taking P_1 to represent the crushing pressure per unity of section, and l_1 the corresponding compression per unit of length, the foregoing formula will express the work expended in crushing the bar.

Having given the formulæ for calculating the resisting powers of the steel bars to a transverse, tensile, and compressive strain, and the amount of work expended in producing fracture, we now proceed to the experiments, as follows.

Analysis of Iron Ores used at the Barrow Hæmatite Iron and Steel Company's Works, Barrow-in-Furness, Lancashire.

No.	Name.	Water.	Solution.											Insoluble residue.	Total.	Insoluble Residue.			
			Sesquioxide of iron.	Iron.	Phosphoric acid.	Phosphorus.	Sulphuric acid.	Carbonic acid.	Silica.	Alumina.	Protoxide of manganese.	Lime.	Magnesia.			Silica.	Alumina.	Lime.	Magnesia.
1	Park ore (average)	1·91	76·77	53·74	0·04	0·02	none.	none.	0·14	0·04	0·63	0·24	trace.	19·79	99·58	18·51	0·99	0·04	trace.
2*	„ „ (best rough)	0·47	94·88	66·42	0·03	0·01	„	„	0·10	0·07	0·04	0·34	„	4·49	100·39	4·45	trace.	trace.	trace.
3*	„ „ („ fine)	0·68	90·44	63·31	none.	none.	„	„	0·09	0·30	0·30	0·30	„	9·11	100·95	8·74	0·24	„	trace.
4	Lindal Moor (blast), No. 1	2·02	78·61	55·03	0·03	0·01	0·04	none.	0·04	trace.	0·24	0·57	0·19	18·31	100·05	16·11	1·67	0·03	0·05
5	„ „ („), No. 2	1·61	76·05	53·24	0·04	0·02	trace.	trace.	0·03	none.	0·08	0·49	0·14	21·07	99·53	18·60	2·04	0·08	0·11
6	„ „ („), No. 3	2·68	70·17	49·12	0·04	0·02	0·03	trace.	0·06	0·37	0·31	0·59	trace.	25·24	99·49	22·24	2·48	0·24	0·16
7	„ „ („) (common).	10·84	65·21	45·65	0·03	0·01	trace.	„	trace.	0·24	1·01	0·41	0·14	22·38	100·26	18·67	3·42	0·05	0·04
8*	Lindal Cote (puddling) ...	2·82	77·24	54·07	none.	none.	none.	4·19	0·09	0·24	0·11	6·00	0·41	9·07	100·17	7·27	1·47	0·08	trace.
9*	Lindal Moor (puddling), No. 1.	3·35	86·20	60·34	trace.	trace.	0·04	1·43	0·08	0·43	trace.	2·23	0·59	6·50	100·85	5·58	0·58	0·05	„
10	„ „ („), No. 2	2·35	66·60	46·62	„	„	none.	5·96	0·13	0·23	0·07	6·64	1·94	16·28	100·20	14·02	1·76	0·10	„
11*	Whitrigg's (puddling)	1·97	83·33	58·33	none.	none.	trace.	2·53	0·04	0·02	0·08	4·05	0·15	7·51	99·68	6·55	0·73	0·05	„
12	Dalton's (blast)	1·80	67·14	47·00	„	„	none.	4·45	trace.	0·25	0·08	6·02	0·15	19·77	99·66	19·09	0·51	0·12	„
13*	Mouzell Mine (best)	2·28	83·94	58·76	0·03	0·01	„	none.	0·09	0·22	0·28	0·65	none.	13·17	100·66	12·37	0·48	0·20	0·09
14	„ „ (average)...	1·40	69·41	48·59	none.	none.	0·03	„	0·06	0·02	0·02	0·44	0·13	27·97	99·48	25·92	1·53	0·07	0·04
15	Newton Mine (blast)	3·08	77·64	54·35	trace.	trace.	trace.	„	0·01	0·15	0·13	1·09	0·14	17·94	100·17	15·44	2·13	0·06	trace.
16	Urswick (blast)	6·59	61·30	42·91	0·02	0·01	„	„	0·02	0·28	0·24	1·01	0·58	29·73	99·75	26·78	2·54	0·16	0·07

Note. The alkalines were not determined.

* Used for making iron by Bessemer process.

FIRST SERIES OF EXPERIMENTS.

TRANSVERSE STRAIN.

EXPERIMENT I. (June 1867).—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1·02 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 1. Hard Steel."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	50	·065	....	Weight of scale &c. 36 lbs.
2	100	·118		
3	150	·179		
4	200	·240		
5	250	·309		
6	300	·364		
7	350	·426		
8	400	·491		
9	450	·555		
10	500	·611		
11	550	·676		
12	600	·742		
13	650	·803		
14	700	·866		
15	750	·946		
16	800	1·006		
17	850	1·076		
18	900	1·146		
19	950	1·206		
20	1000	1·266		
21	1050	1·346		
22	1100	1·406	·000	
23	1150	1·476	·000	
24	1200	1·546	·016	
25	1250	1·646	·055	
26	1300	1·796	·133	
27	1350	2·156	·429	
28	1400	2·746	·883	Experiment discontinued.

Results of Exp. I.

Here the weight (w) at the limit of elasticity is 1210 lbs., and the corresponding deflection (δ) is 1·546.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001308.

By formula (7).—The mean value of the modulus of elasticity (E) = 30,096,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 33,830,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 77·944.

By formula (9).—Work of deflection (u) for unity of section = 77·917.

By formula (12).—Value of C, the unit of working strength = 6·860 tons.

TRANSVERSE STRAIN.

Exp. II.—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar ·995 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 2. Medium."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	50	·065		
2	100	·128		
3	150	·201		
4	200	·266		
5	250	·330		
6	300	·396		
7	350	·466		
8	400	·534		
9	450	·601		
10	500	·682	·000	
11	550	·760	·027	
12	600	·880	·052	
13	650	1·020	·115	
14	700	2·040	1·068	
15	750	......	......	Bar destroyed.

Results of Exp. II.

Here the weight (w) at the limit of elasticity is 510 lbs., and the corresponding deflection (δ) is ·682.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001280.

By formula (7).—The mean value of the modulus of elasticity (E) = 30,754,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 34,443,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 14·242.

By formula (9).—Work of deflection (u) for unity of section = 14·383.

By formula (12).—Value of C, the unit of working strength = 3·108 tons.

TRANSVERSE STRAIN.

EXP. III.—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1·01 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 3. Soft."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	50	·074		
2	100	·127		
3	150	·195		
4	200	·262		
5	250	·330		
6	300	·395		
7	350	·453		
8	400	·515		
9	450	·577	·000	
10	500	·645	·007	
11	550	·716	·018	
12	600	·793	·019	
13	650	·873	·032	
14	700	1·029	·118	
15	750	1·279	·287	
16	800	2·709	1·625	Experiment discontinued.

Results of Exp. III.

Here the weight (w) at the limit of elasticity is 610 lbs., and the corresponding deflection (δ) is ·793.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001319.

By formula (7).—The mean value of the modulus of elasticity (E) = 29,717,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 32,717,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 20·155.

By formula (9).—Work of deflection (u) for unity of section = 19·757.

By formula (12).—Value of C, the unit of working strength = 3·540 tons.

TRANSVERSE STRAIN.

Exp. IV. (January 1868).—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1·071 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 1+."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·072	....	Very soft steel.
2	146	·147		
3	202	·200		
4	258	·275		
5	314	·352		
6	370	·430		
7	426	·497		
8	482	·558	·015	
9	538	·635	·015	
10	594	·691	·021	
11	650	·771	·028	
12	706	·891	·053	
13	762	1·437	·586	

Results of Exp. IV.

Here the weight (w) at the limit of elasticity is 660 lbs., and the corresponding deflection (δ) is ·771.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001383.

By formula (7).—The mean value of the modulus of elasticity (E) = 28,460,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 31,740,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 21·20.

By formula (9).—Work of deflection (u) for unity of section = 18·48.

By formula (12).—Value of C, the unit of working strength = 3·228 tons.

TRANSVERSE STRAIN.

Exp. V.—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1·032 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H2+."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·120	·000	Soft steel.
2	146	·190	·000	
3	202	·254	·011	
4	258	·324	·012	
5	314	·405	·013	
6	370	·486	·021	
7	426	·554		
8	482	·638		
9	538	·692		
10	594	·780		
11	650	·870		
12	706	·968	·028	
13	762	1·199	·150	
14	818	1·448	·474	

Results of Exp. V.

Here the weight (w) at the limit of elasticity is 716 lbs., and the corresponding deflection (δ) is ·968.

By formula (6).—The mean value of the deflection of unity of pressure and section (D_1) = ·001384.

By formula (7).—The mean value of the modulus of elasticity (E) = 28,440,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure =28,610,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 28·28.

By formula (9).—Work of deflection (u) for unity of section = 25·95.

By formula (12).—Value of C, the unit of working strength = 3·938 tons.

TRANSVERSE STRAIN.

Exp. VI.—Bar of Steel from the Hæmatite Steel and Iron Company. Dimension of bar 1·016 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 3+."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·130	....	Very soft steel.
2	146	·199		
3	202	·274	·009	
4	258	·352	·016	
5	314	·428	·016	
6	370	·505	·020	
7	426	·580	·042	
8	482	·656	·048	
9	538	·734	·048	
10	594	·808	·056	
11	650	·882	·079	
12	706	·990	·798	
13	762	1·530	·998	

Results of Exp. VI.

Here the weight (w) at the limit of elasticity is 660 lbs., and the corresponding deflection (δ) is ·882.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001406.

By formula (7).—The mean value of the modulus of elasticity (E) = 28,000,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 29,080,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 24·25.

By formula (9).—Work of deflection (u) for unity of section = 23·49.

By formula (12).—Value of C, the unity of working strength = 3·781 tons.

TRANSVERSE STRAIN.

Exp. VII.—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 4+."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·150	....	Soft steel.
2	146	·215		
3	202	·285	·044	
4	258	·352	·046	
5	314	·432	·048	
6	370	·498	·054	Weight remained on bar from 5 P.M. to 10 A.M. The deflection in that time increased by ·004 of an inch.
7	426	·574		
8	482	·646		
9	538	·734		
10	594	·804		
11	650	·873		
12	706	·968		
13	762	1·136	·151	
14	818	1·528	·516	

Results of Exp. VII.

Here the weight (w) at the limit of elasticity is 716 lbs., and the corresponding deflection (δ) is ·968.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001330.

By formula (7).—The mean value of the modulus of elasticity (E) = 29,600,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 28,590,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 28·28.

By formula (9).—Work of deflection (u) for unity of section = 28·28.

By formula (12).—Value of C, the unit of working strength = 4·315 tons.

TRANSVERSE STRAIN.

Exp. VIII.—Bar of Steel from the Barrow Hæmatite Steel Company. Dimension of bar 1·051 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 5+."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·122	....	Rather harder steel.
2	146	·196		
3	202	·271	·002	
4	258	·348	·002	
5	314	·420	·004	
6	370	·493	·006	
7	426	·566	·008	
8	481	·648	·010	
9	538	·718	·012	
10	594	·783	·014	
11	650	·848	·016	
12	706	·932		
13	762	1·058	....	Weight left on from 1 P.M. to 2 P.M.
14	818	1·182	·104	
15	874	1·410	·295	

Results of Exp. VIII.

Here the weight (w) at the limit of elasticity is 772 lbs., and the corresponding deflection (δ) is 1·058.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001658.

By formula (7).—The mean value of the modulus of elasticity (E) = 23,740,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 25,720,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 34·03.

By formula (9).—Work of deflection (u) for unity of section = 30·81.

By formula (12).—Value of C, the unit of working strength = 4·108 tons.

TRANSVERSE STRAIN.

EXP. IX.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Dimension of bar 1·042 inch square. Length between supports 4 feet 6 inches. Mark on bar, "H 6 +."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·148	·000	This steel is of the same quality as bar 8.
2	146	·220	·000	
3	202	·228	·018	
4	258	·360	·018	
5	314	·443	·018	
6	370	·508	·018	
7	426	·578	·022	
8	482	·650	·022	
9	538	·732	·022	
10	594	·798	·022	
11	650	·864	·024	
12	706	·966		
13	762	1·070	·050	
14	818	1·196	·081	Weight left on bar from 4.30 P.M. to 10 A.M.
15	874	1·544	·494	

Results of Exp. IX.

Here the weight (w) at the limit of elasticity is 772 lbs., and the corresponding deflection (δ) is 1·07.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001595.

By formula (7).—The mean value of the modulus of elasticity (E) = 24,680,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 23,550,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 34·42.

By formula (9).—Work of deflection (u) for unity of section = 31·73.

By formula (12).—Value of C, the unit of working strength = 4·112 tons.

TRANSVERSE STRAIN.

Exp. X. (April 1869).—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·018 × 1·04 inch. Length between supports 4 feet 6 inches. Mark on bar, "1."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	34	·054	....	Hard cast steel.
2	62	·094		
3	118	·162	·006	
4	146	·190	·002	
5	174	·228	·005	
6	314	·436	·004	
7	370	·502	·004	
8	426	·578	·025	
9	454	·614	·026	
10	482	·656	·028	
11	510	·696		
12	538	·730		
13	566	·768		
14	594	·802		
15	622	·860		
16	650	·940		
17	678	·985		
18	706	1·016		
19	762	1·079		
20	818	1·141		
21	874	1·162	·028	
22	930	1·235		
23	986	1·329		
24	1041	1·391		
25	1097	1·443		
26	1153	1·526		
27	1209	1·610		
28	1241	1·693		
29	1321	1·860	·040	

Results of Exp. X.

Here the weight (w) at the limit of elasticity is 1251 lbs., and the corresponding deflection (δ) is 1·693.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001481.

By formula (7).—The mean value of the modulus of elasticity (E) = 26,580,000.

By formula (1).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 26,060,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 88·25.

By formula (9).—Work of deflection (u) for unity of section = 83·410.

By formula (11).—Value of C, the unit of working strength = 6·831 tons.

TRANSVERSE STRAIN.

EXP. XI.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·044 × ·028 inch. Length between supports 4 feet 6 inches. Mark on bar, "2."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·120		
2	146	·186	·008	
3	202	·242	·009	
4	258	·312	·009	
5	314	·378	·009	
6	370	·470	·009	
7	424	·546	·010	
8	482	·612	·010	
9	538	·677	·010	
10	594	·744		
11	650	·812		
12	706	·888		
13	762	·952		
14	818	1·016		
15	874	1·084	·011	
16	930	1·154		
17	986	1·212	·014	
18	1042	1·276		
19	1098	1·336		
20	1154	1·398		
21	1210	1·460		
22	1266	1·522		
23	1322	1·615	·016	
24	1378	1·708	·042	
25	1434	1·801	·082	
26	1466	1·933		
27	1522	2·086	·208	
28	1578	3·836	1·836	

Results of Exp. XI.

Here the weight (w) at the limit of elasticity is 1444 lbs., and the corresponding deflection (δ) is 1·801.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001354.

By formula (7).—The mean value of the modulus of elasticity (E) = 29,070,000.

By formula (1).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 29,640,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity =108·4.

By formula (9).—Work of deflection (u) for unity of section = 101·1.

By formula (11).—Value of C, the unit of working strength = 7·879 tons.

TRANSVERSE STRAIN.

Exp. XII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·022 × 1·013 inch. Length between supports 4 feet 6 inches. Mark on bar, "3."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·144	·000	
2	258	·373	·022	
3	370	·524	·032	
4	482	·672	·026	
5	594	·812	·047	
6	706	·952		
7	762	1·038	·022	
8	828	1·124		
9	884	1·170	·023	
10	940	1·242		
11	996	1·308		
12	1052	1·402		
13	1108	1·464	·021	
14	1164	1·568		
15	1220	1·622	·046	
16	1276	1·722	·062	
17	1332	1·777	·100	
18	1388	1·819	·160	
19	1444	2·652	·842	
20	1556	4·652	2·588	

Results of Exp. XII.

Here the weight (w) at the limit of elasticity is 1398 lbs., and the corresponding deflection (δ) is 1·819.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001419.

By formula (7).—The mean value of the modulus of elasticity (E) = 27,740,000.

By formula (1).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 26,160,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 105·9.

By formula (9).—Work of deflection (u) for unity of section = 102·3.

By formula (11).—Value of C, the unit of working strength = 8·028 tons.

TRANSVERSE STRAIN.

Exp. XIII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·008 × 1·012 inch. Length between supports 4 feet 6 inches. Mark on bar, "4."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·108		
2	314	·406		
3	538	·686		
4	762	·975		
5	874	1·090		
6	986	1·198		
7	1042	1·304		
8	1098	1·408		
9	1154	1·459		
10	1210	1·543		
11	1266	1·592	·001	
12	1322	1·676	·012	
13	1378	1·769	·046	
14	1434	1·908	·094	
15	1490	2·428	·572	

Results of Exp. XIII.

Here the weight (w) at the limit of elasticity is 1388 lbs., and the corresponding deflection (δ) is 1·769.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001295.

By formula (7).—The mean value of the modulus of elasticity (E) = 30,400,000.

By formula (1).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 35,120,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 102·3.

By formula (9).—Work of deflection (u) for unity of section = 100·3.

By formula (11).—Value of C, the unit of working strength = 8·094 tons.

TRANSVERSE STRAIN.

Exp. XIV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·025×1·02 inch. Length between supports 4 feet 6 inches. Mark on bar, "5."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·117	·000	
2	146	·193	·009	
3	202	·257	·009	
4	258	·328	·009	
5	314	·403	·009	
6	370	·477	·009	
7	426	·540	·010	
8	482	·608	·010	
9	538	·673	·010	
10	650	·816	·010	
11	762	·977	·010	
12	818	1·057	·012	
13	874	1·113	·012	
14	930	1·189	·011	
15	986	1·263	·007	
16	1042	1·325	·008	
17	1098	1·387	·009	
18	1154	1·457	·010	
19	1210	1·543	·015	
20	1266	1·607	·017	
21	1322	1·760	·023	
22	1378	1·928	·029	
23	1434	2·188	·073	
24	1490	2·339	·161	
25	1546	2·690	·797	

Results of Exp. XIV.

Here the weight (w) at the limit of elasticity is 1276 lbs., and the corresponding deflection (δ) is 1·607.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001351.

By formula (7).—The mean value of the modulus of elasticity (E) = 29,140,000.

By formula (1).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 31,140,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 85·44.

By formula (9).—Work of deflection (u) for unity of section = 81·60.

By formula (11).—Value of C, the unit of working strength = 7·209 tons.

TRANSVERSE STRAIN.

Exp. XV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Dimension of bar 1·02 × 1·02 inch. Length between supports 4 feet 6 inches. Mark on bar, "6."

No. of Exp.	Weight laid on, in lbs.	Deflection, in inches.	Permanent set, in inches.	Remarks.
1	90	·132	·000	
2	146	·200	·013	
3	202	·268	·016	
4	258	·331	·019	
5	314	·406	·019	
6	370	·474	·019	
7	426	·550	·023	
8	482	·610		
9	538	·680	·018	
10	594	·774	·020	
11	650	·854	·024	
12	706	·926		
13	762	·994	·014	
14	818	1·078	·014	
15	874	1·142		
16	930	1·208		
17	986	1·274	·015	
18	1042	1·344		
19	1098	1·440		
20	1154	1·502	·016	
21	1210	1·578	·022	
22	1266	1·719	·037	
23	1322	1·753	·072	
24	1378	1·866	·078	
25	1434	2·003	·158	
26	1490	3·378	1·378	

Results of Exp. XV.

Here the weight (w) at the limit of elasticity is 1220 lbs., and the corresponding deflection (δ) is 1·578.

By formula (6).—The mean value of the deflection for unity of pressure and section (D_1) = ·001372.

By formula (7).—The mean value of the modulus of elasticity (E) = 28,690,000.

By formula (2).—The modulus of elasticity (E) corresponding to 112 lbs. pressure = 27,590,000.

By formula (8).—Work of deflection (U) up to the limit of elasticity = 80·21.

By formula (9).—Work of deflection (u) for unity of section = 77·13.

By formula (12).—Value of C, the unit of working strength = 6·925 tons.

Summary of Results of the Experiments on Transverse Strain.

No. of experiment.	Manufacturer.	Mark on Bar.	Date of Experiment.	Mean value (D_1) of the deflection for unity of pressure and section. By eq. (6).	Mean value of the modulus of elasticity (E). By eq. (7).	Modulus of elasticity (E) corresponding to 112 lbs. pressure. By eq. (1 & 2)	Work of deflection (U) up to the limit of elasticity. By eq. (8).	Work of deflection (*u*) for unity of section. By eq. (9).	Value of C, the unit of working strength. By eq. (11 & 12).
									tons.
1	The Barrow Hæmatite Steel Company	H 1	June 1867	·001308	30,096,000	33,830,000	77·944	77·917	6·860
2	,, ,,	H 2	,,	·001280	30,754,000	34,443,000	14·242	14·383	3·108
3	,, ,,	H 3	,,	·001319	29,717,000	32,717,000	20·155	19·757	3·540
4	The Barrow Hæmatite Steel Company	H 1 +	January 1868	·001383	28,460,000	31,740,000	21·200	18·480	3·228
5	,, ,,	H 2 +	,,	·001384	28,440,000	28,610,000	28·280	25·950	3·938
6	,, ,,	H 3 +	,,	·001406	28,000,000	29,080,000	24·250	23·490	3·781
7	,, ,,	H 4 +	,,	·001330	29,600,000	28,590,000	28·280	28·280	4·315
8	,, ,,	H 5 +	,,	·001658	23,740,000	25,720,000	34·030	30·810	4·108
9	,, ,,	H 6 +	,,	·001595	24,680,000	23,550,000	34·420	31·730	4·112
10	The Heaton Steel Company	1	April 1869	·001481	26,580,000	26,060,000	88·250	83·410	6·831
11	,, ,,	2	,,	·001354	29,070,000	29,640,000	108·400	101·100	7·879
12	,, ,,	3	,,	·001419	27,740,000	26,160,000	105·900	102·300	8·028
13	,, ,,	4	,,	·001295	30,400,000	35,120,000	102·300	100·300	8·094
14	,, ,,	5	,,	·001351	29,140,000	31,140,000	85·440	81·600	7·209
15	,, ,,	6	,,	·001372	28,690,000	27,590,000	80·210	77·130	6·925

SECOND SERIES OF EXPERIMENTS.

TENSILE STRAIN.

Exp. I. (June 1867).—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 1." Diameter of specimen ·744 inch. Area ·4347 square inch. Reduced diameter after fracture ·744 inch. Area ·4347 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	10249	....	....			
2	11929	....	....			
3	13609	....	....			
4	15289	....	....			
5	16969	....	....			
6	18649	....	....			
7	20329	....	....			
8	22219	....	....			
9	23899	....	....	·0062	·0031	
10	27259	....	....	·0063	·0031	
11	30619	....	....	·0065	·0031	
12	32299	....	....	·0125	·0093	
13	33979	....	....	·0163	·0101	
14	35659	....	....	·0218	·0171	
15	37339	....	....	·0375	·0312	
16	39019	....	....	·0406	·0390	
17	40594	93383	41·700	....	....	Broke in neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 93,383 lbs., or 41·7 tons, and the corresponding elongation (l_1) is ·0406. By formula (13).—The work (u) expended in producing rupture = 1895.

Exp. II.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 2." Diameter of specimen ·69 inch. Area ·3754 square inches. Reduced diameter after fracture ·66 inch. Area ·3401 square inch.

1	15289	....	....	·0062		
2	18649	....	....	·0195	·0178	
3	22009	....	....	·0312	·0226	
4	25369	....	....	·0522	·0515	
5	27049	....	....	·0656	·0647	
6	28729	....	....	·0866	·0863	
7	30309	80724	36·030	....	....	Broke in centre.

Results.—Here the breaking-strain (P_1) per square inch of section is 80,724 lbs., or 36·03 tons, and the corresponding elongation (l_1) is ·0866. By formula (13).—The work (u) expended in producing rupture = 3495.

Exp. III.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 3." Diameter of specimen ·75 inch. Area ·4417 square inch. Reduced diameter after fracture ·542 inch. Area ·2306 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	15289	....	....	·0012		
2	18049	....	....	·0180		
3	22009	....	....	·0290	·0163	
4	25369	....	....	·0656	·0622	
5	28729	....	....	·0656	.0622	[neck.
6	30304	68607	30·63	....	....	Broke 1½ inch from

Results.—Here the breaking-strain (P_1) per square inch of section is 68,607 lbs., or 30·63 tons, and the corresponding elongation (l_1) per unit of length is ·0656. By formula (13).—The work (u) expended in producing rupture = 2250.

Exp. IV. (January 1868).—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 1 +." Diameter of specimen ·763 inch. Area ·4572 square inch. Reduced diameter after fracture ·51 inch. Area ·2043 square inch.

1	15289	....	....	·0006		
2	18649	....	....	·0062		
3	20329	....	....	·0222	·0195	
4	22009	....	....	·0281	·0265	
5	23689	....	....	·0375	·0343	
6	25369	....	....	·0546	·0483	
7	27049	....	....	·0765	·0733	
8	28729	....	....	·1858	·1765	
9	30304	66281	29·59	....	....	Broke in centre.

Results.—Here the breaking-strain (P_1) per square inch of section is 66,281 lbs., or 29·59 tons, and the corresponding elongation (l_1) per unit of length is ·1858. By formula (13).—The work (u) expended in producing rupture = 6157.

Exp. V.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 2+." Diameter of specimen ·764 inch. Area ·4584 square inch. Reduced diameter after fracture ·568 inch. Area ·2696 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	15289	....	....			
2	18649	....	....			
3	22009	....	....	·0003		
4	23689	....	....	·0004	·0003	
5	25369	....	....	·0118	·0106	
6	27049	....	....	·0137	·0125	
7	28729	....	....	·0171	·0156	
8	30304	....	....	·0233	·0218	
9	32014	....	....	·0312	·0296	[from centre.
10	33574	73241	32·69	....	....	Broke 2 inches

Results.—Here the breaking-strain (P_1) per square inch of section is 73,241 lbs., or 32·69 tons, and the corresponding elongation (l_1) per unit of length is ·0312. By formula (13).—The work (u) expended in producing rupture = 1142.

Exp. VI.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 3+." Diameter of specimen ·771 inch. Area ·4656 square inch. Reduced diameter after fracture ·598 inch. Area ·2808 square inch.

1	15289	....	....	·0053		
2	18649	....	....	·0116		
3	20329	....	....	·0187	·0171	
4	22009	....	....	·0265	·0187	
5	23689	....	....	·0321	·0250	
6	25369	....	....	·0375	·0296	
7	27049	....	....	·0450	·0437	
8	28729	....	....	·0718	·0593	
9	30304	....	....	·0812	·0786	[from neck.
10	32014	68758	30·69	....	....	Broke 1½ inch

Results.—Here the breaking-strain (P_1) per square inch of section is 68,758 lbs., or 30·69 tons, and the corresponding elongation (l_1) per unit of length is ·0812. By formula (13).—The work (u) expended in producing rupture = 2791.

Exp. VII.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 4+." Diameter of specimen ·768 inch. Area ·4639 square inch. Reduced diameter after fracture ·768 inch. Area ·4639 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	18649	....	....	·0031		
2	22009	....	....	·0108		
3	23689	....	....	·0226	·0187	
4	25369	....	....	·0297	·0222	
5	27069	....	....	·0343	·0375	
6	28729	....	....	·0438	·0421	
7	30304	....	....	·0500	·0491	
8	32014	....	....	·0671	·0622	
9	33574	....	....	·0906	·0875	
10	35334	75736	33·81	....	....	Broke in neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 75,736 lbs., or 33·81 tons, and the corresponding elongation (l_1) per unit of length is ·0906. By formula (13).—The work (u) expended in producing rupture = 3430.

Exp. VIII.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 5+." Diameter of specimen ·76 inch. Area ·4536 square inch. Reduced diameter after fracture ·558 inch. Area ·2366 square inch.

1	18649	....	....	·0027		
2	22009	....	....	·0062		
3	25369	....	....	·0296	·0250	
4	27049	....	....	·0375	·0312	
5	28729	....	....	·0467	·0437	
6	30304	....	....	·0622	·0562	
7	32014	....	....	·0765	·0750	[centre.
8	33574	74016	33·04	....	....	Broke 1 inch from

Results.—Here the breaking-strain (P_1) per square inch of section is 74,016 lbs., or 33·04 tons, and the corresponding elongation (l_1) per unit of length is ·0765. By formula (13).—The work (u) expended in producing rupture=2831.

Exp. IX.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Elongations taken on 8 inches length. Mark on bar, "H 6+." Diameter of specimen ·772 inch. Area ·4677 square inch. Reduced diameter after fracture ·581 inch. Area ·3651 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	18649	....	....	·0003		
2	22009	....	....	·0062		
3	25369	....	....	·0250	·0218	
4	27049	....	....	·0335	·0281	
5	28728	....	....	·0406	·0375	
6	30304	....	....	·0500	·0468	
7	31864	....	....	·0686	·0678	
8	33424	....	....	·1000	·0937	
9	35124	75120	33·53	....	....	Broke in centre.

Results.—Here the breaking-strain (P_1) per square inch of section is 75,120 lbs., or 33·53 tons, and the corresponding elongation (l_1) per unit of length is ·1. By formula (13).—The work (u) expended in producing rupture = 3756.

Exp. X. (April 1869).—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "1." Diameter of specimen ·748 inch. Area ·4394 square inch. Reduced diameter after fracture ·748 inch. Area ·4394 square inch.

1	16969	....	....	·000		
2	23689	....	....	·000		
3	27049	....	....	·000		
4	29119	....	....	·000		
5	30799	....	....	·000		
6	32479	....	....	·0012		
7	34039	....	....	·0156		
8	35659	....	....	·0208		
9	37189	....	....	·0235	·0208	
10	38704	....	....	·0351	·0315	
11	40264	....	....	·0390	·0351	
12	41104	93545	41·761	....	....	Broke in neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 93,545 lbs., or 41·761 tons, and the corresponding elongation (l_1) per unit of length is ·0390. By formula (13).—The work (u) expended in producing rupture =1824.

Exp. XI.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "2." Diameter of specimen ·758 inch. Area ·4512 square inch. Reduced diameter after fracture ·758 inch. Area ·4512 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	16969	....	....	·0019		
2	23479	....	....	·0024		
3	28669	....	....	·0024		
4	32119	....	....			
5	35479	....	....	·0125	·0103	
6	38839	....	....	·0235	·0187	
7	40519	....	....	·0312	·0235	
8	42199	93526	41·752	....	....	Broke in neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 93,526 lbs., or 41·752 tons, and the corresponding elongation (l_1) per unit of length is ·0312. By formula (13).—The work (u) expended in producing rupture = 1459.

Exp. XII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "3." Diameter of specimen ·746 inch. Area ·4370 square inch. Reduced diameter after fracture ·626 inch. Area ·3077 square inch.

1	16969					
2	22144					
3	26149	....	....	·0019		
4	29794	....	....	·0038		
5	32944	....	....			
6	36019	....	....	·0157	·0125	
7	37699	....	....	·0208	·0157	
8	39379	....	....	·0234	·0227	
9	41059	....	....	·0277	·0250	
10	41899	....	....	·0312	·0250	
11	42739	....	....	·0375	·0253	
12	43379	....	....	....	·0390	
13	44419	....	....			
14	45259	....	....	·0416	·0400	
15	46699	....	....	·0468	·0416	
16	46939	....	....	·0520	·0452	
17	47359	....	....	·0582	·0512	
18	47779	....	....	·0625		
19	48199	....	....	·0645	·0580	
20	48619	....	. ..	·0781	·0728	
21	49039	....	....	·0937	·0750	[centre.
22	49459	113178	50·526	....	....	Broke 2 ins. from

Results.—Here the breaking-strain (P_1) per square inch of section is 113,178 lbs., or 50·526 tons, and the corresponding elongation (l_1) per unit of length is ·0937. By formula (13).—The work (u) expended in producing rupture = 5302.

Exp. XIII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "4." Diameter of specimen ·746 inch. Area ·4370 square inch. Reduced diameter after fracture ·746 inch. Area ·4370 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	16969	....	....			
2	27484	....	....			
3	35459	....	...	·0019		
4	39224	....	....	·0208	·0131	
5	40784	....	....	·0234	·0206	
6	41628	....	....	·0250		
7	43308	....	....	·0274		
8	44988	....	....	·0364	·0312	
9	45828	104869	46·816	....	....	Broke in neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 104,869 lbs., or 46·816 tons, and the corresponding elongation (l_1) per unit of length is ·0364. By formula (13).—The work (u) expended in producing rupture = 1908.

Exp. XIV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "5." Diameter of specimen ·754 inch. Area ·4465 square inch. Reduced diameter after fracture ·754 inch. Area ·4465 square inch.

1	24049	....	....	·0038		
2	33629	....	....	·0208		
3	40784	....	....	·0393	·0307	
4	42464	....	....	·0646		
5	43304	....	....	·0781	·0750	
6	43724	....	....	·0937	·0821	
7	44144	98866	44·136	....	....	Broke near neck.

Results.—Here the breaking-strain (P_1) per square inch of section is 98,866 lbs., or 44·136 tons, and the corresponding elongation (l_1) per unit of length is ·0937. By formula (13).—The work (u) expended in producing rupture = 4631.

Exp. XV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Elongations taken on 8 inches length. Mark on bar, "6." Diameter of specimen ·754 inch. Area ·4465 square inch. Reduced diameter after fracture ·528 inch. Area ·2560 square inch.

No. of Exp.	Weight laid on.	Breaking-strain per square inch of section.		Per unit of length.		Remarks.
				Elongation.	Permanent set.	
	lbs.	lbs.	tons.			
1	24049	....	....	·0038		
2	32629	....	....			
3	39784	....	....	·0412	·0375	
4	41464	....	....	·0468	·0419	
5	42304	....	....	·0500	·0450	
6	43144	....	....	·0500		
7	43984	....	....	·0520		
8	44824	....	....	·0663		
9	45244	....	....	·0693	·0663	
10	45664	....	....	·0702		
11	46504	....	....	·1041	·1012	[neck.
12	46924	105093	46·915	....	....	Broke 2 ins. from

Results.—Here the breaking-strain (P_1) per square inch of section is 105,093 lbs., or 46·915 tons, and the corresponding elongation (l_1) per unit of length is ·1041. By formula (13).—The work (u) expended in producing rupture = 5464.

Summary of Results of the Experiments on Tensile Strain.

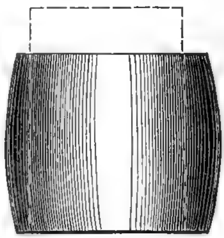
No. of Exp.	Manufacturer.	Mark on Bar.	Date of experiment.	Specific gravity of Specimen.	Weight laid on.	Breaking-strain per square inch of section.		Corresponding elongation per unit of length.	Value of u, or work producing rupture. By eq. (13).	Remarks.
					lbs.	lbs.	tons.			
1	The Barrow Hæmatite Steel Co.	H 1	June 1867	7·7006	40594	93383	41·700	·0406	1895	Broke in neck.
2	,, ,,	H 2	,,	7·7710	30309	80724	36·030	·0866	3495	Broke in centre.
3	,, ,,	H 3	,,	7·7899	30304	68607	30·630	·0656	2250	Broke 1½ in. from neck.
4	The Barrow Hæmatite Steel Co.	H 1+	Jan. 1868	7·7037	30304	66281	29·590	·1858	6157	Broke in centre.
5	,, ,,	H 2+	,,	7·7978	33574	72341	32·690	·0312	1142	Broke 2 ins. from centre.
6	,, ,,	H 3+	,,	7·7952	32014	68758	30·690	·0812	2791	Broke 1½ in. from neck.
7	,, ,,	H 4+	,,	7·7956	35334	75736	33·810	·0906	3430	Broke in neck.
8	,, ,,	H 5+	,,	7·8654	33574	74016	33·040	·0765	2831	Broke 1 in. from centre.
9	,, ,,	H 6+	,,	7·8159	35124	75120	33·530	·1000	3756	Broke in centre.
10	The Heaton Steel Company......	1	April 1869	7·8225	41104	93545	41·761	·0390	1824	Broke in neck.
11	,, ,,	2	,,	7·8176	42199	93526	41·752	·0312	1459	,,
12	,, ,,	3	,,	7·8153	49459	113178	50·526	·0937	5302	Broke 2 ins. from centre.
13	,, ,,	4	,,	7·8003	45828	104869	46·816	·0364	1908	Broke in neck.
14	,, ,,	5	,,	7·8128	44144	98866	44·136	·0937	4631	Broke near neck.
15	,, ,,	6	,,	7·8166	46924	105093	46·915	·1041	5464	Broke 2 ins. from neck.

THIRD SERIES OF EXPERIMENTS.

COMPRESSIVE STRAIN.

Exp. I. (June 1867).—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 1."

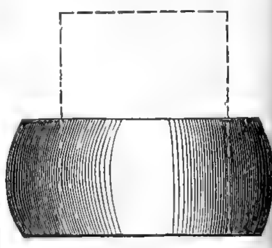
	Before experiment.	After experiment.
Height of specimen	·981 inch........	·784 inch.
Diameter of specimen	·72 inch	·854 inch.
Area of specimen	·4071 sq. in.	·5728 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Com-pression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	37438	16·713	91951	41·049	·033	
2	44966	20·074	110440	49·303	·042	
3	52166	23·288	128124	57·198	·050	
4	58950	26·316	144786	64·637	·066	
5	66022	29·474	162156	72·391	·075	
6	73134	32·649	179722	80·233	·100	
7	80214	35·809	197023	87·952	·133	
8	88134	39·345	216465	96·636	·187	
9	91840	41·000	225568	100·700	·200	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·2. By formula (13).—The work (u) expended in producing rupture = 22556.

Exp. II.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 2."

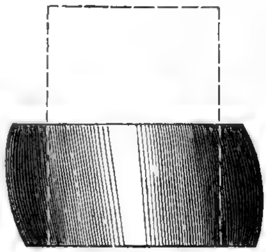
	Before experiment.	After experiment.
Height of specimen	·971 inch........	·498 inch.
Diameter of specimen	·72 inch	1·066 inch.
Area of specimen	·4071 sq. in.	·8922 sq. in.

1	37438	16·713	91951	40·049	·100	
2	44966	20·074	110440	49·303	·133	
3	52166	23·288	128124	57·198	·200	
4	58950	26·316	144786	64·637	·266	
5	66022	29·474	162156	72·391	·310	
6	73134	32·649	179722	80·233	·350	
7	80214	35·809	197023	87·952	·400	
8	88134	39·345	216465	96·636	·425	
9	91840	41·000	225568	100·700	·450	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·45. By formula (13).—The work (u) expended in producing rupture = 50752.

Exp. III.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 3."

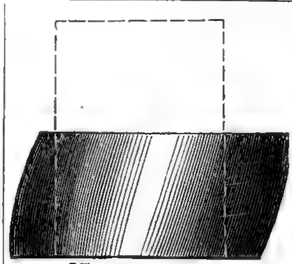
	Before experiment.	After experiment.
Height of specimen	·968 inch........	·536 inch.
Diameter of specimen	·72 inch	1·065 inch.
Area of specimen	·4071 sq. in.	·8906 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Com-pression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	37438	16·713	91951	41·049	·100	
2	44966	20·074	110440	49·303	·153	
3	52166	23·288	128124	57·198	·210	
4	58950	26·316	144786	64·637	·275	
5	66022	29·474	162156	72·391	·312	
6	73134	32·649	179722	80·233	·350	
7	80214	35·809	197023	87·952	·400	
8	88134	39·345	216465	96·636	·412	
9	91840	41·000	225568	100·700	·450	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·45. By formula (13).—The work (u) expended in producing rupture = 50752.

Exp. IV. (January 1868).—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 1+."

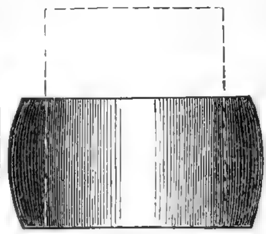
	Before experiment.	After experiment.
Height of specimen	1·00 inch	·51 inch.
Diameter of specimen	·72 inch	1·08 inch.
Area of specimen	·4071 sq. in.	·9175 sq. in.

1	37438	16·713	91951	41·049	·160	
2	44966	20·074	110440	49·303	·160	
3	52166	23·288	128124	57·198	·220	
4	58950	26·316	144786	64·637	·283	
5	66022	29·474	162156	72·391	·340	
6	73134	32·649	179722	80·233	·383	
7	80214	35·809	197023	87·952	·425	
8	88134	39·345	216465	96·636	·475	
9	91840	41·000	225568	100·700	·480	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·48. By formula (13).—The work (u) expended in producing rupture = 54136.

Exp. V.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 2+."

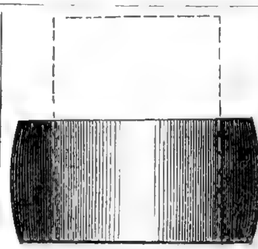
	Before experiment.		After experiment.
Height of specimen	·981 inch.	....	·553 inch.
Diameter of specimen	·72 inch.	....	1·02 inch.
Area of specimen	·4071 sq. in.	....	·8168 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	37438	16·713	91951	41·049	·092	
2	44966	20·074	110440	49·303	·120	
3	52166	23·288	128124	57·198	·175	
4	58950	26·316	144786	64·637	·220	
5	66022	29·474	162156	72·391	·283	
6	73134	32·649	179722	80·233	·325	
7	80214	35·809	197023	87·952	·380	
8	88134	39·345	216465	96·636	·412	
9	91840	41·000	225568	100·700	·525	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·525. By formula (13).—The work (u) expended in producing rupture = 59211.

Exp. VI.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 3+."

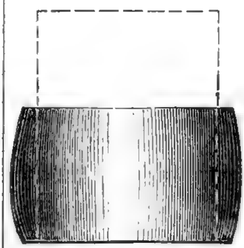
	Before experiment.		After experiment.
Height of specimen......	·97 inch.	....	·504 inch.
Diameter of specimen	·72 inch.	....	1·07 inch.
Area of specimen........	·4071 sq. in.	....	·8984 sq. in.

1	37438	16·713	91951	41·049	·100	
2	44966	20·074	110440	49·303	·160	
3	52166	23·288	128124	57·198	·220	
4	58950	26·316	144786	64·637	·257	
5	66022	29·474	162156	72·391	·325	
6	73134	32·649	179722	80·233	·374	
7	80214	35·809	197023	87·952	·410	
8	88134	39·345	216465	96·636	·450	
9	91840	41·000	225568	100·700	·474	Slight cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·474. By formula (13).—The work (u) expended in producing rupture = 53459.

Exp. VII.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 4+."

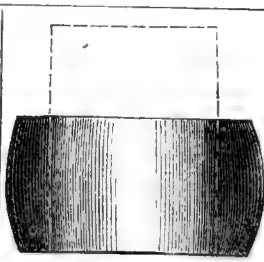
	Before experiment.		After experiment.
Height of specimen	·974 inch.	....	·581 inch.
Diameter of specimen	·72 inch.	....	1·01 inch.
Area of specimen	·4071 sq. in.	....	·8011 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	37438	16·713	91951	41·049	·075	
2	44966	20·074	110440	49·303	·100	
3	52166	23·288	128124	57·198	·133	
4	58950	26·316	144786	64·637	·190	
5	66022	29·474	162156	72·391	·225	
6	73134	32·649	179722	80·233	·295	
7	80214	35·809	197023	87·952	·325	
8	88134	39·345	216465	96·636	·375	
9	91840	41·000	225568	100·700	·392	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·392. By formula (13).—The work (u) expended in producing rupture = 44211.

Exp. VIII.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 5+."

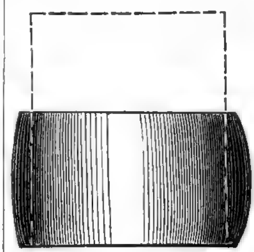
	Before experiment.		After experiment.
Height of specimen	·968 inch.	....	·58 inch.
Diameter of specimen	·72 inch.	....	·996 inch.
Area of specimen	·4071 sq. in.	....	·7791 sq. in.

1	37438	16·713	91951	41·049	·087	
2	44966	20·074	110440	49·303	·100	
3	52166	23·288	128124	57·198	·137	
4	58950	26·316	144786	64·637	·190	
5	66022	29·474	162156	72·391	·233	
6	73134	32·649	179722	80·233	·288	
7	80214	35·809	197023	87·952	·325	
8	88134	39·345	216465	96·636	·375	
9	91840	41·000	225568	100·700	·400	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·4. By formula (13).—The work (u) expended in producing rupture = 45113.

Exp. IX.—Bar of Steel from the Barrow Hæmatite Steel and Iron Company. Mark on bar, "H 6 +."

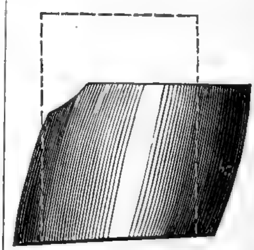
	Before experiment.		After experiment.
Height of specimen......	·985 inch.	....	·586 inch.
Diameter of specimen....	·72 inch.	....	1·012 inch.
Area of specimen	·4071 sq. in.	....	·8042 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	37438	16·713	91951	41·049	·075	
2	44966	20·074	110440	49·303	·100	
3	52166	23·288	128124	57·198	·150	
4	58950	26·316	144786	64·637	·200	
5	66022	29·474	162156	72·391	·260	
6	73134	32·649	179722	80·233	·300	
7	80214	35·809	197023	87·952	·320	
8	88134	39·345	216465	96·636	·383	
9	91840	41·000	225568	100·700	·400	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·4. By formula (13).—The work (u) expended in producing rupture = 45113.

Exp. X. (April 1869).—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "1."

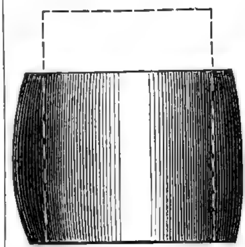
	Before experiment.		After experiment.
Height of specimen......	1·00 inch.	....	·723 inch.
Diameter of specimen	·72 inch.	....	·906 inch.
Area of specimen	·4071 sq. in.	....	·6448 sq. in.

1	44606	19·913	109572	48·916	·030	
2	52158	23·284	128366	57·366	·040	
3	59646	26·627	146514	65·408	·065	
4	68942	30·777	169349	75·602	·130	
5	76110	33·977	186956	83·462	·215	
6	82382	36·777	202363	90·340	·290	
7	85070	37·977	208965	93·288	·300	
8	86862	39·670	213367	95·253	·315	
9	91840	41·000	225568	100·700	·333	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·333. By formula (13).—The work (u) expended in producing rupture = 37557.

Exp. XI.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "2."

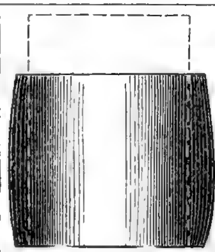
	Before experiment.		After experiment.
Height of specimen..........	1·00 inch.	....	·74 inch.
Diameter of specimen........	·72 inch.	....	·908 inch.
Area of specimen	·4071 sq. in.	....	·6475 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	44606	19·913	109572	48·916	·060	
2	52030	23·227	127806	57·056	·080	
3	59102	26·384	145178	64·811	·110	
4	66662	29·759	163748	73·101	·150	
5	74390	33·209	182731	81·576	·200	
6	81558	36·409	200339	89·437	·240	
7	88726	39·609	217946	97·297	·270	
8	92840	41·000	225568	100·700	·288	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·288. By formula (13).—The work (u) expended in producing rupture = 32481.

Exp. XII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "3."

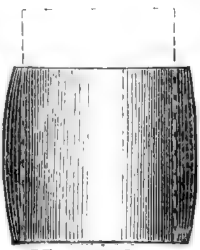
	Before experiment.		After experiment.
Height of specimen..........	1·00 inch.	....	·76 inch.
Diameter of specimen........	·72 inch.	....	·866 inch.
Area of specimen	·4071 sq. in.	....	·5898 sq. in.

1	44606	19·913	109572	48·916	·060	
2	52030	23·227	127806	57·056	·070	
3	59102	26·384	145178	64·811	·090	
4	66662	29·759	163748	73·101	·120	
5	74390	33·209	182731	81·576	·170	
6	81558	36·409	200339	89·437	·200	
7	88726	39·609	217946	97·297	·230	
8	91840	41·000	225568	100·700	·257	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·257. By formula (13).—The work (u) expended in producing rupture = 28985.

Exp. XIII.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "4."

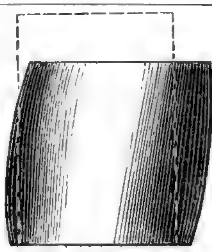
	Before experiment.		After experiment.
Height of specimen..........	1·00 inch.	....	·784 inch.
Diameter of specimen........	·72 inch.	....	·864 inch.
Area of specimen	·4071 sq. in.	....	·5863 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	44606	19·913	109572	48·916	·050	
2	52030	23·227	127806	57·056	·070	
3	59102	26·384	145178	64·811	·080	
4	66662	29·759	163748	73·101	·120	
5	74390	33·209	182731	81·576	·160	
6	81558	36·409	200339	89·437	·190	
7	88726	39·609	217946	97·297	·230	
8	91840	41·000	225568	100·700	·247	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·247. By formula (13).—The work (u) expended in producing rupture = 27857.

Exp. XIV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "5."

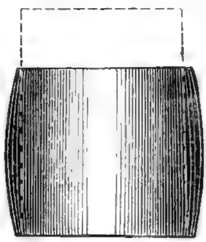
	Before experiment.		After experiment.
Height of specimen..........	1·00 inch.	....	·78 inch.
Diameter of specimen........	·72 inch.	....	·87 inch.
Area of specimen	·4071 sq. in.	....	·5944 sq. in.

1	44606	19·913	109572	48·916	·050	
2	52030	23·227	127806	57·056	·070	
3	59102	26·384	145178	64·811	·090	
4	66662	29·759	163748	73·101	·120	
5	74390	33·209	182731	81·576	·106	
6	81558	36·409	200339	89·437	·200	
7	88726	39·609	217946	97·297	·240	
8	91840	41·000	225568	100·700	·257	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225,568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·257. By formula (13).—The work (u) expended in producing rupture = 28985.

Exp. XV.—Bar of Steel from the Heaton Steel and Iron Company, Langley Mills. Mark on bar, "6."

	Before experiment.		After experiment.
Height of specimen	1·00 inch.	....	·734 inch.
Diameter of specimen	·72 inch.	....	·903 inch.
Area of specimen	·4071 sq. in.	....	·5404 sq. in.

No. of Exp.	Weight laid on specimen.		Weight laid on per square inch of section.		Compression, in inches.	Remarks.
	lbs.	tons.	lbs.	tons.		
1	44606	19·913	109572	48·916	·060	
2	52030	23·227	127806	57·056	·080	
3	59102	26·384	145178	64·811	·110	
4	66662	29·759	163748	73·101	·150	
5	74390	33·209	182731	81·576	·190	
6	81558	36·409	200339	89·437	·230	
7	88726	39·609	217946	97·297	·270	
8	91840	41·000	225568	100·700	288	No cracks.

Results.—Here the strain per square inch (P_1) causing rupture is 225·568 lbs., or 100·7 tons, and the corresponding compression (l_1) per unit of length is ·288. By formula (13).—The work (u) expended in producing rupture = 32481.

Summary of Results of the Experiments on Compression.

No. of Exp.	Manufacturer.	Mark on bar.	Date of Exp.	Greatest weight laid on per square inch of section.		Corresponding compression per unit of length.	Value of u, or work expended in crushing the bar. By eq. (13).	Remarks.
				lbs.	tons.			
1	The Barrow Hæmatite Steel Co.	H 1	June 1867	225568	100·700	·200	22556	No cracks.
2	,, ,, ,,	H 2	,, ,,	225568	100·700	·450	50752	,, ,,
3	,, ,, ,,	H 3	,, ,,	225568	100·700	·450	50752	,, ,,
4	The Barrow Hæmatite Steel Co.	H 1+	Jan. 1868	225568	100·700	·480	54136	No cracks.
5	,, ,, ,,	H 2+	,, ,,	225568	100·700	·525	59211	,, ,,
6	,, ,, ,,	H 3+	,, ,,	225568	100·700	·474	53459	Slight cracks.
7	,, ,, ,,	H 4+	,, ,,	225568	100·700	·392	44211	No cracks.
8	,, ,, ,,	H 5+	,, ,,	225568	100·700	·400	45113	,, ,,
9	,, ,, ,,	H 6+	,, ,,	225568	100·700	·400	45113	,, ,,
10	The Heaton Steel Company ...	1	April 1869	225568	100·700	·333	37557	No cracks.
11	,, ,, ,,	2	,, ,,	225568	100·700	·288	32481	,, ,,
12	,, ,, ,,	3	,, ,,	225568	100·700	·257	28985	,, ,,
13	,, ,, ,,	4	,, ,,	225568	100·700	·247	27857	,, ,,
14	,, ,, ,,	5	,, ,,	225568	100·700	·257	28985	,, ,,
15	,, ,, ,,	6	,, ,,	225568	100·700	·288	32481	,, ,,

Abstract of Experiments on Hæmatite Steel.

The strength of these bars, owing to their flexibility, is inferior to the strength of the other Bessemer steel bars before experimented upon. Taking the average of all these latter bars, the mean value of C, the unit of working strength, is 5·8 tons; whereas this constant for the hæmatite bars is only 4·2 tons, showing that the former are about $\frac{1}{3}$ stronger than the latter. With about $\frac{1}{7}$ more weight laid on the bars their power of restitution was measured by about $\frac{2}{3}$ of the whole deflection, showing that this load was considerably within that requisite to produce rupture. Owing to the high flexibility of the hæmatite bars, their modulus of elasticity is low. It may be here worthy of observation that, for bars of the same length, the modulus of elasticity varies inversely as the coefficient (D_1) of the deflection for unity of pressure and section, that is, $E \propto \frac{1}{D_1}$.

These bars underwent a great elongation by a tensile strain, and a large compression by a compressive strain, the average elongation being, per unit of length, ·0792, and that of compression ·419; whereas these numbers for the other bars, before experimented upon, did not, on an average, exceed ·06 and ·355 respectively, showing the flexibility and superiority of this steel in its powers to resist impact. The average tensile resistance of the bars is about 35 tons per square inch, whereas the resistance for the other Bessemer bars, before experimented upon, was about 42 tons; so that the tensile strength of the latter is $\frac{1}{5}$ greater than that of the former.

The quality of hardness of steel and wrought iron may be comparatively measured by the amount of extension under a given tensile strain, and the amount of compression under a given compressive strain. Applying this test to the results of the experiments on the various steel bars, we find that the hardest bars are the strongest, *irrespective of the companies by whom they were manufactured.* We find, for example, that the elongation per unit of length for eight of the best Bessemer bars did not exceed ·018, and the compression per unit of length did not exceed ·25. These bars had a temper probably exceeding that of spring-steel, and less than that for tools. The hæmatite bars are of a totally different description of steel from that manufactured for springs and tools, and this accounts for their comparatively low powers of resistance.

The experiments first made upon the hæmatite steel are anomalous. The first bar experimented upon showed great powers of resistance, but the last two gave results inferior to those obtained by the last experiments. At the same time the value (D_1) for unity of pressure and section, in the first experiments, is somewhat below the general average of the results of all the other experiments, thereby giving a considerable value to the modulus of elasticity. I suspect that the temper of the first bar was high; but whether the last two bars had a temper too high or too low, I am at a loss to determine. If it is desirable to have full justice done to the hæmatite steel bars as to their powers of resistance, a series of bars of the same degree of hardness as to the first bar mentioned, which gave considerably more than average powers of resistance, should be made, in order to compare with the harder descriptions of steel, as exhibited by other makers—numbers of which have, no doubt, been melted in the crucible, and selected for the purposes of experiment.

Abstract of the Experiments on the Heaton Steel.

This steel being the product of a totally different process of manufacture from that of all the other steel bars previously experimented upon, and as those bars were derived from the best known processes and received from the best of makers, it is a matter of the greater moment to ascertain how it stands in relation to them as regards strength and those other properties which are peculiar to steel. It is for this object that an abstract separate from that of the Barrow steel manufacture has been drawn up.

These bars, in their resistance to a transverse strain, show a very decided superiority over the steel bars which I experimented upon before, and on which I reported to the British Association of 1867. For instance, the mean value of C, the unit of working strength for these bars, is 7·494 tons, whereas this value for the other bars was only 5·746 tons, showing that these bars are ·3 stronger. The value of u, or the work of deflection for unity of section, for these bars is 90·970, whereas for the other steel bars it is only 51·696. This value of u exhibits the powers of the several bars to resist a force analogous to that of impact. It is therefore clearly shown that this steel must be peculiarly well adapted to resist the force of sudden shocks, considering that it is $\frac{3}{4}$ superior in this quality to any other of the steel bars before experimented upon.

The flexibility of this steel is slightly inferior to that of other steel; the measure of flexibility (D_1) being for these bars ·001345, and for the other bars ·001361. The modulus of elasticity is somewhat low for steel, although at the same time it is very little below the general average of those from my former experiments.

This steel, I consider, well adapted to withstand severe transverse strains, for it combines the two essential qualities of great strength and superior powers in its resistance to the force of impact.

The mean breaking tensile strain, per square inch of section, of this steel is 45·28 tons; whereas this value for the other steel bars, before experimented upon, is 41·77 tons. The Heaton bars are, therefore, ·08 stronger in their resistance to the force of tension than the average result obtained from the steel bars previously experimented upon. This result, whilst placing the Heaton steel in a highly satisfactory position when compared with the mean of the whole of the steel experimented upon, places it at the same time below that produced by some individual manufacturers. The elongation of these bars was considerable, and a good deal above the mean for the other bars, thereby giving a large value for the work done in breaking the bar.

These bars show high powers of resistance to a compressive strain, all the specimens having undergone the test of 100 tons on the square inch without any visible external signs of fracture.

It would be very difficult to compare the different bars in their resistance to compression, for nearly all the specimens underwent a strain of above 100 tons on the square inch without exhibiting the slightest trace of a crack. As the lever by which the specimens were crushed was not competent to produce a greater strain, it was impossible to find out the crushing weight; besides, even then, supposing it possible to produce the requisite strain, it would be a task of extreme difficulty to find out at what precise weight the column began to give way. Under these circumstances, it can only be left to the judgment of the person wishing to select steel to resist a compressive force to choose that which he thinks best adapted to his purpose, the choice being regulated by the ductility of the metal as exhibited by the amount of compression. In looking through the experiments, however, one thing is clear, that the hardest steels sustained very little compression, whilst the softer ones, in the majority of cases, were reduced to almost half their original height.

From this abstract it will be seen that this steel, manufactured by Mr. Heaton, stands in the most favourable light in comparison with steel produced by other manufacturers; and if it be taken into consideration that two-thirds of the iron from which this steel was converted, was composed of Northamptonshire pig-iron, we may reasonably look forward to this invention creating a considerable improvement in the production and cost of steel.

Comparison of Wrought Iron with Steel.

Having lately had occasion to experiment on some wrought-iron bars, of the best quality, used in the manufacture of armour-plates, by Messrs. J. Brown and Co., I avail myself of this opportunity of comparing the results obtained from this iron with those obtained from the steel bars. The wrought-iron bars were tested in exactly the same manner as the steel ones, and were successively subjected to transverse, tensile, and compressive strains; the results obtained from which will be found in the following abstract, where they are compared in their several strains to the steel bars.

The average value of C, the unit of working strength for wrought iron, is about 2·25 tons, whereas the value of this constant taken for fifteen of the best steel bars is 7·4 tons, so that the strength of the latter is $3\frac{3}{10}$ times that of the former. The average value, however, of C for the whole of the steel bars experimented upon is 5·921, showing that the average strength of steel in resisting a transverse strain is more than $2\frac{1}{2}$ times that of wrought iron. The mean transverse resistance per square inch for the wrought-iron bars, at the elastic limit, is equal to 6 C, or $6 \times 2\frac{1}{4}$, or $13\frac{1}{2}$ tons, which is somewhat greater than the resistance usually assigned to wrought-iron bars. The average value of D_1, for unity of pressure and section, for the wrought-iron bars is ·00167, whereas the value of this constant for the steel bars is about ·0013, showing that wrought-iron bars have a much greater flexibility than steel bars, and, as a necessary consequence, they have a much lower modulus of elasticity. Under a transverse strain the work of deflection up to the limit of elasticity is exceedingly low for wrought-iron bars; but the work expended in elongation up to the point of rupture is greater than the average of that determined for the steel bars: this is owing to the *extensibility* of the wrought iron; for whilst the unit of elongation for the average of the steel bars is not quite ·05, that of wrought iron is ·14, or about three times greater. The same observation applies to the work of compression. The average compression per unit of length is ·45, whereas for the steel bars it is only about ·3 of an inch.

The average breaking tensile strain, per square inch of section, of the wrought-iron bars is $25\frac{1}{4}$ tons, while this average for the steel bars is $42\frac{1}{2}$ tons, showing that the latter are $\frac{3}{4}$ stronger than the former. With a strain of $22\frac{1}{2}$ tons per square inch the wrought-iron bars had not entirely lost their powers of restitution, or the power of regaining, to some extent, the preceding set.

Although the short columns underwent a large compression under the action of a compressive force, yet the pressure corresponding to the first visible indication of rupture is considerable, being, on an average, about seventy tons per square inch, which is about two-thirds of that of hard steel columns. With comparatively soft material, like that of wrought iron, it is difficult to determine the exact point at which the material in such columns is fractured, so that the fullest reliance cannot be placed on the results of such experiments.

I have appended a general summary of all my experiments on steel, in order that comparisons may be readily made without the inconvenience of referring to the preceding Report. It may be stated that the experiments have given good results, and prove that steel can be produced of double the strength of wrought iron; and, at the same time, the homogeneity of its structure can be depended upon. If the cost of steel be reduced and approximates closer to that of iron, we may soon look forward for the substitution of this important metal in the place of iron.

GENERAL SUMMARY OF RESULTS.

TRANSVERSE STRAIN.

Manufacturer.	Mean value (D_I) of the deflection for unity of pressure and section.	Mean value of the modulus of elasticity (E).	Modulus of elasticity (E) corresponding to 112 lbs. pressure.	Work of deflection (U) up to the limit of elasticity.	Work of deflection (*u*) for unity of section.	Value of C, the unit of working strength.	Remarks.
						tons.	
Messrs. Naylor, Vickers, & Company...	·0013007	30,278,000	29,481,000	66·660	65·049	6·548	Mean breaking-weight 1250 tons.
Messrs. S. Osborn & Company	·0014296	27,482,000	27,540,000	54·150	52·574	5·622	,, ,, 1253 ,,
Messrs. C. Sanderson Brothers	·0013209	29,973,000	29,355,000	50·920	47·411	5·521	,, ,, 1200 ,,
Messrs. T. Turton & Sons	·0013120	30,294,000	30,750,000	54·456	52·680	5·886	,, ,, 1000 ,,
Messrs. J. Brown & Company	·0012739	30,370,000	31,551,000	51·038	52·721	5·918	,, ,, 950 ,,
Messrs. C. Cammell & Company	·0013518	29,166,000	30,690,000	65·059	59·897	5·921	,, ,, 975 ,,
Messrs. H. Bessemer & Company	·0016684	29,810,000	28,673,000	48·404	49·489	5·659	
The Titanic Steel & Iron Company ...	·0012350	31,901,000	33,088,000	64·168	63·542	6·435	
The Hæmatite Steel & Iron Company	·0013800	28,754,000	30,772,000	32·928	31·907	4·208	
The Heaton Steel & Iron Company ...	·0013450	28,603,000	29,285,000	95·080	90·970	7·494	
Mean	·0013611	29,663,000	30,118,000	58·286	56·624	5·921	

TENSILE STRAIN.

Manufacturer.	Specific gravity.	Weight laid on, producing rupture.	Breaking-strain per square inch of section.		Elongation per unit of length.	Value of u, or work producing rupture.
		lbs.	lbs.	tons.		
Messrs. Naylor, Vickers, & Company	7·8198	39449	108099	48·25	·0372	1827
Messrs. S. Osborn & Company	7·7758	44131	103214	46·07	·0341	1842
Messrs. C. Sanderson Brothers	7·7563	39592	95553	42·65	·0229	1566
Messrs. T. Turton & Sons	7·7990	39295	93380	41·61	·0165	807
Messrs. J. Brown & Company	7·7665	33603	90379	40·35	·0460	2002
Messrs. C. Cammell & Company	7·8119	34085	101132	45·14	·0595	2714
Messrs. H. Bessemer & Company	7·7726	38189	89955	40·16	·0753	3212
The Titanic Steel & Iron Company	7·7883	37179	93616	41·79	·0551	2413
The Hæmatite Steel & Iron Company	7·7744	33527	76550	34·17	·0792	2949
The Heaton Steel & Iron Company	7·8142	44943	101513	45·28	·0663	3414
Mean	7·7878	38399	95339	42·54	·0492	2274

COMPRESSION.

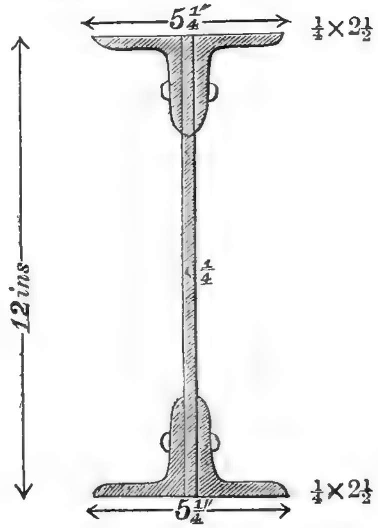
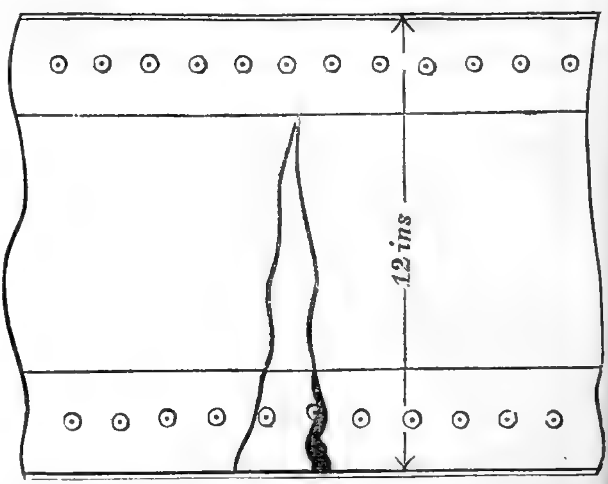
Manufacturer.	Weight laid on.	Greatest weight laid on per square inch of section.		Compression, per unit of length.	Value of u, or work expended in crushing the bar.
	lbs.	lbs.	tons.		
Messrs. Naylor, Vickers, & Company	91840	225568	100·700	·286	32300
Messrs. S. Osborn & Company	91840	225568	100·700	·267	30014
Messrs. C. Sanderson Brothers	91840	225568	100·700	·328	36906
Messrs. T. Turton & Sons	91840	225568	100·700	·398	44888
Messrs. J. Brown & Company	91840	225568	100·700	·347	39136
Messrs. C. Cammell & Company	91840	225568	100·700	·339	38233
Messrs. H. Bessemer & Company	91840	225568	100·700	·379	42720
The Titanic Steel & Iron Company	91840	225568	100·700	·315	35551
The Hæmatite Steel & Iron Company	91840	225568	100·700	·419	45813
The Heaton Steel & Iron Company	91840	225568	100·700	·278	31391
Mean	91840	225568	100·700	·335	37695

Appendix I.

In addition to the foregoing experiments, it was considered desirable to have a steel beam made of the usual form, in order to ascertain the comparative merits of steel and wrought-iron girders. For this purpose two beams were constructed, of that quality of steel best suited to ensure durability and safety. A much harder description of steel (40 tons to the square inch) might have been chosen; but that was not wanted, for the object sought was ductility and moderate strength in its powers to resist impact. The following experiments will show the results.

Experiment on a Steel Girder from the Barrow Hæmatite Steel Company.

Length between the supports 13·9 feet. Sectional area 2·31 inches.

No. of Expt.	Weight laid on girder.		Deflection, in inches.	Remarks.
	lbs.	tons.		
1	866	0·386	....	Weight of slings &c.
2	3106	1·386	·056	
3	5346	2·386	·108	
4	7586	3·386	·147	
5	9826	4·386	·184	
6	12068	5·386	·201	
7	14308	6·386	·260	
8	16550	7·386	·304	
9	18790	8·386	·322	
10	21020	9·386	·339	
11	23260	10·386	·372	
12	26880	12·000	·423	
13	29120	13·000	·480	
14	33600	15·000	·545	
15	35840	16·000	·626	
16	36060	16·098	·802	
17	38080	17·000	·965	
18	39200	17·500	1·430	
19	40320	18·000	1·872	
20	40544	18·100	....	Broke by tension through the angle-iron of the bottom flange, as above.

A wrought-iron girder of the same dimensions would break with 11·8 tons. The comparison, therefore, stands as 18·1: 11·8, being in the ratio of 1 : ·652. The resistance of this description of steel to a transverse strain is therefore more than one and a half times greater than that of wrought iron.

Experiment on a Steel Girder from the Barrow Hæmatite Steel Company (April 1868).

Length between supports 13·9 feet. Sectional area 2·31 inches.

No. of Exp.	Weight laid on girder.		Deflection, in inches.	Remarks.
	lbs.	tons.		
1	12152	5·425	·196	This weight remained on 120 hours.
2	18872	8·425	·330	
3	24192	10·800	·442	
4	29512	13·175	·524	This last weight having remained upon the beam a short time, it suddenly gave way by lateral flexure, and one of the angle-irons being broken, the experiment was discontinued.

There is great difficulty in testing beams of this description, arising from the narrow top and bottom flanges, which, to prevent injury from lateral flexure, should be loaded and broken through the sides of a rigid frame. In this case the beam was identical in every respect with the previous one, and would have carried the same weight but for the lateral injuries it received in the early stages of the experiment. Taking, however, the strength of steel beams and the amount of deflection when submitted to a transverse strain, it will be found that they are not only one-third stronger than those of the best wrought iron, but they are much superior in their powers to resist impact, and therefore more secure under the influence of a rolling load or severe vibratory action often repeated.

Taking into account the peculiar properties of this material, its superior strength, the saving of one-third in weight, and other conditions of security, it is (under the conditions of perfect uniformity of character in the manufacture) admirably adapted for rolled joists and girders, as also for bridges, where high powers of strength and elasticity are required to resist the united forces of load and impact.

Appendix II.

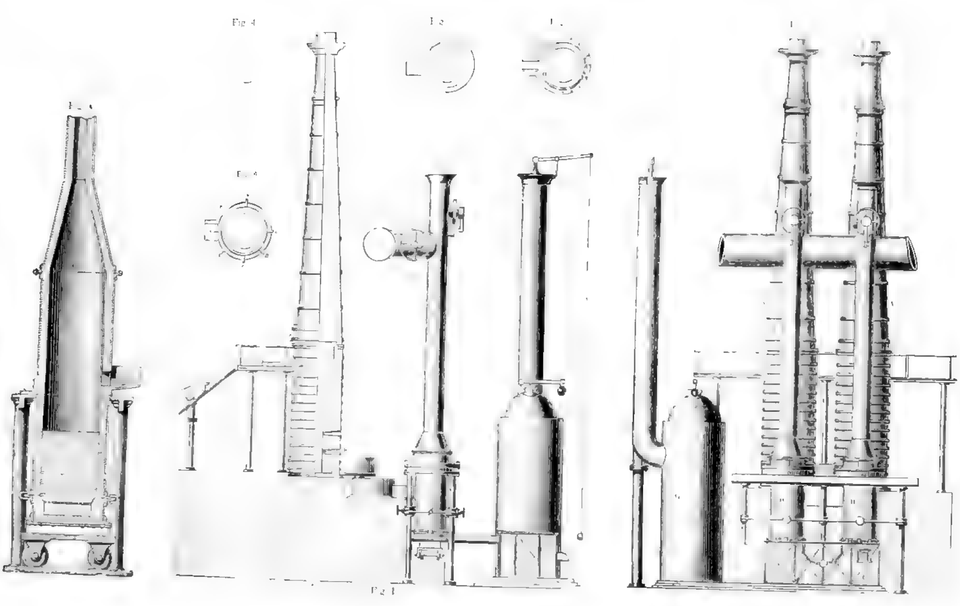
The 'Practical Mechanics' Journal' gives the following description of the furnace and apparatus for the manufacture of steel on the Heaton system. See Plate II. :—

The Heaton converter (fig. A) is nearly a cylindrical cupola, lined with 4½-inch fire-brick, the shell of boiler plate, and surmounted by a plate-iron conical cap and narrower cylindrical flue of a few feet in height. The cupola may be supposed cut in two horizontally at about one diameter and a half in height, and the bottom part rendered moveable and capable of being withdrawn on wheels, without disturbance to the supports &c. of the remaining upper portion of the converter. Ready means of temporary attachment by clamps and cotters are provided to connect the two parts, which thus so far present a close resemblance to the *Calebasse* cupola still in use in Belgium. At one side of the cylindric fixed part of the converter, a sort of hopper, with a loosely hinged iron-plate cover, is provided, which communicates with the cavity within.

"The lower part, or "converting-pot," has a cylindrical cavity with a flat bottom, and with the sides near the top edge sloping inwards to a cone all round. The cavity, up to the level of the lower edge of this cone, is prepared to just hold the bulk of crude nitrate of soda required for the volume of liquid iron to be operated on, and for the latter when converted; the proportion of nitrate, as at present employed by the patentee, being 2 cwts. to the ton of liquid iron, or 10 per cent.—a proportion, we may remark, which both the metallurgists who have been engaged in examining this process by the present owners of the patents are of opinion is a good deal in excess of what is needed, when the conditions for the most favourable reaction shall be more completely and more scientifically understood. The "converting-pot" is lined with fire-brick and refractory clay. When the crude nitrate is filled in and levelled up to, or a trifle beyond, the narrow part of the conical lining, the cast-iron perforated plate is simply laid upon its level surface, and worked round a little until its edges bed firmly into and upon the clay lining. In this state the converting-pot is rolled in under the upper part of the converter, clamped up to it, and the whole is now ready for work.

"The charge of crude cast iron is melted with coke in an ordinary cupola; at present it is tapped out into a crane-ladle. This is swung round by the crane, and the contents at once emptied into the opened hopper of the converter. The molten iron falls upon the cold cast-iron plate; its lowermost stratum is for the moment chilled and nearly consolidated by the heat withdrawn by contact, and for some minutes there is no perceptible action. In this state a vertical section of the charged and filled converter is represented by fig. 1. Soon, however, the lower stratum recovers its liquidity, and begins to penetrate below the now more than red-hot and softened perforated cast-iron plate, and reaction commences, evidenced by the appearance of white and grey vapours at the top of the converter-funnel. The nitrate has no doubt by this time got much impacted and partly fused at its upper strata. The reaction producing a large accession of heat at the plane of contact of the molten iron and of nitrate, the plate melts and disappears. A burst of brilliant yellow flame at the top of the converter-funnel indicates that the reaction is then at its height. This lasts steadily for some few minutes (three to five usually, with 12 or 15 cwt. charges), and then rapidly subsides. The conversion is now complete. The bottom of the converter, or "converting-pot," is now detached and rolled away, and the converter is ready for another bottom and another charge.

"When we examine the converting-pot withdrawn, we find its surface covered to the depth of an inch or two with a dark "blabby slag," through which brilliant jets of yellow sodium-coloured flame from escaping gases are constantly spurting. This slag consists chiefly of the soda of the nitrate, combined with silica and clayey matters derived from the lining of the converter, and involving some "shots" of metallic iron or steel, and some little silicate of iron, &c. Beneath this is the converted metal, which the patentee calls "crude steel." It forms a white-hot, *boursouflée*, and tolerably liquid



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mass, not sufficiently fluid upon the small scale of the 12-cwt. converters to be readily run or *tapped* out of the converting-pot, but quite readily capable of that with a larger converter, and therefore larger mass of material.

"The converter is upset upon the iron-plated floor, some water is aspersed to bring the mass to its frangible state at a dull red heat, and it is then broken up into lumps of convenient size, to be brought, after receiving a little renewal of heat, under the "shingling hammers," and patted into "cakes of crude steel," as denominated by the patentee. It is purely a matter of "metallurgical taste" whether these are to be called crude steel or crude iron. The material is in reality a form of steely malleable iron, or mild malleable steel, whichever we choose to call it. It will not harden in water as perfectly as complete steel; it always (probably where the process is rightly conducted) contains more combined carbon than usually belongs to wrought iron. It is, however, metal of the purest and finest quality, and from which, by two different methods of treatment, either very strong, but soft, tough, and malleable, wrought iron may be made, or fine cast steel.

"In the first instance the "cakes of crude steel" are piled, heated in a common balling-furnace, and at once rolled out into "steel-iron" bars, plates, or rails, &c.; and so fine is the material that but little difference is produced, except that of increased fibre, by cutting up, piling, and balling these bars and rolling a second time.

"Then, for the cast-steel manufacture, these "cakes of crude steel" are broken or cut up, melted in 60- or 80-lb. crucibles, with about 2 or 3 lb. per 100 lbs. of spiegeleisen, or its equivalent of oxide of manganese, and some charcoal, poured out into ingots of iron, *i. e.* into the usual *ingot moulds of iron.* These ingots of cast steel are then titled into bars, and are then fit for the market, or for any use to which excellent steel is suitable.

"This is the whole process through its bifurcate train, up to wrought iron as good and stronger than Low Moor or Bowling on the one side, and to cast steel as good as any other process can produce upon the other.

"Our illustrations (figs. 1 to 6) represent the plant, as the patentee, Mr. Heaton, at present advises its construction, and as proposed for the steel plant at the Langley Mill Steel and Iron Works, to a scale of one-eighth of an inch to a foot.

"Fig. 1 is a side view of the apparatus, showing also a vertical section of one-half of the cupola. Fig. 2 is a front view; and the same letters refer to the same parts in both views. Figs. 3, 4, 5, & 6 show different parts of the apparatus in plan. A, A are cupola furnaces in which the metal is melted; F, F in fig. 1 are the tuyeres; G the hole through which the cupola is charged with metal and coke from a platform with an inclined tramway leading to it. B, B are the converters into which the metal is run direct from the cupolas, and from which the melted crude steel is run into the reverberatory furnace, C. D is a steam-boiler, heated with the waste heat from the reverberatory furnace. Fig. 3 is a horizontal section of the moveable bottom of a converter, showing the fire-brick lining, *a*, *a*, *a*. When charged, the converter-pot is filled with nitrate of soda. Fig. 4 shows a perforated metal plate, which is placed upon the nitrate of soda. Fig. 5 is a horizontal section of a converter, showing the perforated plate in position. Fig. 6 is a sectional plan of a converter, showing the cramps (*c*, *c*, &c.) for holding the converter-pot up to the cylinder of the converter whilst the converting process is going on; these cramps are shown also in figs. 1 and 2.

"As given by the patentee, and we have no doubt correctly, the cost per ton of converting crude pig-iron into "crude steel," exclusive of the cost of the pig, but allowing for the waste upon it at the ratio of 60 lbs. per ton, is £2 4*s.* per ton, or £2 15*s.* in crude steel cakes; the cost of making it into "steel-iron" bars, *from the pig-iron*, is £3 10*s.* per ton for finished bars, and the cost of making tilted cast-steel bars, from the pig-iron, is £12 15*s.* per ton. We have seen the invoices of cast-steel bars of this sort, sold from Langley Mills, at prices equal to those now current at Sheffield for well reputed cast steel made by the process of cementation."

Second Report on the British Fossil Corals.
By Dr. P. Martin Duncan, *F.R.S., F. & Sec. Geol. Soc.*

This Report comprehends the description of the Coral-fauna of the periods when the strata of the Gault, Lower Greensand, Portland Oolite, Coral Rag, Great Oolite, and Inferior Oolite were deposited. It contains a general view of the physico-geographical conditions of the British area during the Tertiary and Secondary periods so far as relates to coral growth, and also an enumeration and a list of the species.

The result of the labour entailed by the study of the Tertiary and Secondary British Fossil corals has been to add 146 species and many varieties to the 111 or 112 previously known.

Since the last Report was read, the fossil Corals of the Upper and Lower Red Chalk and of the Upper Greensand have been published in my monograph for the Palæontographical Society.

Much progress has been made in the Report on the Palæozoic Corals, but the Report itself cannot be completed for some time.

Corals from the Gault.

Only six well-marked species of corals were known to MM. Milne-Edwards and Jules Haime as having been found in the Gault. They were all simple or solitary forms, and such as one would expect to find in moderately deep water. It is evident that the area occupied by the English Gault was not the coral tract of the period. The resemblance of the coral-faunas of the Gault and the London Clay is somewhat remarkable, and probably the physical conditions of the areas during the deposition of the strata were not very dissimilar.

MADREPORARIA APOROSA.

Family TURBINOLIDÆ.

Subfamily Caryophyllinæ.

Division Caryophylliaceæ.

Genus Caryophyllia.

MM. Milne-Edwards and Jules Haime have changed the generic term *Cyathina* into that of its predecessor *Caryophyllia*; consequently *Cyathina Bowerbanki*, Ed. & H., is now called *Caryophyllia Bowerbanki*, Ed. & H. (Hist. Nat. des Corall. vol. ii. p. 18).

A very interesting variety of this species is in the Rev. T. Wiltshire's Collection, and has its costæ running obliquely to the long axis of the corallum. They are profusely granulated.

Division Trochocyathaceæ.

Genus Trochocyathus.

1. *Trochocyathus Harveyanus*, Ed. & H.

This species was described by MM. Milne-Edwards and Jules Haime in their 'Monograph of the British Fossil Corals,' part 1. p. 65. They associated it with two species, which are, as they suggest, undistinguishable, viz. *Trochocyathus Konigi* and *Trochocyathus Warburtoni*. The first of these species is the *Turbinolia Konigi* of Mantell.

An examination of a series of specimens attributed to *Trochocyathus Harveyanus*, Ed. & H., and the consideration of the value of the *Trochocyathi* just mentioned, have led me to recognize five forms of *Trochocyathi breves*, all closely allied and well represented by the original type of *Trochocyathus Harveyanus*, Ed. & H. When placed in a series with this *Trochocyathus* at the head, there is a gradation of structure which prevents a strictly specific distinction being made between the consecutive forms; but when the first and the last forms are compared alone, no one would hesitate to assert that there is a specific distinction between them. All the forms are simple, short, and almost hemispherical; all have four cycles of septa and the same proportion of pali. These are the primary and most essential peculiarities of the genus.

The costæ differ in their size, prominence, ornamentation, and relation to the septa in some of the forms; and the exsert nature of the septa, their granulation, and the size of the corallum also differ. The structural differences are seen in many examples, and are therefore more or less persistent; nevertheless it is found that whilst several specimens have the septa springing from intercostal spaces instead of from the ends of the costæ, one or more, having all the other common structural peculiarities, present septa arising from the costal ends. This method of origin can hardly constitute a specific distinction. I propose to retain *Trochocyathus Harveyanus* as the type of a series of forms, the sum of whose variations in structure constitutes the species.

Variety 1. The corallum is nearly double the size of the type; its septa are rather exsert, and are very granular. The costæ are very prominent, ridged, marked with numerous small pits, and are continuous with the septa. The epitheca is waved and well developed. The spaces between the larger costæ are more or less angular. The peduncle is large.

Locality. Gault, Folkestone. In the British Museum.

Variety 2. The corallum is as large as that of *variety* 1, but it is more conical. The costæ are less pronounced, and the septa, which are more granular than those of *variety* 1, arise from the intercostal spaces. The costal ends are very elegant in shape, and form a margin of rather sharp curves.

Locality. Gault, Folkestone. In the British Museum.

Variety 3. The corallum is rather flat, but hemispherical. The septa are not exsert, and they arise from the costal ends. The costæ are equal: none are more prominent than others. They are all rather broad, flat, and beautifully ornamented with diverging curved lines. Their free ends are equal and curved.

Locality. Gault, Folkestone. In the collection of the Rev. T. Wiltshire, F.G.S.

Variety 4. The corallum and costæ are like *variety* 3, but the septa arise from the intercostal spaces.

Locality. Gault, Folkestone.

In the collection of the Rev. T. Wiltshire, F.G.S.

Variety 5. The corallum is rather more conical inferiorly than in *varieties* 3 and 4. The septa are exsert, and project slightly beyond the costal margin. The costæ are all rudimentary. The epitheca is well developed, and reaches up to the septa.

Locality. Gault, Folkestone.

The forms may be distinguished as follows:—

With more or less ridged costæ	The type. Variety 1. " 2.
With nearly equal flat costæ	Variety 3. " 4.
Costæ rudimentary	" 5.
Septa arising from the costal ends	The type. Variety 1. " 3.
Septa arising from the intercostal spaces	Variety 2. " 4.

All the forms have four cycles of septa and pali before the first, second, and third orders.

2. *Trochocyathus Wiltshiri*, Duncan.

The corallum is straight, conical, and either cylindrical above or compressed; its base presents the trace of a peduncle for attachment. The epitheca is scanty and in transverse masses. The costæ are distinct and subequal. The calice is very open and rather deep. The septa are unequal, hardly exsert, and broad at the margin of the calice. There are four cycles of septa, and six systems. The pali are large, and are placed before all the cycles except the last. The columella is rudimentary.

Height $\frac{3}{10}$ inch. Breadth of calice $\frac{3}{10}$ inch.

Locality. Gault, Folkestone. In the zone of *Ammonites dentatus*.

In the Royal School of Mines, and in the collection of the Rev. T. Wiltshire, F.G.S.

This species is closely allied to *Trochocyathus conulus*, Phillips, sp. The compressed calice, the rudimentary columella, and the shape of the corallum distinguish the new species from *Trochocyathus conulus*.

Genus Leptocyathus.

Leptocyathus gracilis, Duncan.

The corallum is small, flat, and circular in outline. The costæ are very prominent, and join exsert septa; the primary and secondary costæ are very distinct, and the others less so. All the costæ unite centrally at the base; many are slightly curved. The septa are thick externally, very unequal, thin internally, and the largest are more exsert than the others. There are six systems and four cycles of septa. The pali are small and exist before all the septa. The columella is very rudimentary. The calicular fossa is rather wide and shallow.

Height hardly $\frac{1}{10}$ inch. Breadth $\frac{3}{10}$ inch.

Locality. Gault, Folkestone.

In the British Museum.

This species is very closely allied to *Leptocyathus elegans*, Ed. & H., of the London Clay. *Leptocyathus elegans* has not a flat base, and it has very granular septa. Moreover, its costæ are large and small in sets. Nevertheless the alliance is of the closest kind.

Genus Bathycyathus.

MM. Milne-Edwards and Jules Haime described a species of this genus in their 'Monograph of the British Fossil Corals,' pt. 1. pp. 67, 68. Two specimens in the collection of the Rev. T. Wiltshire present all the appearances recognized by those distinguished authors. The costæ are very granular, and not in a simple row. In one specimen the breadth of the base is very great.

Subfamily Turbinolinæ.

Division Turbinoliaceæ.

Genus Smilotrochus.

Some species of this genus were described amongst the corals from the Upper Greensand, and one was noticed as belonging to this geological horizon which should have been included in the Lower Greensand forms.

The Upper Greensand *Smilotrochi* are:—

Smilotrochus tuberosus, *Ed. & H.*
—— elongatus, *Duncan.*
Smilotrochus angulatus, *Duncan.*

There are four species of the genus found in the Gault, which are all closely allied; one of them cannot be distinguished from *Smilotrochus elongatus* of the Upper Greensand.

The specimens of this species found in the Upper Greensand are invariably worn and rolled, and are generally in the form of casts; but in the Gault the structural details are well preserved, and even the lateral spines on the septa are distinct.

The Gault forms are shorter and more cylindro-conical and curved than those from the Upper Greensand.

The species of the genus *Smilotrochus* from the Gault are as follows:—

1. Smilotrochus elongatus, *Duncan.*
2. —— cylindricus, *Duncan.*
3. Smilotrochus granulatus, *Duncan.*
4. —— insignis, *Duncan.*

1. *Smilotrochus elongatus*, Duncan.

This species was described in the first Report.

Locality. Folkestone.

In the collection of the Royal School of Mines.

The lateral spines of the septa are very well marked, and the costæ are equal in size in this species. Its septal number varies, on account of the very late perfection of the fourth cycle of septa.

2. *Smilotrochus cylindricus*, Duncan.

The corallum is small, cylindrical, nearly straight, and has a truncated base. The costæ are equal, very distinct above, and rudimentary below and in the middle; they are marked with a few large granules in one series. The septa are subequal, very exsert, thin, close, and marked with large granules, few in number. The septa are in six systems, and there are three cycles.

Height $\frac{3}{10}$ inch. Greatest breadth rather less than $\frac{2}{10}$ inch.

Locality. Gault, Folkestone.

In the collection of the Rev. T. Wiltshire, F.G.S.

3. *Smilotrochus granulatus*, Duncan.

The corallum is conico-cylindrical in shape, and has a more or less truncated base. The costæ are subequal, prominent, very granular, and distinct superiorly. The septa are subequal, thick, and very granular. The septa are in six systems, and there are three cycles.

Height $\frac{9}{10}$ inch. Breadth $\frac{3}{20}$ inch.

Locality. Gault, Folkestone.

In the collection of the Rev. T. Wiltshire, F.G.S.

4. *Smilotrochus insignis*, Duncan.

The corallum is trochoid, short, has a wide calice and a conical and rounded base; the calice is circular in outline, the fossa is deep and small, and the septa are wide, exsert, curved above, and so marked with one row of granules that their free margin appears to be spined. There are three cycles of septa, and the orders are nearly equal as regards size. The costæ are large, prominent, broad at their base, and are marked with one row of granules on the free surface.

Height $\frac{2}{10}$ inch. Breadth of calice $\frac{2}{10}$ inch.

Locality. Gault, Folkestone.

In the collection of the Rev. T. Wiltshire, F.G.S.

An analysis of the genus will be found after the description of the species from the Lower Greensand.

There is a compound or aggregate Madreporarian found in the Gault of Folkestone. It has much endotheca, and resembles worn specimens of the well-known *Holocystis elegans* of the Lower Greensand. The specimens are not sufficiently well preserved for identification with any genus.

Family FUNGIDÆ.

Subfamily Funginæ.

Genus Micrabacia.

Micrabacia Fittoni, Duncan.

The corallum is nearly hemispherical in shape; its base is flat and extends beyond the origin of the septa in a sharp and uninverted margin. The breadth of the base exceeds the height of the corallum. The costæ are flat, straight, convex externally at the calicular margin, and equal. The septa are unequal, much smaller than the costæ. There are four cycles of septa, in six systems; the synapticulæ between the septa are large.

Height $\frac{2}{10}$ in. Breadth nearly $\frac{1}{2}$ inch.

Locality. Gault, Folkestone.

In the collection of the Rev. T. Wiltshire, F.G.S.

The flat base, the flat costæ, and the limitation of the septal number to four cycles distinguish this species from *Micrabacia coronula** of the Upper Greensand, and from *Micrabacia Beaumontii*†, Ed. & H., of the Neocomian.

List of new Species from the Gault.

Variety of Caryophyllia Bowerbanki, *Ed. & H.*
Five varieties of Trochocyathus Harveyanus, *Ed. & H.*
Trochocyathus Wiltshiri, *Duncan.*
Leptocyathus gracilis, *Duncan.*
Smilotrochus elongatus, *Duncan.*
—— granulatus, *Duncan.*
—— insignis, *Duncan.*
—— cylindricus, *Duncan.*
Micrabacia Fittoni, *Duncan.*

* Hist. Nat. des Coral. vol. iii. p. 30.

† Ibid. p. 30.

List of species from the Gault *.

1. Caryophyllia Bowerbanki, *Ed. & H.*, and one variety.
2. Trochocyathus conulus, *Phillips*, sp.
3. —— Wiltshiri, *Duncan.*
4. —— Harveyanus, *Ed. & H.*, and five varieties.
5. Bathycyathus Sowerbyi, *Ed. & H.*
6. Leptocyathus gracilis, *Duncan.*
7. Cyclocyathus Fittoni, *Ed. & H.*
8. Smilotrochus elongatus, *Duncan* †.
9. —— granulatus, *Duncan.*
10. —— cylindricus, *Duncan.*
11. —— insignis, *Duncan.*
12. Trochosmilia sulcata, *Ed. & H.*
13. Micrabacia Fittoni, *Duncan.*

Corals from the Lower Greensand.

One species of Coral was described by MM. Milne-Edwards and Jules Haime from the Lower Greensand, in their 'Monograph of the British Fossil Corals.'

Fitton had noticed a compound coral in the Lower Greensand, and named it *Astræa* in his "Essay on the Strata below the Chalk," Geol. Trans. 2nd series, vol. iv. p. 352 (1843). In 1847 he called the species *Astræa elegans*; and Lonsdale separated it from the *Astræidæ* under the name *Cyathophora elegans* in 1849 (Proceed. Geol. Soc. vol. v. pt. 1, p. 83, tab. iv. figs. 12, 15: 1849).

MM. Milne-Edwards and Jules Haime recognized the quadrate arrangement of the septa of this species, and classified it amongst the *Rugosa*, in the family *Stauridæ*. Their *Holocystis elegans*, Fitton, sp., is a very good species, and specimens are found varying in the size of the corallum and of the calices.

Since the publication of their 'Monograph on the British Corals,' MM. Milne-Edwards and Jules Haime have named a species from Farringdon *Smilotrochus Austeni* (Hist. Nat. des Corall. vol. ii. p. 71). I have noticed it inadvertently in my description of the Upper Greensand Corals. In order to complete this part it is introduced here again.

Family TURBINOLIDÆ.

Division Turbinoliaceæ.

Genus Smilotrochus.

Smilotrochus Austeni, Ed. & H.

The corallum is regularly cuneiform, very much compressed below, and slightly elongate. The calice is elliptical; the summit of the larger axis is rounded. Forty-eight costæ, subequal, straight, fine and granular.

Height of the corallum about $\frac{1}{3}$ inch.

Locality. Farringdon.

MM. Milne-Edwards and Jules Haime do not mention where the specimen is deposited.

The genus *Smilotrochus* has become of some importance in the palæonto-

* The following authors have written upon the fossil Corals of the Gault:—MM. Milne-Edwards and Jules Haime, 'Monograph of the British Fossil Corals' (Pal. Soc); 'Hist. Nat. des Coralliaires.' Phillips, 'Illust. of Geol. of Yorkshire.' Mantell, 'Geol. of Sussex.' Lonsdale in Fleming's, 'British Animals.'

The authors who have written upon the Corals of the Lower Greensand are:—MM. Milne-Edwards and Jules Haime, *op. cit.* Fitton, 'Quart. Journ. Geol. Soc.' vol. iii. p. 296 (1847). Lonsdale, 'Proc. Geol. Soc.' vol. v. pt. 1. p. 83. M. de Fromentel has paid especial attention to the French Neocomian corals, and C. J. Meyer, Esq., has enabled me to study the most interesting species in his collection.

† Common to the Gault and Upper Greensand.

logy of the Cretaceous rocks. The species are distributed as follows in Great Britain:—

Smilotrochus tuberosus, *Ed. & H.* —— elongatus, *Duncan.* —— angulatus, *Duncan.*	Upper Greensand.
—— elongatus, *Duncan.* —— granulatus, *Duncan.* —— insignis, *Duncan.* —— cylindricus, *Duncan.*	Gault.
—— Austeni, *Ed. & H.*	Lower Greensand.

Smilotrochus elongatus, Duncan, is found in the Gault and Upper Greensand.

Smilotrochus Hagenowi, Ed. & H., is a fossil from the Maestricht Chalk (Ed. & H. Hist. Nat. des Corall. vol. ii. p. 71).

Subfamily Caryophyllinæ.

Division Caryophylliaceæ.

Genus Brachycyathus.

Brachycyathus Orbignyanus, Ed. & H.

The corallum is very short. The costæ are indistinct. The septa are long, very slightly exsert, granulated from below upwards, and there are four cycles in six systems. The primary and secondary septa are equal; the tertiary are a little longer than those of the fourth cycle; all are thin and straight. The pali are like continuations of the tertiary septa before which they are placed; they are granular.

Height $\frac{1}{10}$ inch. Breadth $\frac{6}{10}$ inch.

Locality. East Shalford, Surrey, base of the Lower Greensand. Found with *Cerithium Neocomiense*, D'Orbig.; *Exogyra subplicata*, Tqm.; *Arca Raulina*, Leym.; *Terebratula sella*, Sow.

In the collection of C. J. Meyer, Esq., F.G.S.

The specimen upon which the genus was founded was found in the Neocomian formation of the Hautes Alpes, at St. Julien, Beauchêne. I have added to the original description, as some portions of the English specimen are better preserved than the type.

Family ASTRÆIDÆ.

Subfamily Eusmilinæ.

Division Trochosmiliaceæ.

Genus Trochosmilia.

Trochosmilia Meyeri, Duncan.

The corallum is small, cylindrical or cylindro-conical; its base may be wide or very small, and was adherent. The epitheca is complete. The costæ are very small, and are occasionally seen where the epitheca is worn. The calice is rather deep. The septa are crowded, unequal, spined near the axis, and form six systems. There are four cycles of septa. The calice is usually circular in outline, but it is occasionally compressed. The axial space is small. The endotheca is very scanty.

Height $\frac{4}{10}$ inch. Greatest breadth $\frac{2}{10}$ inch.

Variety. The corallum is short, broad, cylindrical, slightly constricted centrally, and has a broad base.

Height $\frac{3}{20}$ inch. Breadth $\frac{8}{20}$ inch.

Locality. Bargate Stone, upper division of the Lower Greensand, Guildford, Surrey. Found with "*Avicula pectinata*," Sow.

In the collection of C. J. Meyer, Esq., F.G.S.

The small *Trochosmiliæ* are common in the Bargate Stone, where they were discovered by Mr. Meyer, from whom I have obtained the names of the associated fossils. The presence of epitheca would apparently necessitate these fossils being placed in a new genus; but after a careful examination of the bearings of the absence or presence of the epithecal structures upon the natural classification of simple corals, I do not think the point sufficiently important to bring about the separation of Mr. Meyer's little corals from the *Trochosmiliæ*; they form (*i. e.* the type and variety) a subgenus of the *Trochosmiliæ*.

Subfamily Astræinæ.

Division Astræaceæ.

Genus Isastræa.

Isastræa Morrisi, Duncan.

The corallum is flat and very short. The corallites are unequal and usually five-sided. There is no columella. The wall is thin. The septa are slender, unequal, and most of them reach far inwards. There are in the perfect calices three cycles of septa in six systems; usually some of the septa of the third cycle are wanting.

Breadth of a calice rather more than $\frac{1}{10}$ inch.

Locality. Bargate Stone, Guildford, Surrey; with *Terebratella Fittoni*, Meyer.

In the collection of C. J. Meyer, Esq., F.G.S.

This small *Isastræa* is usually found as a cast, and the restored drawing is taken from an impression. The central circular structure is due to fossilization.

The species is closely allied to *Isastræa Guettardana*, Ed. & H., of the Lower Chalk of Uchaux.

Family FUNGIDÆ.

Subfamily Lophoserinæ.

Genus Turbinoseris, gen. nov.

The corallum is simple, more or less turbinate or constricted midway between the base and calice; the base is either broad and adherent, or small and free.

There is no epitheca, and the costæ are distinct. There is no columella, and the septa unite laterally, and are very numerous.

Turbinoseris de-Fromenteli, Duncan.

The corallum is tall, and more or less cylindro-turbinate. The calice is shallow, and circular in outline. The septa are very numerous, long, thin, straight, and many unite laterally with longer ones. There are 120 septa, and the cyclical arrangement is confused. The synapticulæ are well developed. There is no columella, and the longest septa reach across the axial space. The costæ are well developed, and often are not continuous with the septal ends.

Height $1\frac{3}{10}$ inch. Breadth of calice $1\frac{2}{10}$ inch.

Variety. With a constricted wall and large base.

Locality. Atherfield, in the Lower Greensand.

In the collection of the Royal School of Mines.

The necessity for forming a new genus for this species is obvious; it is the neighbour of *Trochoseris* in the subfamily of the *Lophoserinæ*. This last genus has a columella, and the new one has none.

The species has not been hitherto described, but it has been familiarly known as a *Montlivaltia*; but the synapticulæ between the septa and costæ determine the form to belong to the *Fungidæ*.

List of new Species from the Lower Greensand.

1. Brachycyathus Orbignyanus, *Ed. & H.*
2. Trochosmilia Meyeri, *Duncan.*
3. Isastræa Morrisi, *Duncan.*
4. Turbinoseris de-Fromenteli, *Duncan.*

List of the Species from the Lower Greensand.

1. Brachycyathus Orbignyanus, *Ed. & H.*
2. Smilotrochus Austeni, *Ed. & H.*
3. Trochosmilia Meyeri, *Duncan.*
4. Isastræa Morrisi, *Duncan.*
5. Turbinoseris de-Fromenteli, *Duncan.*
6. Holocystis elegans, *Lonsdale*, sp.

List of the Species from the Cretaceous Formations.

A. *Upper and Lower White Chalk.*

1. Caryophyllia cylindracea, *Reuss*, sp.
2. —— Lonsdalei, *Duncan.*
3. —— Tennanti, *Duncan.*
4. Onchotrochus serpentinus, *Duncan.*
5. Trochosmilia laxa, *Ed. & H.*, sp., and three varieties.
6. —— cornucopiæ, *Duncan.*
7. —— Wiltshiri, *Duncan.*
8. —— Woodwardi, *Duncan.*
9. —— granulata, *Duncan.*
10. —— cylindracea, *Duncan.*
11. Parasmilia centralis, *Mantell*, sp., and two varieties.
12. —— cylindrica, *Ed. & H.*
13. —— Fittoni, *Ed. & H.*
14. —— serpentina, *Ed. & H.*
15. —— monilis, *Duncan.*
16. —— granulata, *Duncan.*
17. Diblasus Gravensis, *Lonsdale.*
18. Synhelia Sharpeana, *Ed. & H.*
19. Stephanophyllia Bowerbanki, *Ed. & H.*

B. *Upper Greensand.*

20. Onchotrochus Carteri, *Duncan.*
21. Smilotrochus tuberosus, *Ed. & H.*
22. —— elongatus, *Duncan.*
23. —— angulatus, *Duncan.*
24. Peplosmilia Austeni, *Ed. & H.*
25.*—— depressa, *E. de From.*
26.*Placosmilia cuneiformis, *Ed. & H.*
27.*—— Parkinsoni, *Ed. & H.*
28.*Placosmilia magnifica, *Duncan.*
29.*Astrocœnia decaphylla, *Ed. & H.*
30.*Isastræa Haldonensis, *Duncan.*
31. Cyathophora monticularia, *D'Orbigny.*
32. Favia stricta, *Ed. & H.*
33. —— minutissima, *Duncan.*
34. Thamnastræa superposita, *Michelin.*
35. Micrabacia coronula, *Goldfuss*, sp.

C. *Red Chalk of Hunstanton.*

36. Cyclolites polymorpha, *Goldfuss*, sp.
37. Podoseris mammiliformis, *Duncan.*
38. —— elongata, *Duncan.*
39. Micrabacia coronula, *Goldfuss*, sp., and variety.

D. *Gault.*

40. Caryophyllia Bowerbanki, *Ed. & H.*, and a variety.
41. Trochocyathus conulus, *Phillips*, sp.
42. —— Wiltshiri, *Duncan.*
43. —— Harveyanus, *Ed. & H.*, and five varieties.
44. Bathycyathus Sowerbyi, *Ed. & H.*
45. Leptocyathus gracilis, *Duncan.*
46. Cyclocyathus Fittoni, *Ed. & H.*
47. Smilotrochus elongatus, *Duncan.*
48. —— granulatus, *Duncan.*
49. —— insignis, *Duncan.*
50. —— cylindricus, *Duncan.*
51. Trochosmilia sulcata, *Ed. & H.*
52. Micrabacia Fittoni, *Duncan.*

E. *Lower Greensand.*

53. Brachycyathus Orbignyanus, *Ed. & H.*
54. Smilotrochus Austeni, *Ed. & H.*
55. Trochosmilia Meyeri, *Duncan.*
56. Isastræa Morrisi, *Duncan.*
57. Turbinoseris de-Fromenteli, *Duncan.*
58. Holocystis elegans, *Lonsdale*, sp.

Micrabacia coronula is common to the Upper Greensand and the Red Chalk, and *Smilotrochus elongatus* is found in the Gault and in the Upper Greensand.

* The six species from Haldon marked * were described by me after the reading of this Report (see Pal. Soc. vol. for 1869).

The number of species of *Madreporaria* in the British Cretaceous formations is therefore fifty-eight.

MM. Milne-Edwards and Jules Haime had described twenty-three species before this Report was commenced; of these I have ventured to suppress *Parasmilia Mantelli*, *Trochocyathus Konigi*, and *Trochocyathus Warburtoni*.

The coral-fauna of the British area was by no means well developed or rich in genera during the long period during which the Cretaceous sediments were being deposited. The coral tracts of the early part of the period were on the areas now occupied by the Alpine Neocomian strata, and those of the middle portion of the period were where the Lower Chalk is developed at Gosau, Uchaux, and Martigues.

There are no traces of any coral-reefs or atolls in the British Cretaceous area, and its corals were of a kind whose representatives for the most part live a depth of from 30 to 600 fathoms.

Corals from the Oolitic Strata.

The following authors have contributed to our knowledge of the Oolitic Corals:—Parkinson, 'Organic Remains,' 1808. W. Conybeare and W. Phillips, 'Outlines of the Geol. of Eng. and Wales,' 1822. Fleming, 'British Animals,' 1828. E. Bennet, 'Cat. Org. Remains, Wilts,' 1837. Fitton, "Strata below the Chalk," Geol. Trans. 2nd series, 1843. Morris, 'Cat. of British Fossils,' 1843. MM. Milne-Edwards and Jules Haime, 'Monog.' (Pal. Soc.) 1851. M'Coy, Ann. Nat. Hist. 1848 (several essays). W. Smith, 'Strata Identified,' 1816. J. Phillips, 'Geol. of Yorkshire,' 1829. R. C. Taylor, Mag. Nat. Hist. 1830. S. Woodward, 'Synopt. Table of Org. Rem.' 1830. G. Young, 'Geol. Survey of York,' 1828. R. Plot, 'Nat. Hist. Oxfordshire,' 1676. J. Walcott, 'Descr. and Fig. of Petref. found near Bath,' 1779. T. Wright, M.D., F.G.S., Cotteswold Club Trans. 1866.

An analysis of the work of these authors, with the exception of that of Dr. Wright, is found scattered over the pages of MM. Milne-Edwards and Jules Haime's "Monograph of the Oolitic Corals," Pal. Soc. 1851. No new species of fossil Corals have been described from the Oolitic rock since that date. During the last year I have added to the species already known five from the Great Oolite, and thirteen from the Inferior Oolite. A careful study of the 251 *Thecosmiliæ* of the Inferior Oolite at Crickley has enabled me to distinguish five very remarkable varieties of *Thecosmilia gregaria*, M'Coy, sp., and to satisfy myself that the relations of the *Thecosmiliæ* of the Lias to the genera *Isastræa*, *Latimæandra*, and others were repeated in the Inferior Oolite. There are specimens of *Thecosmilia gregaria* in Dr. Wright's collection which, had I not had a considerable series to examine from other sources, might have been associated with Reuss's new genus *Heterogyra*, with *Symphyllia* and *Latimæandra*. The relation of these genera to *Montlivaltia* has been noticed (except *Heterogyra*) in the first Report (Brit. Assoc. Report, Norwich, p. 106 *et seq.*), and there is a clear proof that the same phenomena of evolution may occur consecutively. That is to say, the St.-Cassian *Montlivaltiæ* and *Thecosmiliæ* varied and became permanent, compound, and serial corals of such genera as *Elysastræa*, *Isastræa*, and *Latimæandra*: then the Liassic *Thecosmiliæ* did the same; and now it is evident that a *Montlivaltia* of the Inferior Oolite occasionally took on fissiparous growth, and superadded to others a marginal gemmation and a serial growth, and evolved forms which cannot be distinguished from those of the genera above mentioned and *Symphyllia* and *Heterogyra*. There was evidently an inherent power of variation which declared itself in the same direction during the ages which witnessed the formation of the St. Cassian and the Liassic and the Lower Oolitic deposits; and it is impossible to deny a genetic value to these oft-repeated structural phenomena.

One of the *Thecosmiliæ* from the Inferior Oolite at Crickley, which I have named *T. Wrighti*, is very closely allied to the Lower-Liassic species.

It is interesting to find the genus *Cyclolites* represented in the Inferior Oolite by two well-marked species, one of which is like the rest of the forms of the genus in shape, and the other is exceptional in its trochoid form. This last species has, however, all the characteristics of the genus. The *Cyclolites* are extinct; they flourished in the Lower Cretaceous seas, and lasted during the Miocene. MM. Milne-Edwards and Jules Haime (Hist. Nat. des Corall.) mention that the genus originated in the Jurassic age, but they give no evidence. The species now under consideration are, however, clearly from the Inferior Oolite.

A form belonging to a new genus of the *Fungidæ* was found by Mr. Mansel at East Coker in the Inferior Oolite. In general shape and the arrangement of the calices the specimen resembles *Dimorphastræa*; but the synapticulæ between the septa and costæ necessitate its association with the *Fungidæ*. There is a central calice, and the others are in a circle around it, being separated by long horizontal septo-costal prolongations; the whole is surrounded by an epitheca, and forms a turbinate shape, the free surface being flat and circular. The genus foreshadows the genera *Cyathoseris* and *Trochoseris* of the Lower Chalk.

There are several new species of the genus *Thamnastræa*; *T. Browni*, nobis (MS. sp.), is remarkable for having in some specimens a long stalk surmounted by a knob-shaped head. The calices are small on the stalk, and very large on the head; so that when the form is examined before it is mature, there is a danger of producing two species instead of one. The stalk often attains the height of 3 or 4 inches. In other specimens there is no stalk, and the knob-shaped corallum is sessile.

A large specimen of *Thamnastræa Manseli* (MS. sp.), Inferior Oolite, is pedunculate, short, and very expanded superiorly; the epitheca is well preserved, and the endothecal dissepiments can be seen. This is a very satisfactory species, and I have had it very carefully drawn, so that the suspiciously synapticular endotheca can be proved to be really dissepimental.

A specimen of *Cladophyllia Babeana*, d'Orb., sp., figured in the inedited plates of the Palæontographical Society at my instance, is remarkable from the disposition of the corallites to combine and form serial and fissiparous calices as in *Thecosmilia*.

The new species of the genera *Cyathophora* and *Isastræa* are well marked, and that of the last is a dendroid form.

MM. Milne-Edwards and Jules Haime collected and described the following Oolitic species* in their 'Monograph' (Pal. Soc.), 1851:—

Portland Stone.

1. Isastræa oblonga, *Fleming*, sp.

Coral Rag.

1. Stylina tubulifera, *Phillips*, sp.
2. —— De la Bechi, *Ed. & H.*
3. Montlivaltia dispar, *Phillips*, sp.
4. Thecosmilia annularis, *Fleming*, sp.
5. Rhabdophyllia Edwardsi, *M'Coy*, sp.
6. Calamophylla Stokesi, *Ed. & H.*
7. Cladophyllia cæspitosa, *Con. & Phil.*, sp.
8. Goniocora socialis, *Römer*, sp.
9. Isastræa explanata, *Goldfuss*, sp.
10. —— Greenoughi, *Ed. & H.*
11. Thamnastræa arachnoides, *Parkins.*, sp.
12. —— concinna, *Goldfuss*, sp.
13. Comoseris irradians, *Ed. & H.*
14. Protoseris Waltoni, *Ed. & H.*

* There are three species common to the Great Oolite and the Inferior Oolite, and one is common to the Coral Rag, the Great and the Inferior Oolite. The varieties of *Thecos-*

Great Oolite.

1. Stylina conifera, *Ed. & H.*
2. —— solida, *M'Coy*, sp.
3. —— Ploti, *Ed. & H.*
4. Cyathophora Luciensis, *d'Orb.*, sp.
5. —— Pratti, *Ed. & H.*
6. Convexastræa Waltoni, *Ed. & H.*
7. Montlivaltia Smithi, *Ed. & H.*
8. —— Waterhousei, *Ed. & H.*
9. Calamophyllia radiata, *Lamouroux*, sp.
10. Cladophyllia Babeana, *d'Orb.*, sp.
11. Isastræa Conybeari, *Ed. & H.*
12. —— limitata, *Lamouroux*, sp.
13. —— explanulata, *M'Coy*, sp.
14. —— serialis, *Ed. & H.*
15. Clausastræa Pratti, *Ed. & H.*
16. Thamnastræa Lyelli, *Ed. & H.*
17. —— mammosa, *Ed. & H.*
18. —— scita, *Ed. & H,*
19. —— Waltoni, *Ed. & H.*
20. Anabacia orbulites, *Lamouroux*, sp.
21. Comoseris vermicularis, *M'Coy*, sp.
22. Microsolena regularis, *Ed. & H.*
23. —— excelsa, *Ed. & H.*

Inferior Oolite.

1. Discocyathus Eudesi, *Michelin*, sp.
2. Trochocyathus Magnevillianus, *Michelin*, sp.
3. Axosmilia Wrighti, *Ed. & H.*
4. Montlivaltia trochoides, *Ed. & H.*
5. —— tenuilamellosa, *Ed. & H.*
6. —— Stutchburyi, *Ed. & H.*
7. —— Wrighti, *Ed. & H.*
8. —— cupuliformis, *Ed. & H.*
9. —— De la Bechi, *Ed. & H.*
10. —— lens, *Ed. & H.*
11. —— depressa, *Ed. & H.*
12. Thecosmilia gregaria, *M'Coy*, sp.
13. Latimæandra Flemingi, *Ed. & H.*
14. —— Davidsoni, *Ed. & H.*
15. Isastræa Richardsoni, *Ed. & H.*
16. —— tenuistriata, *M'Coy*, sp.
17. —— Lonsdalei, *Ed. & H.*
18. Thamnastræa Defranciana, *Michelin*, sp.
19. —— Terquemi, *Ed. & H.*
20. —— Mettensis, *Ed. & H.*
21. —— fungiformis, *Ed. & H.*
22. —— M'Coyi, *Ed. & H.*
23. Anabacia hemispherica, *Ed. & H.*

Mr. Walton has forwarded me *Zephrentis? Waltoni*, Ed. & H., from the Inferior Oolite at Dundry, which MM. Milne-Edwards and Jules Haime felt inclined to think was a *remanié* fossil. There is no doubt about the specimen being a *Zephrentis*, and it is clear that it was derived from an older rock, just as the Carboniferous corals mixed up with the Lower-Lias corals were.

I can add the following species to the list of Oolitic fossil corals, and most of them have been figured, but are not yet published (in 6 plates of the Pal. Soc.):—

New Species.

Great Oolite.

1. Thecosmilia obtusa, *d'Orb.*
2. Cyathophora insignis, *nobis.*
3. —— tuberosa, *nobis.*
4. Thamnastræa Browni, *nobis.*
5. Isastræa gibbosa, *nobis.*

Inferior Oolite.

1. Montlivaltia Holli, *nobis.*
2. —— Temmincki, *nobis.*
3. Montlivaltia Morrisi, *nobis.*
4. Thecosmilia Wrighti, *nobis.*
5. Thamnastræa Walcotti, *nobis.*
6. —— Manseli, *nobis.*
7. —— Etheridgii, *nobis.*
8. Isastræa Crickleyi, *nobis.*
9. —— dendroidea, *nobis.*
10. Dimorphoseris Oolitica, *nobis.*
11. Cyclolites Lyceti, *nobis.*
12. —— Beanii, *nobis.*

The fauna may be divided as follows:—

	Species.
Portland Stone	1
Coral Rag	14
Great Oolite	28
Inferior Oolite	35
	78

The Oolitic corals, as a whole, indicate the geographical conditions incident to reefs and atolls, and do not represent those bathymetrical states which the Upper and Middle Liassic coralliferous strata appear to have illustrated. A deep-sea coral-fauna is not found amongst the relics of the Oolites, and the

milia gregaria are not mentioned or considered as species, although they have a very fair claim. There are three varieties very Symphyllian, and two very Heterogyran in their aspect. There is a well-marked variety of *Montlivaltia trochoides* at Painswick in the Inferior Oolite.

forms peculiarizing the reefs are positively aggregated in an upper and lower mass at Crickley on the Inferior Oolitic beds.

Dr. Wright noticed some years since* an Oolitic coral-reef near Frith Quarry, on the northern spur of Brown's Hill, about two miles from Stroud. There is a corresponding reef on the opposite side of the valley, the whole of the intervening space having been excavated by denudation. The coral-bed consists of large masses of coralline limestone imbedded in a fine-grained cream-coloured mudstone. The corals are in a highly crystalline state, so that the genera and species are determined with difficulty. The bed is from 15 to 20 feet in thickness, and forms one of the finest examples of fossil coral-reefs that Dr. Wright is acquainted with in the district. The bed may be traced along the escarpment, in a north-westerly direction, for several miles, to Witcomb and Crickley on the west, and to near Cubberley and Cowley on the east, where it was worked several years ago. Judging from the thickness of the bed, and the abundance of corals it contains, it must have formed a barrier reef of considerable magnitude in the Jurassic sea. The following is a section showing the relative position of the Lower Coral-reef.

Section of the Lower Coral-reef, in the Inferior Oolite, at the Quarry, North Frith Wood, near Brown's Hill, Gloucestershire.

Lithological Characters and Thickness.	Beds.	Organic Remains. Leading Fossils.
	UPPER FREESTONES.	
Cream-coloured Marl, with several inconstant layers of Mudstone, upper part passing into a loose, friable Freestone, with large *Terebratula fimbria*. From 20 to 25 feet.	OOLITE, MARL. MIDDLE CORAL-BED.	*Thamnastræa, Isastræa, Axosmilia, Terebratula fimbria, T. carinata, T. maxillata, Rhyn. Lycetti, Lucina Wrighti, Lima pontonis.*
Fine-grained Oolitic Limestone, very white, and emitting a metallic ring when struck with a hammer. 40 to 50 feet.	FREESTONES.	Shelly fragments, not determinable.
Coarse brown ferruginous Oolite.	LOWER RAGSTONES.	*Terebratula plicata.*
Masses of Coralline Limestone, imbedded in a light-coloured Mudstone; the Corals highly crystalline, forming the chief part of the bed. 15 to 25 feet.	LOWER CORAL-REEF.	*Latimæandra, Thamnastræa, Isastræa, Axosmilia, Thecosmilia, Pecten Dewalquei, Trichites, Lucina Wrighti.*
Brown ferruginous Pisolitic rock. Pea-grit structure not much exposed.	PEA-GRIT.	*Lima sulcata, Hinnites abjectus, Ceromya Bajociana, Avicula complicata, Nerita costata, Trochotoma carinata, Pygaster, Hyboclypus, Diadema.*

* Dr. Wright has kindly sent me these details. See "On Coral-Reefs," by T. Wright, M.D., F.G.S., Cotteswold Club.

The Middle Coral-bed is included in the Oolite Marl, and in some localities as at Frith, Leckhampton, Sheepscombe, and others, it contains masses of corals.

The Upper Coral-reef occupies the horizon of the upper Trigonia Grit, and is very well exposed in many sections. That of Cleeve Hill has yielded the best corals. The following section is open near Frith. Ascending the bank above this quarry for a short distance some fields of arable land are passed over, on which are several heaps of the Upper Ragstones, with *Trigonia costata*, *Gryphæa subloba*, and other shells of the higher zone. Walking in the direction of the Grove, after passing over the summit of the hill and descending a short distance, a good section of the upper reef may be seen in the Slad Valley.

Section of the Quarry at Worgin's Corner, Upper Zone of Inferior Oolite.*

Lithology.	Beds.	Organic Remains.
Masses of Coralline Limestone, 4 feet thick.	UPPER CORAL-REEF.	*Thamnastræa*, *Isastræa*, *Thecosmilia*, *Magnotia Forbesi*, *Stomechinus intermedius*, *Pecten*, *Trigonia costata*.
Hard shelly Limestone, full of the shells of Brachiopoda, 5 feet.	TEREBRATULA-GLOBATA BED.	*Terebratula globata*, *Rhynchonella spinosa*, *Pholadomya fidicula*, *P. Heraulti*, *Ostræa*, *Gervillia*, *Trichites*.
Hard shelly sandy Oolite, full of *Gryphæa*, 6 feet.	GRYPHÆA BED.	*Gryphæa subloba*, *Lima proboscidea*.

The remarkable varieties of *Thecosmilia gregaria*, which resemble the genus *Symphyllia* and *Heterogyra*, are found principally in the lower reef, but they exist in the upper also. Some species appear to be peculiar to the different reefs, but it is unsafe to form lists at present. There is evidently a considerable affinity between the faunas of the reefs, and there is nothing to indicate anything more than a temporary absence from, and a return of the species to an area.

The corals of the Great Oolite are found in the Upper Ragstones underlying the Bradford Clay. Near Bath large masses of *Calamophyllia radiata* are associated with the roots, stems, and heads of *Apiocrinites rotundus*, Mill., which flourished like a miniature forest on the reef, and luxuriated amongst the polypes until the clear water was invaded by a current charged with mud, which destroyed the Encrinites and the Corals also†.

The Coral Rag in Wiltshire is divisible into (1) Upper Calcareous Grit, (2) Coral Rag, (3) Clay, (4) Lower Calcareous Grit. It is in the Coral Rag proper (2) that the Coral-beds are found. Of these Mr. Lonsdale‡ remarks:

* See Dr. Wright's pamphlet. † Dr. Wright, *op. cit.*
‡ "Oolitic District of Bath," Trans. Geol. Soc. 2nd ser. vol. iii. p. 261.

"The irregular beds of Polyparia consist of nodules or masses of crystallized carbonate of lime, which afford, invariably, evidences of the labours of the Polypus; and associated with them are others of earthy limestone, which bear only partial proofs of an organic origin. The whole are connected by a pale bluish or yellowish stiff clay. It happens frequently that a bed is composed of one genus of Polyparia."

In Yorkshire the Coralline Oolite is well developed, and several reefs are found at Hackness, Ayton, Seamer, &c. John Leckenby, Esq., F.G.S., of Scarborough, gives the following details (see Dr. Wright, *op. cit.*):—

"In various parts of the district occupied by the Coralline Oolite around Scarborough are found patches of coral-reef sometimes occupying an area of fully an acre; and although never attaining an altitude so high as the beds on the inclined surfaces of which they rest, they are truly the uppermost beds of the formation.

"They are sometimes from 10 to 15 feet in thickness, and consist of a series of layers of crystallized coral from 18 to 24 inches in thickness, of the species *Thamnastræa concinna*, Goldf. (which is the *T. micraston*, Phillips), each layer being separated by rubbly clay and mud, in all probability being the decomposition of each successive reef. The rock is quarried to supply material for repairing the roads of the district; but it is by no means so well adapted for the purpose as the adjacent calcareous grit, which, at the cost of a little additional labour, would furnish a material much more durable. The crystalline coral-reef is quickly ground to powder, and its use affords less satisfaction to the traveller than to the geologist, as the blocks which are stored up for use along the sides of the road yield many a handsome specimen to adorn his collection.

"The largest deposit is near the village of Ayton: there are others not quite so extensive; one near the village of Seamer, another close to the hamlet of Irton, and others in the neighbourhood of Wykeham and Brompton —the intervening distances being about a mile in every case."

Messrs. Leckenby and Cullen visited the coral-reefs of the Coralline Oolite near Scarborough with Dr. Wright, who writes as follows:—

"One quarry, near Ayton, which may be considered as a type of the others, consisted of masses of crystalline coralline limestone, the beds having an irregular undulating appearance. The corals appear to have grown in areas of depression of the coralline sea; the rock consists of large masses of highly crystalline limestone, forming nodulated eminences and concave curves, in beds of from 12 to 18 inches in thickness, having a stratum of yellowish clay filling up the hollows, and forming a horizontal line again to the stratification; then follows another stratum of crystalline limestone, which assumes the same nodulated condition as the one below it, the surface of the coral masses, where exposed, showing that the whole is almost entirely composed of a small-celled *Astræa*, *Thamnastræa concinna*, Goldf., *Micraston*, Phillips, in some altered condition; the reef is exposed to about 10 feet in section, and rests on another, forming the floor of the quarry, and which descends many feet deeper; the corals are bored by *Gastrochænæ*, and numerous shells were seen imbedded in the coral mass, which had nestled in the crannies of the reef."

Dr. Wright sums up with regard to the French, German, and British strata of the Étage Corallien as follows:—

"From this general view of the geographical distribution of the Coralline zone, it would appear that this formation was composed of a series of coral-reefs in the Jurassic sea, which, during the period of their construction, occupied a large portion of the region now constituting the soil of modern Europe; and that the bed of the Jurassic sea was a slowly subsiding area of great extent, like many parts of the Coral Sea in the Indo-Pacific Ocean of our day" *.

The restriction of species to very definite areas, and to limited zones amongst these succeeding coral-reefs, is very remarkable, and, as was noticed to occur in the Lias, the corals are occasionally persistent, and are associated with different molluscan species. But the physico-geological changes which produced new reefs must have been preceded by considerable geographical changes, for, as a rule, the species of the grand divisions of the Jurassic system are different. *Thecosmilia Wrighti* of the lower reef of the Inferior Oolite has considerable resemblance to the *Thecosmiliæ* of the Inferior Lias; but no Liassic species pass upwards into the Oolites. Only four species are common to the Inferior and Great Oolites, and one to the Coral Rag and Great Oolite; yet there was a succession of the physico-geographical conditions favourable for the formation of reefs on the same area. The existence of reefs in so high a latitude during the Oolitic period, and their formation by polypes whose genera were all extinct during the early Cainozoic period, but which are clearly represented by allied genera in the existing reefs, are very suggestive. These were the last reefs of the British area; for there are no traces of agglomeration of reef-building genera in the Lower Greensand, the Gault, Upper Greensand, Chalk, or Tertiary formations. The nearest approach to a reef must have been in the Lower Oligocene period, when the Tabulate corals and *Solenastrææ* of Brockenhurst formed a small outlier of the European coral sea of the time between the Nummulitic age and the lowest Falunian deposits.

The succession of reefs and deep-sea or littoral coral conditions appears to have been as follows on the British area south of Yorkshire, after the termination of the Permian period:—

Triassic		No corals (dry land).
Rhætic		Few corals. Littoral and deep water, from 5 to 200 fathoms.
L. Lias.	Zone of Amm. planorbis	Scattered reefs and littoral corals.
	" angulatus	Barrier reefs and deep-water corals.
	" Bucklandi	Scattered reefs and deep-water corals.
Middle Lias		No reefs. Littoral and deep-water corals.
Upper Lias		No reefs. Littoral and deep-water corals.
Inferior Oolite		Successive reefs.
Great Oolite		Successive reefs.
Coral Rag		Reefs.
Portland Oolite		Reefs rare. No other corals.
Lower Greensand		Littoral and deep-sea corals. No reefs.
Gault		Littoral and deep-sea corals. No reefs.
Red Chalk		Littoral and deep-sea corals. No reefs.
Upper Greensand		Littoral corals. No reefs †.
Lower and Upper Chalk		Deep-sea corals. Few littoral corals.
Eocene		Deep-sea corals. No reefs. Littoral corals.
Lower Oligocene		Deep-sea corals. Scattered reefs. Littoral corals.
Crag		Deep-sea corals. No reefs. Littoral corals.
Recent		Deep-sea corals. No reefs. Littoral corals.

* Dr. Wright, *op. cit.*

† Deep-sea and small reefs in the west.

The reefs were doubtless developed on areas where depression and elevation of the sea-bottom was constant, and where old rocks were occasionally sufficiently near the surface to afford a nidus for reef-species. The depths around these rocks must have been considerable; there could not have been any large bodies of fresh water near, and the sea-water must have been pure and in constant motion. The littoral corals resembled the *Caryophyllia Smithi* of our coasts in bathymetrical distribution, and the deep-sea corals, like the existing *Caryophyllia borealis* and *Lophohelia prolifera*, were simple solitary forms distributed at a depth of from 30 to 600 or more fathoms.

The British reefs of the early Secondary period were not necessarily situated in a tropical climate; for there is no reason why reef-building corals should not have been able to exist and multiply in the same temperature of sea-water that deep-sea corals now do. The deep-sea corals are abundant between Norway and the Shetlands, and are quite out of the range of the Gulf-stream. The Bermuda reefs are dependent upon the Gulf-stream for the supply of sufficiently warm water to produce the development of ova. It may have happened that the early Secondary species may not have required a greater amount of sea-temperature than that in which the great coral called *Dendrophyllia ramea* flourishes off Cadiz. These facts and considerations must have some weight against the argument that, because all existing reefs are tropical, all former reefs must have been so.

If the area of Europe is compared with that of Great Britain during the periods that have elapsed since the Palæozoic epoch, the distribution of reefs and centres of oscillation, and of deep-sea and littoral corals indicating very stationary conditions, gives a very good idea of the successive physico-geographies of the old seas.

	Great Britain.	Rest of Europe.
Trias	Uncoralliferous	Reefs in St. Cassian district.
Rhætic	Few deep-sea and littoral corals.	Reefs in Lombardy and Switzerland.
Lower Lias. Zone of Amm. planorbis	Scattered reefs and deep-sea and littoral corals.	Scattered reefs in France, Lombardy, and Switzerland.
Lower Lias. „ angulatus	Barrier reefs, deep-sea and littoral corals.	Reefs in Switzerland. Vast areas with simple deep-sea and littoral corals in France.
Lower Lias. „ Bucklandi	Scattered reefs	Rare deep-sea corals in Europe.
Middle Lias	Deep water and littoral corals.	Rare deep-sea corals.
Upper Lias	Very uncoralliferous	Very uncoralliferous.
Inferior Oolite	Successive reefs	Reefs in Western Europe.
Great Oolite	Successive reefs	Reefs in Western Europe.
Coral Rag	Few reefs	Few reefs.
Portland Oolite	Reefs rare	Reefs rare.
Neocomian	Littoral and deep-sea corals.	Reefs in France, Switzerland, Germany.
Gault	Littoral and deep-sea corals.	Littoral and deep-sea corals.
Cenomanian	Littoral corals	Scattered reefs in France and Western Germany.
Lower Chalk	Deep-sea corals	Reefs in France, Spain, Switzerland, Germany,
Upper Chalk	Deep-sea corals	Few reefs and deep-sea corals.
Eocene	Deep-sea corals and a few littoral.	Reefs in the Lombardo-Swiss, Pyrenean, and Austrian areas.

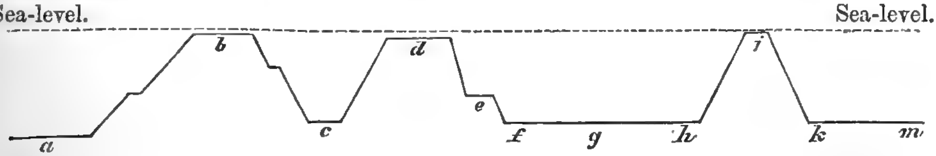
	Great Britain.	Rest of Europe.
Lower Oligocene	Scattered reefs	Reefs in the Vicentin; deep-sea corals in Germany, and littoral species also.
Crag................................	Deep-sea corals and littoral corals.	Deep-sea and littoral species in Sicily, south of Spain, Belgium. Reefs very rare.
Recent	Deep-sea and littoral species.	Deep-sea and littoral species in the Mediterranean and western seas of Europe.

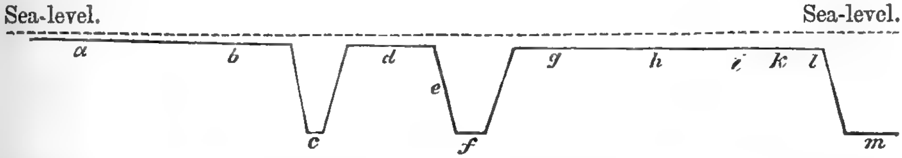
The Miocene reefs were in South France, Italy, Spain, and Germany, where there were also deep-sea and littoral species.

The seas of Europe and Great Britain during the period of the Middle and Upper Lias were most uncoralliferous, and also during the deposit of the Gault. On the other hand, there were reef and atoll seas during the deposition of the sediments of the zone of *A. angulatus* and *bisulcatus* of the Lower Lias, of the Inferior and Great Oolite, and of the Oligocene.

The European area was more or less a centre of oscillation and of reef-formation during the Triassic and the Lower-Liassic periods, during the Lower-Oolitic periods, and from the Neocomian to the end of the Miocene, inclusive of these periods. There was a great change in the depth of the seas and of the physico-geographical conditions after the formation of the deposits containing *A. Bucklandi*, and a second change produced the reefs of the Oolites. Again, the deposits of the Portland Oolite and the Gault were preceded and followed by great bathymetrical changes.

The changes on the British area were before the Lower Lias and after it, after the Great Oolite and Coral Rag, and after the Eocene and before the Crag. Whilst the European area was coralliferous in the Trias, the British area was uncoralliferous; and whilst the Cretaceous reefs of Western Europe flourished, the British area was characterized by deep-sea and littoral corals. The lines and curves which may be drawn to explain these variations in the two areas are as follows* :—





a. Trias.	*d.* Oolites.	*g.* Cretaceous.	*k.* Miocene.
b. Lower Lias.	*e.* Neocomian.	*h.* Eocene.	*l.* Pliocene.
c. Upper Lias.	*f.* Gault.	*i.* Oligocene.	*m.* Recent.

The reef-areas of the Upper Lias and Gault have yet to be discovered.

It is very remarkable that the Tabulate corals, which were so abundant in the Palæozoic Coral-fauna, and which constitute whole reefs at the present time, should not be represented in the British Secondary Coral-fauna. The first trace of them is found in the Eocene beds. The perforate corals, omitting the Fungidæ, which are not included in them by MM. Milne-Edwards and Jules Haime, are unknown in the Secondary rocks of Great Britain,

* The upper diagram refers to the British area, and the lower to the European. The "*a*" commences at the upper part of the Trias.

yet they form masses of existing reefs, and were abundant in the Oligocene. One of the class, *i. e.* the *Protarœa vetusta,* appeared in the Lower Silurian formation of Ohio; but the class was not apparently represented on our area until the Eocene, if we except the *Microsolenas,* which are very exceptional perforate forms of the Oolites. The absence of these forms must be accounted for by the deficiency of the geological record.

Enumeration of Species.

		Species.
Cainozoic.	Crag	4
	Lower Oligocene	13
Mesozoic.	Eocene	38
	Upper / Lower Chalk	19
	Upper Greensand	16
	Red Chalk	4
	Gault	13
	Lower Greensand	6
	Portland Oolite	1
	Coral Rag	14
	Great Oolite	28
	Inferior Oolite	35
	Upper Lias	1
	Middle Lias	2
	Lower Lias	65
		259

List of Tertiary and Secondary British Fossil Corals.

Crag.

Sphenotrochus intermedius, *Münster*, sp.
Flabellum Woodii, *Ed. & H.*
Cryptangia Woodii, *Ed. & H.*
Balanophyllia calyculus, *Wood.*

Oligocene.

Solenastræa cellulosa, *Duncan.*
—— Kœneri, *Duncan.*
—— Reussi, *Duncan.*
—— gemmans, *Duncan.*
Beyrichi, *Duncan.*
—— granulata, *Duncan.*
Balanophyllia granulata, *Duncan.*
Lobopsammia cariosa, *Goldfuss*, sp.
Axopora Michelini, *Duncan.*
Litharæa Brockenhursti, *Duncan.*
Madrepora Anglica, *Duncan.*
—— Römeri, *Duncan,*
—— Solanderi, *Defrance.*

Eocene.

Turbinolia sulcata, *Lamarck.*
—— Dixoni, *Ed. & H.*
—— Bowerbanki, *Ed, & H.*
—— Fredericiana, *Ed. & H.*
—— humilis, *Ed. & H.*
—— minor, *Ed. & H.*
—— firma, *Ed. & H.*
—— Prestwichi, *Ed. & H.*
—— affinis, *Duncan.*
—— exarata, *Duncan.*
—— Forbesi, *Duncan.*
Leptocyathus elegans, *Ed. & H.*
Trochocyathus sinuosus, *Brongniart*, sp.
—— Austeni, *Duncan.*
—— insignis, *Duncan.*
Paracyathus crassus, *Ed. & H.*
—— caryophyllus, *Lamarck*, sp.
—— brevis, *Lamarck*, sp.
—— Haimei, *Duncan.*
Paracyathus cylindricus, *Duncan.*
Dasmia Sowerbyi, *Ed. & H.*
Oculina conferta, *Ed. & H.*
—— incrustans, *Duncan.*
—— Wetherelli, *Duncan.*
Diplohelia papillosa, *Ed. & H.*
Stylocœnia emarciata, *Lamarck*, sp.
—— monticularia, *Schweigger*, sp.
Astrocœnia pulchella, *Ed. & H.*
Stephanophyllia discoides, *Ed. & H.*
Balanophyllia desmophyllum, *Lonsdale*, sp.
Dendrophyllia elegans, *Duncan.*
—— dendrophylloides, *Lonsdale.*
Stereopsammia humilis, *Ed. & H.*
Dendraceis Lonsdalei, *Duncan.*
Porites panicea, *Lonsdale.*
Litharæa Websteri, *Bowerbank*, sp.
Axopora Forbesi, *Duncan.*
—— Parisiensis, *Michelin.*

Chalk.

Caryophyllia cylindracea, *Reuss*, sp.
—— Lonsdalei, *Duncan.*
—— Tennanti, *Duncan.*
Onchotrochus serpentinus, *Duncan.*
Trochosmilia laxa, *Ed. & H.*, sp. and varieties 1 2, 3.
—— cornucopiæ, *Duncan.*
—— Wiltshiri, *Duncan.*
—— Woodwardi, *Duncan.*
—— granulata, *Duncan.*
—— cylindracea, *Duncan.*
Parasmilia centralis, *Mantell*, sp., varieties 1, 2.
—— cylindrica, *Ed. & H.*
—— Fittoni, *Ed. & H.*
—— serpentina, *Ed. & H.*
—— monilis, *Duncan.*
—— granulata, *Duncan.*
Diblasus Gravensis, *Lonsdale.*
Synhelia Sharpeana, *Ed. & H.*
Stephanophyllia Bowerbanki, *Ed. & H.*

Upper Greensand.

Onchotrochus Carteri, *Duncan.*
Smilotrochus tuberosus, *Ed. & H.*
—— elongatus, *Duncan.*
—— angulatus, *Duncan.*
Cyathophora monticularia, *D'Orbigny.*
Favia stricta, *Ed. & H.*
—— minutissima, *Duncan.*
Thamnastræa superposita, *Michelin.*
Micrabacia coronula, *Goldfuss*, sp.
Peplosmilia Austeni, *Ed. & H.*
—— depressa, *E. de From.*
Placosmilia cuneiformis, *Ed. & H.*
—— Parkinsoni, *Ed. & H.*
—— magnifica, *Duncan.*
Astrocœnia decaphylla, *Ed. & H.*
Isastræa Haldonensis, *Duncan.*

Red Chalk of Hunstanton.

Cyclolites polymorpha, *Goldfuss*, sp.
Podoseris mammiliformis, *Duncan.*
—— elongata, *Duncan.*
Micrabacia coronula, *Goldfuss*, sp., and variety.

Gault.

Caryophyllia Bowerbanki, *Ed. & H.*, and a variety.
Trochocyathus conulus, *Phillips*, sp.
—— Wiltshiri, *Duncan.*
—— Harveyanus, *Ed. & H.*, and 5 varieties.
Bathycyathus Sowerbyi, *Ed. & H.*
Leptocyathus gracilis, *Duncan.*
Cyclocyathus Fittoni, *Ed. & H.*
Smilotrochus elongatus, *Duncan.*
—— granulatus, *Duncan.*
—— insignis, *Duncan.*
—— cylindricus, *Duncan.*
Trochosmilia sulcata, *Ed. & H.*
Micrabacia Fittoni, *Duncan.*

Lower Greensand.

Brachycyathus Orbygnyanus, *Ed. & H.*
Smilotrochus Austeni, *Ed. & H.*
Trochosmilia Meyeri, *Duncan.*
Isastræa Morrisi, *Duncan.*
Turbinoseris de-Fromenteli, *Duncan.*
Holocystis elegans, *Ed. & H.*

Portland Oolite.

Isastræa oblonga, *Fleming*, sp.

Coral Rag.

Stylina tubulifera, *Phillips*, sp.
—— De la Bechi, *Ed. & H.*
Montlivaltia dispars, *Phillips*, sp.
Thecosmilia annularis, *Fleming*, sp.
Rhabdophyllia Edwardsi, *M'Coy*, sp.
Calamophyllia Stokesi, *Ed. & H.*
Cladophyllia cæspitosa, *Con. & Phil.*, sp.
Goniocora socialis, *Römer*, sp.
Isastræa explanata, *Goldfuss*, sp.
—— Greenoughi, *Ed. & H.*
Thamnastræa arachnoides, *Parkinson*, sp.
—— concinna, *Goldfuss*, sp.
Comoseris irradians, *Ed. & H.*
Protoseris Waltoni, *Ed. & H.*

Great Oolite.

Stylina conifera, *Ed. & H.*
—— solida, *M'Coy*, sp.
—— Ploti, *Ed. & H.*
Cyathophora Luciensis, *d'Orb.*, sp.
—— Pratti, *Ed. & H.*
—— insignis, *Duncan.*
—— tuberosa, *Duncan.*
Convexastræa Waltoni, *Ed. & H.*
Montlivaltia Smithi, *Ed. & H.*
—— Waterhousei, *Ed. & H.*
Thecosmilia obtusa, *d'Orb.*
Calamophyllia radiata, *Lamouroux*, sp.
Cladophyllia Babeana, *d'Orb.*, sp.
Isastræa Conybeari, *Ed. & H.*
—— limitata, *Lamouroux*, sp.
—— explanata, *M'Coy*, sp.
—— serialis, *Ed. & H.*
—— gibbosa, *Duncan.*
Clausastræa Pratti, *Ed. & H.*
Thamnastræa Lyelli, *Ed. & H.*
—— mammosa, *Ed. & H.*
—— scita, *Ed. & H.*
—— Waltoni, *Ed. & H.*
—— Browni, *Duncan.*

Anabacia orbulites, *Lamouroux*, sp.
Comoseris vermicularis, *M'Coy*, sp.
Microsolena regularis, *Ed. & H.*
—— excelsa, *Ed. & H.*

Inferior Oolite.

Discocyathus Eudesi, *Michelin*, sp.
Trochocyathus Magnevillianus, *Michelin*, sp.
Axosmilia Wrighti, *Ed. & H.*
Montlivaltia trochoides, *Ed. & H.*
—— tenuilamellosa, *Ed. & H.*
—— Stutchburyi, *Ed. & H.*
—— Wrighti, *Ed. & H.*
—— cupuliformis, *Ed. & H.*
—— De la Bechi, *Ed. & H.*
—— lens, *Ed. & H.*
—— depressa, *Ed. & H.*
—— Holli, *Duncan.*
—— Painswicki, *Duncan.*
—— Morrisi, *Duncan.*
Thecosmilia gregaria, *M'Coy*, sp.
—— Wrighti, *Duncan.*
Latimæandra Flemingi, *Ed. & H.*
—— Davidsoni, *Ed. & H.*
Isastræa Richardsoni, *Ed. & H*
—— tenuistriata, *M'Coy*, sp.
—— Lonsdalei, *Ed. & H.*
—— Crickleyi, *Duncan.*
—— dendroidea, *Duncan.*
Thamnastræa Defranciana, *Michelin*, sp.
—— Terquemi, *Ed. & H.*
—— Mettensis, *Ed. & H.*
—— fungiformis, *Ed. & H.*
—— M'Coyi, *Ed. & H.*
—— Walcotti, *Duncan.*
—— Manseli, *Duncan.*
—— Etheridgi, *Duncan.*
Anabacia hemispherica, *Ed. & H.*
Dimorphoseris Oolitica, *Duncan.*
Cyclolites Lyceti, *Duncan.*
—— Beani, *Duncan.*

Upper Lias.

Thecocyathus Moorei, *Ed. & H.*

Middle Lias.

Lepidophyllia Hebridensis, *Duncan.*
Montlivaltia Victoriæ, *Duncan.*

Lower Lias.

Lepidophyllia Stricklandi, *Duncan.*
Oppelismilia gemmans, *Duncan.*
Montlivaltia Walliæ, *Duncan.*
—— Murchisoniæ, *Duncan.*
—— Ruperti, *Duncan.*
—— parasitica, *Duncan.*
—— simplex, *Duncan.*
—— brevis, *Duncan.*
—— pedunculata, *Duncan.*
—— polymorpha, *Terq. et Piette.*
—— Haimei, *Ch. et Dew.*
—— Hibernica, *Duncan.*
—— papillata, *Duncan.*
—— Guettardi, *Blainville.*
—— nummiformis, *Duncan.*
—— radiata, *Duncan.*
—— patula, *Duncan.*
—— rugosa, *Wright*, sp.
—— mucronata, *Duncan.*
Thecosmilia Suttonensis, *Duncan.*
—— mirabilis, *Duncan.*
—— serialis, *Duncan.*
—— irregularis, *Duncan.*
—— Terquemi, *Duncan.*
—— affinis, *Duncan.*
—— dentata, *Duncan.*
—— plana, *Duncan.*
—— Brodiei, *Duncan.*
—— Martini, *E. de From.*
—— Michelini, *Terq. et Piette.*
Rhabdophyllia rugosa, *Laube.*
—— recondita, *Laube.*
Astrocœnia Sinemuriensis, *d'Orb.*
—— gibbosa, *Duncan.*
—— plana, *Duncan.*
—— insignis, *Duncan.*
—— reptans, *Duncan.*
—— parasitica, *Duncan.*
—— pedunculata, *Duncan.*
—— costata, *Duncan.*
—— favoidea, *Duncan.*
—— superba, *Duncan.*
—— dendroidea, *Duncan.*
—— minuta, *Duncan.*
Cyathocœnia dendroidea, *Duncan.*
—— incrustans, *Duncan.*
—— costata, *Duncan.*
—— globosa, *Duncan.*
Elysastræa Fischeri, *Laube.*
—— Moorei, *Duncan.*
Septastræa excavata, *E. de From.*
—— de-Fromenteli, *Terquem.*
—— Evershami, *Duncan.*
—— Haimei, *Wright*, sp.
Latimæandra denticulata, *Duncan.*
Isastræa Sinemuriensis, *E. de From.*
—— globosa, *Duncan.*
—— Murchisoni, *Wright.*
—— Tomesii, *Duncan.*
—— endothecata, *Duncan.*
—— insignis, *Duncan.*
—— Stricklandi, *Duncan.*
—— latimæandroidea, *Duncan.*

Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing. The Committee consists of Henry Woodward, *F.G.S.,* Dr. Duncan, *F.R.S.,* Professor Harkness, *F.R.S., and* James Thomson, *F.G.S.* (Reporter).

The operations of this Committee have been carried on indefatigably during the past year; the results are very promising, but much additional work must be performed before any satisfactory conclusions can be arrived at.

We have cut several hundred sections, but many of them have been so crushed and fractured, that they are absolutely useless for our purpose; thus in one lot of eighty-seven we found only two specimens sufficiently perfect to be of any use; this is to be regretted, as it is desirable to select as perfect specimens as possible for photographing, and also for the use of Dr. Duncan for describing in the Transactions of the Palæontological Society.

Those cut, and partly cut, consist of the following genera:—*Cyathophyllum, Cyclophyllum, Clisiophyllum,* and allied forms, *Lonsdalia, Zephrentis, Amplexus, Michelinia, Syringopora, Lithostrotion* and its varieties.

The time and labour involved in superintending the cutting, examining, and finishing those which are sufficiently perfect, will explain the impossibility of producing this year so complete a set as we could have wished. However, we have been sufficiently successful to warrant us in saying that with those made, and others in readiness to make, we will be able to produce in another year a very full set of plates.

With the plates already finished we have been trying a number of experiments in photography; finding that by the usual process the colour fades by exposure to light, we went to Newcastle and examined Mr. Swan's carbon process; and, being satisfied that it was an improvement, we left three plates with him, and we now exhibit the results, satisfactory in two of them, while the other has some defects; we are, however, in hopes that soon we will be able to produce fac-similes on zinc or copper plates. Mr. Swan has been trying experiments for that purpose, and he is in hopes of being successful. If so, we will be able to produce them in any number, and at such a moderate price that they will be available for ordinary publishing purposes. If not successful, we expect to be able, by the carbon process, to produce sets of plates which will be placed in a few of the principal Museums when completed.

Report on Ice as an Agent of Geologic Change. By a Committee, consisting of Professor Otto Torell, Professor Ramsay, *LL.D., F.R.S., and* H. Bauerman, *F.G.S.* (Reporter).

We are of opinion that the work already done in the investigation of the phenomena connected with ice is not sufficient to enable us to prepare a Report showing the precise effect of "ice as an agent of geologic change;" but enough has been done to show in part the manner in which the subject may be followed, for the purpose of obtaining information as to the quantitative action of glaciers, both as regards their erosive and transporting powers.

First. We would select a well-known glacier-region, such as the Alps, and there for preliminary investigation fix on a large glacier, simple in structure and easily accessible, such, for example, as the lower glacier of the

Aar. If not already done, the glacier and the surrounding mountains ought to be well surveyed and mapped, and its moraines clearly expressed.

Secondly. The amount of rocky and earthy matter forming each medial and lateral moraine would require to be determined as accurately as possible, probably in the manner illustrated by the accompanying rough diagram of an imaginary glacier.

Take of the medial moraine marked *a* a space, say, from 100 to 500 yards in length, and estimate the solid contents of that portion of the moraine. This should be done as near as possible to the place where the medial moraine is formed by the union of the two lateral moraines *x* and *y*; for lower down part

of the material may disappear by falling into crevasses. The same must be done for the moraines *b* and *c*, or for each medial moraine; and also, in several places, for the lateral moraines *d* and *e*. Then ascertain the rates of the onward movement of the glacier, according to circumstances, in various portions of its length, and at various seasons of the year; and by these means will be ascertained to a great extent (but not precisely) the quantity of matter carried annually on the surface of the glacier to its termination, and this matter will represent a very large part of the waste of the sides of the mountains that bound the snow and glacier basins *o*, *p*, *q*, and the sides of the mountains that bound the glacier lower down towards its terminal moraine.

Thirdly. The chief part of the *remainder* of the rocky and earthy matter that is carried from the mountains to the level of the glacier will pass under it at its sides, and mingle with the material that finds its way to the bottom of the glacier through the means of crevasses and moulins, and also with that which is the product of the erosive action of the glacier exerted on its bed and on the stone blocks imprisoned at the bottom of the ice. A small part of the above-named *remainder* may also be caught in the ice and imprisoned in rejoined crevasses.

Fourthly. We see no way of precisely estimating the amount of erosion produced by the weight and movement of the glacier—that is to say, the rate at which any given glacier may deepen and widen its valley by pure wearing action, owing to the circumstance that the sediments discharged along with the water that flows from the end of a glacier do not represent the amount produced by mere erosive force, for the reason stated under head 3. But it is essential to the main question that correct estimates should be made of the amount of solid matter brought from under the glacier by the help of running water, and also of the amount carried away by the continual wasting by streams of the terminal moraine.

As regards the matter in suspension in the river, and also that forced along its bottom, it should be estimated, if possible, at a point *r*, just below where the various streams unite that flow from the ends of most great glaciers. Where there is only one stream (as in the Aletsch glacier), the closer to the glacier the better. The operation would be very laborious; for, unless frost and snow prevented it, it would require to be done for every day in a year or years, and several times each day, at least in summer and autumn, and probably in spring and winter also. For example, in summer the quantity of water varies largely, according to the heat of various periods of the day; and it would probably be necessary to make an observation every day before sunrise, another some time before noon, another between four and six o'clock in the afternoon, and another after nightfall; in fact sufficiently often to obtain an average for each day in the year.

With rgard to the transport of heavier matter from the terminal moraine (which forms a portion of this part of the subject) by the glacier-streams that waste it, an index to the amount may approximately be obtained by means of the estimates indicated under head 2, assuming that all terminal moraines are formed chiefly from matter transported on the surface of the glacier.

Other methods involving special study on the spot would be required for the terminal and lower side-moraines of such glaciers as those of La Brenva and Miage, which on the sides that face up the valley towards the Lake of Comballe are still growing.

Fifthly. If the foregoing methods are correct, they might afterwards be applied to all the glaciers of the Alps, and the rate of waste and transport by glacier-action might be approximately determined; and in like manner they might also be used for well-known and comparatively accessible mountain-ranges like the Scandinavian chain, the Himalaya, the mountains of New Zealand, and in time to the Rocky Mountains, the Andes, and others.

Sixthly. But the above only forms part of the subject, and to attempt to estimate the existing importance of "ice as an agent of geologic change," the *glacier* and *glacial* phenomena generally as regards erosion and terrestrial and marine transport of material must be taken into account in such regions as Spitzbergen, Greenland, and Victoria Land in the southern hemisphere. Something on a small scale may be done in Spitzbergen and the southern part of Greenland; but at present we see no likelihood of definite observations being made on the western side of Greenland further north, and in the extreme north of that continent, or on its eastern shores, either in respect to the erosion produced by its great glaciers, the effect of floe and shore-ice, or the transporting work done by the icebergs that float southwards from its shores.

Something is known of the general results, but it seems very improbable, with regard to the number and size of icebergs, and the quantity of matter they bear southwards, that anything definite is likely to be ascertained at present. The same remarks bear yet more strongly on the glacial phenomena of Victoria Land.

Seventhly. But when so much remains to be done on the Alps and on other accessible mountain-areas, such difficult points can afford to wait for the present; and we are of opinion that perhaps it is possible, after the subject has been investigated with regard to the existing glaciers of the Alps, to apply approximately the same method to the older extension of the Alpine glaciers during the last glacial period, and to invent a process by which we may be able in some degree to estimate the amount of erosive waste, and of transport of moraine matter on the surface, of the great glaciers of that epoch. Accurate surveys of the old moraines of that epoch would be essential to this end, such, for example, as that of the great moraine of Ivrea. The extent of the glacier has been shown by Gastaldi, and the area occupied by, and cubic contents of, the moraine must be estimated; and if it be possible to feel our way towards the data, attempts must be made to estimate the amount of waste of the moraine going on at the time it was deposited by the streams flowing from the end of the glacier. Numerous other considerations arise from this extended view of the question, one of which is, that perhaps it may be applied to other glaciated regions where glaciers no longer exist, such as the Vosges, the Black Forest, Wales, the north of England, Scotland, &c., thus:—Given an area such as the Alps and the Lowlands of Switzerland, covered with glacier-ice; if an approximate estimate can be formed of the amount of waste suffered by that land due to glacier-action, so under like circumstances is it possible more or less accurately to estimate the amount of erosions and other waste suffered by an equal area in such a territory as the north of Greenland at the present day.

In conclusion, any qualified person, with proper assistance and time at his disposal, could undertake the preliminary work on a single glacier; but to do what is necessary to complete it for such an area as the Alps would probably involve national scientific cooperation.

Provisional Report of a Committee consisting of Professor TAIT, Professor TYNDALL, *and* Dr. BALFOUR STEWART, *appointed for the purpose of repeating* Principal J. D. FORBES'S *Experiments on the Thermal Conductivity of Iron, and of extending them to other Metals. By* Professor TAIT.

IN consequence of a misunderstanding, the standard thermometers ordered from the Kew Observatory did not arrive in time to be employed in the experiments hitherto made, so that the results now to be stated, besides being only *approximate*, are, for the most part, confined to a range of temperature of about 100° C. merely. Before the next meeting of the British Association the whole question will have been reexamined with far superior instruments; but with such thermometers as I had at hand (including some of those used by Principal Forbes, of which, however, I have not succeeded in obtaining the corrections determined by Welsh at Kew), results have been obtained of a character sufficiently definite for publication, though, of course, subject to (slight) future corrections and perhaps limitations.

The substances experimented on were iron, lead, and copper. Two specimens of the latter metal were employed, one of high, the other of low *electric* conductivity, the resistances of equal lengths of wires of the same gauge being about 1 to 1·64. The ratio of the *thermal* conductivities of these bars was at once found to be within 5 per cent., the same as that of their electric conductivities, a result certainly anticipated, but still very striking. In specific gravity and specific heat, as well as in chemical composition, mode of manufacture, and drawing, these bars of copper scarcely differ. As yet they have been treated for thermal conductivity in the hard-drawn state alone; but annealed wires of the same materials, while showing a slightly improved electric conductivity, maintain towards one another a ratio practically unaltered.

Two points have been observed which enable us materially to simplify the determination of thermal conductivities by Forbes's method, so long at least as moderate ranges of temperature are concerned; and we seek no greater accuracy than admits of 1 or 2 per cent. of error.

1. The *Curve of Cooling* is practically the same for all the substances I have tried (even for gas-coke), merely foreshortened or elongated in terms of a parameter, which involves the product of the specific gravity and the specific heat of the substance employed. This was, of course, to be expected, provided the radiating power of the surface be kept the same, and provided conductivity do not interfere with the results.

2. The *Curve of Statical Temperature* possesses, practically, the same property, at least for the four different bars employed. This proves that within the range of the experiments, and subject to the errors of the thermometers, the law of change of thermal conductivity with temperature is the same for lead and copper as for iron. I showed (Proc. R. S. Edin., 1867–68) that Forbes's results for iron agree closely with the statement that the conductivity is inversely as the absolute temperature, a result which is identical with Matthiessen's determinations of electric resistance of pure metals at different temperatures. With a view to follow up this analogy still further, I have ordered a bar of German silver, a substance whose *electric* conductivity is but little altered by temperature. The results cannot fail to be interesting.

Very simple reasoning from the (plotted) curves of *Cooling* and of *Statical Temperature* shows that, to the amount of accuracy before mentioned, the thermal conductivities of two metals are *as the squares of the foreshortenings in their respective curves of statical temperature.* I have not considered my observations sufficiently exact (chiefly on account of the imperfection of the thermometers) to warrant my undertaking the labour of calculating the constants of empirical formulæ to represent them, but have contented myself with results derived from tracing, *liberâ manu,* curves closely representing the result of experiment.

I may mention, in concluding this provisional Report, that an air-bath has been found preferable to melted solder for heating the bars employed in the cooling experiments, and that the conductivity of copper is so much superior to that of iron that, when a source of heat above 100° C. is employed, the further ends of the 8-feet copper bars require to be kept cold by a constant stream of water. In this case the curve of statical temperature undergoes an obvious and easily allowed for modification.

Report of the Committee 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 Professor EVERETT, *at the request of the Committee, consisting of* Sir WILLIAM THOMSON, *LL.D., F.R.S.,* E. W. BINNEY, *F.R.S., F.G.S.,* ARCHIBALD GEIKIE, *F.R.S., F.G.S.,* JAMES GLAISHER, *F.R.S.,* Rev. Dr. GRAHAM, Prof. FLEEMING JENKIN, *F.R.S.,* Sir CHARLES LYELL, *Bart., LL.D., F.R.S.,* J. CLERK MAXWELL, *F.R.S.,* GEORGE MAW, *F.L.S., F.G.S.,* Prof. PHILLIPS, *LL.D., F.R.S.,* WILLIAM PENGELLY, *F.R.S., F.G.S.,* Prof. RAMSAY, *F.R.S., F.G.S.,* BALFOUR STEWART, *LL.D., F.R.S.,* G. J. SYMONS, Prof. JAMES THOMSON, *C.E.,* Prof. YOUNG, *M.D., F.R.S.E., and* Professor EVERETT, *D.C.L., F.R.S.E., Secretary.*

IN the last Report it was stated that several small hardy maximum thermometers suited for rough work were being constructed by Casella under the direction of the Committee. These instruments have now been in use for a year and have been found to work well.

Their construction is as follows:—A Phillips's maximum thermometer, about 10 inches long, graduated in Fahr. degrees from about 30° to 90°, is hermetically sealed within a glass tube, which is about three-quarters filled with air and one-fourth with alcohol, the thermometer being kept from touching the tube by cork rings. The thermometer thus enclosed is inserted in a copper case for protection, contact between the glass and the copper being prevented by india-rubber. The air within the hermetically sealed tube prevents the great pressure which acts upon the exterior of the tube in deep bores filled with water from being transmitted to the thermometer within. The use of the alcohol is to lessen the time required for the thermometer to come to the temperature of the surrounding medium.

The Committee would take this opportunity of stating that they will be happy to supply these instruments to any persons who will undertake to make observations of the temperature in borings.

Mr. M'Farlane (assistant to Sir W. Thomson), who furnished for the last Report a series of observations taken at Blythswood bore, now furnishes observations taken with the thermometer above described at two other bores. At Kirkland Neuk bore near Blythswood, his observations were made in March and April 1868, and again in August and September of the same year. At South Balgray on the north side of the Clyde, his observations were made in July 1869. The following are the particulars of the observations.

Observations of Underground Temperature at Kirkland Neuk Bore, Blythswood, 1868.

Diameter of bore 2½ inches.

Taken during March and April.			Taken during August and September.
Depth.	Temp. Fahr.		Temp. Fahr.
feet. 60	44°·67	Mar. 28.	48°·0
	45·50	„ 31.	
120	48·15	„ 20.	48·7
	48·20	„ 23.	48·65
			49·0
			49·0
180	50·29	„ 18.	50·20
	50·30	„ 21.	50·35
240	51·70	„ 13.	51·3
			51·5
300	53·10	„ 7.	52·5
			52·5
354	53·60	Apr. 2.	53·5
			53·53

This bore was originally 570 feet deep, but was filled with sediment to 354 feet from the surface. During March and April the weather was rainy, and a continual flow of water from the surface passed into the bore, escaping at some unknown depth. The temperature observed varied considerably at different times, especially towards the surface. Those here recorded were taken when the surface-flow was least, the others have been rejected from their irregularity as not trustworthy.

In August and September the weather was dry, and the surface of the water in the bore remained at a nearly constant depth of 30 feet, and the temperatures observed are much more regular.

An attempt was made to have the sediment taken out so as to render the whole depth available for observation, when an accident occurred to the iron tube protecting the upper part of the bore, and nothing further has been done.

Observations of Underground Temperature at South Balgray, west from Glasgow, north from the Clyde. Diameter of bore 3 inches.

This bore, originally 1040 feet deep, is available to a depth of 525 feet. The observations here recorded were made at the beginning of July 1869, the surface of the water being constant at 5½ feet from that of the ground. Diameter of bore 3 inches.

Depth. feet.	Temp.	Date.	Depth. feet.	Temp.	Date.
60	48°·2	July 2, 1869.	60	48°·22	July 6, 1869.
	48·2	„ 2 „		48·20	„ 9 „

Depth. feet.	Temp. °	Date.
120	49·5	July 2, 1869.
	49·5	„ 2 „
	49·60	„ 5 „
	49·65	„ 5 „
	49·52	„ 6 „
	49·60	„ 9 „
	49·60	„ 9 „
180	51·0	„ 2 „
	51·0	„ 2 „
	51·21	„ 5 „
	51·20	„ 5 „
	51·21	„ 6 „
240	52·7 } ?	„ 2 „
	52·7 } ?	„ 2 „
	52·90	„ 5 „
	52·75 ?	„ 5 „
	52·91	„ 9 „
	52·90	„ 9 „
	52·90	„ 13 „
	52·95	„ 13 „
300	53·9	„ 2 „
	53·8	„ 2 „
	53·86	„ 5 „
	53·92	„ 5 „
	53·90	„ 6 „
	53·90	„ 9 „
	53·90	„ 9 „
360	55·7 ?	„ 2 „
	55·40	„ 5 „
	55·36	„ 5 „
	55·39	„ 6 „
	55·31	„ 9 „
360	55·30	July 9, 1869.
	55·45	„ 13 „
	55·33	„ 13 „
	55·35	„ 13 „
390	56·11	„ 9 „
	56·09	„ 9 „
	56·13	„ 13 „
420	56·9	„ 2 „
	57·30	„ 5 „
	57·20	„ 5 „
	57·10	„ 6 „
	57·09	„ 6 „
	57·18	„ 9 „
	57·20	„ 9 „
450	57·80 ?	„ 9 „
	58·10	„ 9 „
	58·10	„ 9 „
	58·32	„ 13 „
	58·00	„ 13 „
480	58·7	„ 2 „
	58·72	„ 5 „
	58·70	„ 6 „
	58·70	„ 6 „
488	59·05	„ 9 „
	59·00	„ 9 „
525	59·3	„ 2 „
	59·6	„ 2 „
	59·9 ?	„ 5 „
	59·40	„ 6 „
	59·40	„ 6 „
	59·45	„ 9 „

In regard to these observations, I have to remark that the thermometer had to be drawn up with great caution, as I found that the thermometer case, or a knot on the cord, meeting with a slight obstruction from rugged parts of the bore, produced a sufficient shock to cause the detached portion of the mercury to sink, which rendered the observation useless. The discrepancies in some of the observations marked (?) may be due to this cause. In several cases, when the shock was distinctly felt, I found the reading very low, and at once rejected it.

The mode of procedure was as as follows :—the readings were taken generally at intervals of 60 feet (10 fathoms). For the smaller depths iced water was used to set the thermometer below the temperature of the locality to be tested, and on being brought to the surface, it was put into the water while taking the reading for considerable depths ; this was unnecessary, as its passage through the colder upper strata served the purpose sufficiently. Frequently two observations were taken at one depth in succession, but never more, before proceeding to the next greater ; and in no case was a reading taken at any depth after one had been made at a lower on the same day.

Between the depths 390 feet and 450 feet there is continuous shale, and I thought it might be interesting to have the temperature of both these localities.

At the depth of 488 feet commences a bed of greenstone about 140 feet thick, but the sediment prevented me from getting more than 37 feet into this bed.

As it would be interesting to get through the greenstone, I am at present making inquiries as to the expense of having the mud pumped out.

The following is an account of the strata penetrated by this bore, together with an abstract of the foregoing results: –

July 1869. South Balgray Bore.

Depth.	Nature of strata.	Number of layers.	Thickness.		Temperature.	Difference.	Difference per foot.
ft.			ft.	in.	°	°	°
	Surface-soil	1	1	0			
	Sandy clay	1	3	6			
	Dark fakes	1	2	6			
	Grey fakes	2	18	9			
	Dark blaes	8	22	6½			
	Sandstone	1	10	0			
	Coal..........	1	1	0			
	Ironstone	4	0	9			
60							
		19	60	0½	48·20		
	Dark fakes	2	6	9			
	Dark blaes	9	29	7			
	Sandstone	2	17	6		1·36	0·0227
	Coal..........	1		3			
	Ironstone	6	5	11			
120							
		20	60	0	49·56		
	Dark fakes	4	9	6			
	Grey fakes	3	16	3			
	Dark blaes	3	8	5½			
	Light blaes	1	1	2		1·56	0·0260
	Sandstone	3	22	2			
	Coal..........	2	1	5			
	Ironstone	3	1	0½			
180							
		19	60	0	51·12		
	Grey fakes	1	3	6			
	Dark blaes	10	38	9		1·72	0·0287
	Sandstone	1	10	8			
	Ironstone	8	7	1			
240							
		20	60	0	52·84		
	Dark fakes	2	17	3			
	Grey fakes	2	12	10			
	Dark blaes	1	4	0		1·04	0·0173
	Sandstone	1	25	8			
	Ironstone	1	0	3			
300							
		7	60	0	53·88		

July 1869. South Balgray Bore (*continued*).

Depth.	Nature of strata.	Number of layers.	Thickness.	Temperature.	Difference.	Difference per foot.
ft.			ft. in.	°	°	°
	Dark fakes	3	11 4½	53·88		
	Fakey sandstone	2	25 7			
	Dark blaes	8	17 6½		1·52	0·0253
	Ironstone	7	5 6			
360		20	60 0	55·40		
	Dark fakes	3	19 8½			
	Dark blaes	1	6 4½		0·71	0·0237
	Sandstone	3	3 11			
390		7	30 0	56·11		
					1·03	0·0343 } Continuous blaes.
420	Dark blaes	..	30 0	57·14		
					0·99	0·0330 } Continuous blaes.
450	Dark blaes	..	30 0	58·13		
	Dark blaes	..	6 4½			
	Dark limestone.	1	3 1			
	Light do. hard	4	7 0		0·57	0·0190
	Limey fakes ..	4	13 1			
	Parting	1	0 1			
	Fakey limestone	1	0 4½			
480		11	30 0	58·70		
	Fakey limestone	..	10 10½			
	Greenstone	1	34 1½		0·82	0·0182
525		1	45 0	59·52		

Difference of temperature for 465 feet . 11°·32,
Mean difference of temperature per foot 0°·0244,

being at the rate of 1° for 41 feet. It will be remarked that the shale, which extends from 390 feet to 450 feet, shows a more rapid increase of temperature, and therefore smaller conductivity than the other strata*.

The following is an account of the strata penetrated by the Blythswood bore (No. 1), together with an abstract of the temperatures observed in it. The particulars of the observations of temperature were given in last year's Report.

* As regards the relation between rate of increase of temperature downwards and thermal conductivity, it is to be borne in mind that in comparing different parts of one bore these quantities are generally in inverse proportion to each other; but this rule does not apply to the comparison of two bores in different localities. See Mr. Hopkins's paper, Phil. Trans. vol. cxlvii.

1867–68. Blythswood Bore, No. 1.

Depth.	Nature of strata.	Number of layers.	Thickness.		Tempera-ture.	Differ-ence.	Difference per foot.
ft.			ft.	in.	°	°	°
	Surface-soil....	1	1	6			
	Till with stones.	1	46	6			
	Dark till	1	12	0			
60							
		3	60	0	47·95		
	Dark till	..	11	0			
	Fakes	2	6	3			
	Dark blaes	10	12	4½			
	Blaes and fakes.	4	12	6		1·27	·0212
	Sandstone	6	15	7½			
	Coal..........	3	1	8			
	Ironstone......	3	0	7			
120							
		28	60	0	49·22		
	Sandstone fakes.	8	21	2½			
	Blaes	7	18	1½			
	Sandstone	4	18	3		1·28	·0213
	Coal..........	2	1	6½			
	Ironstone......	4	0	10½			
180							
		25	60	0	50·50		
	Sandstone fakes.	7	33	2½			
	Sandstone	5	10	4		1·08	·0180
	Blaes	9	15	8½			
	Ironstone......	4	0	9			
240							
		25	60	0	51·58		
	Sandstone fakes.	2	10	0½			
	Sandstone	2	8	6½		1·18	·0197
	Dark blaes	12	36	11			
	Ironstone......	11	4	5¾			
300							
		27	59	11¾	52·76		
	Sandstone	2	18	2			
	Dark blaes	4	27	9½		·93	·0198
	Fakes	1	0	3			
	Ironstone......	2	0	9½			
347							
		9	47	0	53·69		

Our attempts to obtain the journal of the Kirkland Neuk bore, showing the strata penetrated by it, have not as yet been successful. The mean rate of increase, calculated from the observations in August and September, is 0°·0187 per foot, or 1° for 53·5 feet.

This is the bore which was referred to in the following passage of last year's Report.

"It has been selected because the mining engineer states in his report that the coal has been very much burned or charred, showing the effects of heat; and it becomes an interesting question, Are there any remains of that heat that charred the coal in ancient times, or has it passed off so long ago that the strata are now not sensibly warmer on account of it?"

The observations seem to establish the latter alternative, this bore being rather colder than its neighbour, the Blythswood No. 1.

Mr. G. J. Symons, Member of the Committee, has furnished the following account of observations taken by him to the depth of 1100 feet in an artesian boring at Kentish Town:—

"Observations have been made during a considerable length of time, and with every precaution and care, through the London Clay, Thanet Sands, Chalk, Upper Greensand, and Gault, in the vicinity of the metropolis, under the following circumstances.

"There exists in the northern suburbs of London, between Kentish Town and Highgate, a remarkably large well, 8 feet in diameter and 540 feet deep, lined throughout with the finest brickwork, and reaching 214 feet deep into the Chalk. This well was the property of a Company whose Act of Parliament bore date 35th Henry VIII. (A.D. 1544), and afforded a supply of water to the surrounding neighbourhood until, in 1852, when, under the joint influence of the Board of Health, who objected to hard water, of increasing demand and decreasing quantity, the Company decided on seeking a fresh supply. It was represented to them as most probable that by sinking a bore-tube to a depth of about 1000 feet, the Lower Greensand would be tapped, and an abundant supply of excellent water obtained. The then existing well being more than half the entire depth required, it was decided to bore from its bottom, and thus save half the cost. The boring was carried down to 1302 feet (nearly a quarter of a mile), but the Lower Greensand was absent; some unknown rocks were penetrated, and the Company, after spending on their works, well, and boring nearly £100,000, became bankrupt; the New River Company purchased the plant, but were advised not to continue the search; the buildings were sold for old materials, and the whole left in a ruinous condition.

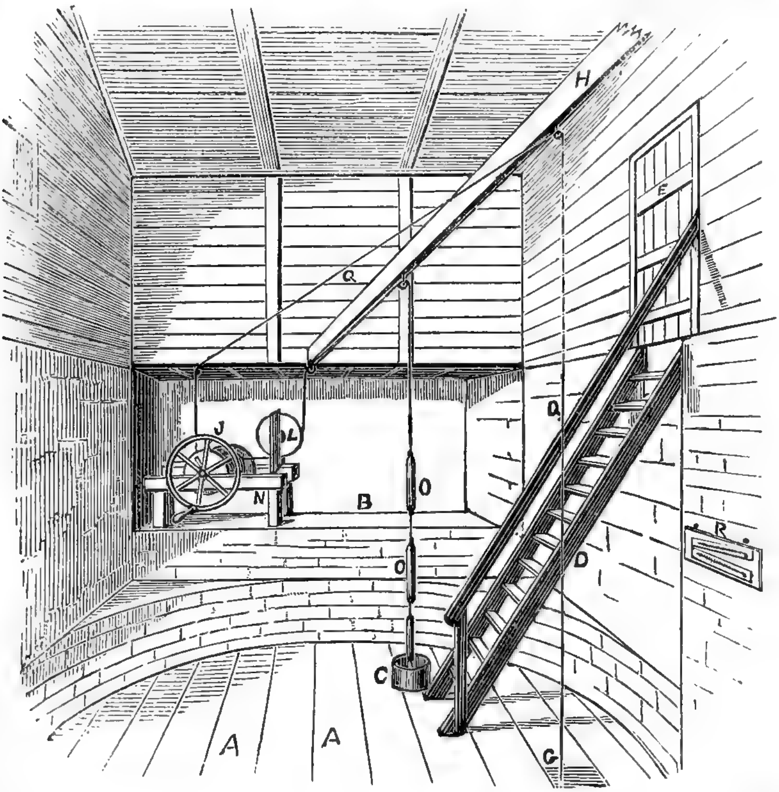
"I consulted other members of this Committee as to the expediency of obtaining from the New River Comp. permission to experiment on this bore, and consent having (through the courtesy of Mr. Muir, the Company's engineer) been obtained, it was decided that observations should be forthwith commenced.

"Owing to the ruinous condition of the top of the well, and the depth of the top of the bore-tube below the ground, very considerable danger and discomfort attended the preliminary arrangements, although these very difficulties have eventually led to the detection of sources of error not previously suspected, and to exceptionally accurate results.

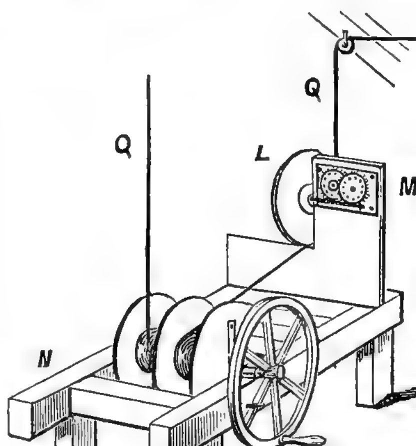
"The accompanying sketches explain pretty clearly the exact circumstances under which the observations were taken, viz. that a hut was erected over the top of the well to shut out, as far as practicable, external temperature and to protect the apparatus; that a stout floor was fixed 10 feet down the well to afford access to the tube* and safety to the observer, the top of the

* "It is scarcely necessary to say that the tube commences 9 feet below the surface of the ground, and passes down through the well."

tube only rises one foot above the floor, and is plugged with a large ball of felt to prevent external air having free communication with the tube. The exact limits of the various strata are also shown, together with the *constant*



A, floor, 10 feet below surface of ground. B, brick-ledge. C, bore-tube, fitting tightly in floor. D, steps leading to entrance door E. G, opening into well, with trap-door. H, beam suporting pulleys, over which pass two cords Q Q, one leading to tube and the other to well. J, windlass, separately represented in second figure. L, registering-apparatus, with dials M, indicating amount of cord paid out. N, stand of windlass, fixed to brick-work B. R, thermometers for temperature of observing room. O O, thermometers for underground temperature.



depth at which water stands in the tube: this constancy is worth notice; for whereas in most cases water-levels vary with the rainfall in the districts whence they obtain their supply, the water at Kentish Town has not varied more than six inches during the last ten months, and is very muddy. The diameter of the bore-tube is 8 inches.

Two thermometers have always been used in these observations,—one similar to those designed for the use of the Committee by Sir Wm. Thomson, and the other an extra strong Six's thermometer, as supplied to the Admiralty by Casella. The influence of great pressure on the indications of thermometers having recently attracted considerable attention, it may be well to state that the greatest pressure to which those used at Kentish Town have been submitted is about a fifth of a ton per square inch, and this causes the Six's thermometer to rise about 0°·4; Sir W. Thomson's thermometer being protected by an outer glass tube is entirely uninfluenced by this pressure, or even, as Professor Miller's experiments have shown, by a pressure of *two tons and a half on the square inch**. Hence it is certain that pressure has been deprived of all influence. The use of two thermometers of different constructions ensured the detection of any slipping or accidental error in the observations, but in the regular series not a single instance of the kind has occurred.

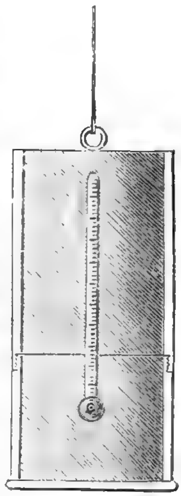
"In order to ascertain the depth of the instruments easily, accurately, and independently of any variation in the hygrometric condition of the lowering-cord, it was conducted from the windlass round a grooved wheel exactly 36 inches in circumference, to whose axle an endless screw was attached, which worked a train of divided wheels, so that the exact distance could be taken at any instant.

"It was supposed that several trustworthy observations could be obtained in the course of one day; but the following Table shows that this was not the case, and confirms the expediency, where practicable, of allowing considerable time for the instruments &c. to come to thermal equilibrium. At Kentish Town the observations on which reliance is placed have been made at intervals of not less than six days, and generally of seven. On two or three occasions, however, attempts have been made to obtain observations at short intervals, and the following are the results:—

Depth, in feet.	Time allowed.	Date.	Temperature indicated.	True temperature.	Error.
100	1 hour.	March 5.	50°·1	51°·0	−0°·9
200	"	"	51·8	53·6	−1·8
300	"	"	56·1	56·1	0·0
400	"	"	55·0	58·1	−3·1
500	"	"	58·1 }		2·1
"	"	"	60·0 }	60·2	−0·2
"	"	"	60·2 }		0·0
550	"	Feb. 12.	61·0	61·0	0·0
600	"	March 5.	58·0 }	61·2	−3·2
"	"	"	58·2 }		−3·0
700	"	"	62·5 }	62·8	−0·3
"	"	"	62·6 }		−0·2
710	Half-hour.	"	62·8 }	62·9	−0·1
"	"	"	62·9 }		0·0
750	20 minutes.	Feb. 19.	63·0	63·4	−0·4

* "Professor W. A. Miller's experiments were made with an hydraulic press, and are described in the Roy. Soc. Proceedings for June 17, 1869 (No. 113). Several thermometers

"It is well known that in the solid crust of the earth the influence of seasons penetrates but a slight depth, say 60 feet; but it occurred to me that this might not hold good in the case of such an opening as the Kentish Town well. I therefore decided on commencing my observations at midwinter, continuing them regularly to midsummer, and then repeating every observation; those at each depth will therefore have been taken twice at exactly opposite seasons, and at intervals of six months. The necessity for this extreme care did not appear obvious at first, and it seemed as if the various precautions against the ingress of atmospheric temperatures had rendered it superfluous; but during recent hot periods its desirability has become abundantly manifest: the temperature at a depth of 50 feet was 49°·2 in January and 54°·1 in July; that at 100 feet was 51° in January and 54°·3 in July; at 150 feet 52°·1 in January and 54°·7 in July. It is therefore evident that under the circumstances existing at Kentish Town, it is more easy to determine accurately the temperature at great depths than at the lesser ones. It is certain that but for the precautions taken, and the unusual mildness of the winter, the temperature at 50 feet would have been much below 49°·2. Whence it further appears that though a single observation at depths below 200 feet will probably give accurately the true temperature at any selected depth, yet in shafts and bores similarly circumstanced to that now under notice, very discordant results may be obtained at lesser depths. Moreover, it is obviously impossible, by any but long-continued observations, to determine accurately the surface-temperature of the ground, or the equivalent of a depth of 0 feet; it may therefore be expedient, for the purpose of completing the series, to assume that the mean temperature of the surface of the soil at Kentish Town, 187 feet above mean sea-level, is identical with that of the air at Greenwich (49°) at 159 feet above the sea, and it is satisfactory to find that the observations hitherto made agree perfectly with this hypothesis. Although, as we have already stated, the experiments are by no means concluded, it may be convenient to tabulate the results hitherto obtained. Being impressed with the high importance of accurate knowledge of the rate and amount of seasonal change in the shaft, Mr. Symons designed, and Mr. Casella (aided in part by Messrs. Silver & Co.) constructed, a very delicate thermometer, which was cased 5 inches thick in felt and non-conducting materials, and enclosed in an ebonite box, as in the annexed section; the non-conducting powers of this instrument were such that on one occasion it was raised into the observing-room showing a temperature of 51°·14, and after being in a temperature of 60° for thirty-five minutes it had only risen 0°·02.



By this means it was therefore possible to bring up the exact temperature of any required depth, uninfluenced by the warmer or colder strata through which it might have to pass. It was regularly observed for some time during the present spring, and the following readings obtained:—

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were experimented on. Sir W. Thomson's is that which is designated 'No. 9645. A mercurial maximum thermometer, on Professor Phillips's plan, enclosed in a strong outer tube containing a little spirit of wine, and hermetically sealed.'"

"Temperature by Insulated Thermometer 100 feet below Surface.

		Temperature	Increase per diem.
"1869, April 3	....	51°·21	.... 0°·021
" " 12	....	51·40	.... 0·008
" " 17	....	51·44	.... 0·011
" " 24	....	51·52	.... 0·003
" " 30	....	51·54	.... 0·006
" May 7	....	51·58	.... 0·024
" " 14	....	51·85	.... 0·021
" " 21	....	52·00	.... 0·011
" " 28	....	51·92	.... —0·003
" June 4	....	51·94	.... +0·025
" " 11	....	52·10	

Increase, April 3 to June 11, 0·89 or 0°·013 per diem.

"The main results of the experiments in the bore-tube are shown in the following Table:—

"Abstract of Results obtained at Kentish Town Well, Jan. 1 to June 30, 1869.

Depth.	Date of observation.	Observed temperature.	Difference for 50 feet.	Rate of increase, in degrees per foot.	Temperature in observing-room.		Depth of rain.	Depth to surface of water in tube.
					Max.	Min.		
ft.							in.	ft. in.
50	Jan. 8.	49°·2	1°·8	·036	46°·8	38°·2	1·06	
100	" 15.	51·0	1·1	·022	49·2	39·5	·20	
150	" 22.	52·1	1·5	·030	46·8	36·0	·22	210 0
200	" 29.	53·6	2·4	·048	43·0	31·8	·64	
250	Feb. 5.	56·0	0·1	·002	48·4	39·5	·83	208 6 (*a*)
300	" 12.	56·1	0·0	·000	49·4	42·3	·89	210 6
350	" 19.	56·1	2·0	·040	48·2	39·2	·38	
400	" 26.	58·1	1·0	·020	46·5	36·8	·67	209 6
450	Mar. 5.	59·1	1·1	·022	46·5	35·2	·59	210 0 (*b*)
500	" 12.	60·2	0·8	·016	45·8	35·2	·10	
550	" 19.	61·0	0·2	·004	44·0	34·8	·15	
600	" 23.	61·2	0·2	·004	44·5	37·6	·95	
650	" 27.	61·4	1·4	·028	43·0	34·9	·05	?219 0 (*c*)
700	April 3.	62·8	0·6	·012	43·6	36·0	·22	211 0
750	" 12.	63·4	0·8	·016	54·0	37·3	·19	
800	" 17.	64·2	0·8	·016	54·4	46·2	·38	209 0
850	" 24.	65·0	0·8	·016	52·4	40·8	·53	
900	" 30.	65·8	0·9	·018	56·2	40·6	·01	210 0
950	May 7.	66·7	1·1	·022	53·8	43·5	1·00	
1000	" 14.	67·8	1·2	·024	54·2	45·4	·47	210 6
1050	" 21.	69·0	...	...	55·2	44·2	·47	210 6 (*d*)
1070	" 24.	69·3	...	...				
1085*	" 28.	69·6	...	...	58·0	47·2	·75	210 6
1085*	June 4.	69·8	0·7	·014	56·0	43·0	·58	
1100*	" 11.	69·7	1·0	·020	61·9	48·5	·01	210 6
1100*	" 14.	70·0						

REMARKS.

"(*a*) First observation in the water.

"(*b*) Water becomes muddy.

"(*c*) This water-measurement seems erroneous.

"(*d*) On attempting to lower the thermometers to 1100 feet, found the mud supported them, and the cord became slack. The observations to which an asterisk is attached were obtained by leaving the cord so slack as to allow the thermometers to bury themselves in the mud; but there is much risk in attempting to withdraw them."

"Assuming 49° as the surface-temperature, and adopting 70° as the temperature at 1100 feet, we find, for the mean rate of increase downwards, ·0191° per foot, or 1° for 52·4 feet.

"Comparing the first observation in the water (56°) with the temperature at the bottom (70°), the mean rate of increase comes out ·0165, or 1° for 60·6 feet.

"During the remainder of the present year the repetition of the observations will be continued, and it is hoped the influence of seasonal changes will be measured and eliminated. In conclusion, we have to acknowledge the liberality of the New River Company in allowing Mr. Symons unreserved access to their grounds, and permission to erect the necessary apparatus, which has been efficiently protected by their servants."

I desire to say, in reference to the foregoing Report, that the length of time which Mr. Symons found it necessary to interpose between his observations is a peculiar circumstance of which I can at present offer no sufficient explanation, and I cannot help thinking that it might be obviated by some modification of the arrangements. Mr. M'Farlane, in three different bores, has found 15 minutes amply sufficient to give the correct temperature. Can the difference be owing to the greater size and smoothness of the bore in this instance offering less resistance to vertical currents?

As regards the first 210 feet, being the portion occupied by air, it is not surprising that the influence of season should here be perceptible, seeing that the well is 8 feet in diameter. The temperature of the air in an opening of this size, *even for the average of the year*, cannot be taken to represent that of the solid earth at the same depth, but will doubtless be found to be intermediate between the latter and the mean temperature of the external air.

The Rev. Dr. Graham (Member of the Committee) has taken observations in a bore at Logie Works, near Dundee, through the kindness of the proprietors, Messrs. Edwards, from whom he received much assistance. The bore was available to the depth of 640 feet, and was described, before the observations, as being filled nearly to the surface with water, in which there was no perceptible motion. Much difficulty was experienced from the shaking down of the detached column of mercury in the thermometer; but this was at length obviated by fixing the thermometer horizontally in a hollow cup in a piece of hard wood, which had a hinged glass cover to permit of reading the indications, provision being made for the free circulation of the water, and a weight being attached to the bottom to act as sinker. The temperatures observed were exceedingly anomalous, being about 10° greater at 100 feet than at 50 feet, then increasing to the depth of about 400 feet, and afterwards decreasing to the bottom. Dr. Graham states that he and his assistant observers were convinced that the water which filled the bore was obtained at the depth of about 170 feet, and that while one portion rose to the surface, another and smaller flowed downwards and escaped through the lower strata.

Mr. John Hunter, Assistant to the Professor of Chemistry, Queen's College, Belfast, has taken a few observations in two shafts, sunk with a view to salt-mining, at high ground near Carrickfergus. In both of them the water stood only to the depth of a few feet. It was found that the temperature of the air within the shafts increased downwards, at any one time, with tolerable uniformity, but varied greatly with the weather. The shafts were kept constantly closed by boarded covers, except during the actual process of observing. The temperature of the water at the bottom, which is assumed to represent pretty accurately the temperature of the soil at the same depth, was 62°·4 in Duncrue shaft at the depth of 570 feet (observed November 7, 1868), and 66° in Mr. Dalway's new shaft at the depth of 770 feet (observed November 14, 1868). Assuming 48° as the mean surface-temperature, the increase of temperature downwards would be at the rates of 1° in 40 feet and 1° in 43 feet respectively. The soil in both cases was yellow clay.

Mr. David Burns, of H.M. Geological Survey, now stationed at Allendale near Carlisle, has taken observations in that neighbourhood, which he thus describes:—"The first shaft I tried is over 50 fathoms in depth, and is about half full of water. It is situated on the summit of a ridge a few yards distant from a fault of some 900 feet throw. The flow, or rather change, of water in it, from these or other causes, is considerable, as is shown by the temperature. The result of my observations may be put thus:—

"After a period of drought—

	feet.		°
"Depth	160	Temperature	47·5
"	200	"	47
"	250	"	47·7
"	300	"	47·7

"The minimum temperature is at 200 feet. This reading may be relied on, as I repeated the observation to make sure of it. Perhaps at this level lies the chief feeder of water.

"Shortly after heavy rains—

	feet.		°
"Depth	160	Temperature	47
"	200	"	47·5
"	250	"	47·3
"	300	"	47·3"

Mr. Burns goes on to relate his unsuccessful attempts to take observations in two other shafts, which turned out to be closed, probably by platforms, at a depth of several feet below the surface of the water.

In concluding this Report, I would beg to direct attention to a valuable summary of observations of underground temperature at great depths contributed by Mr. Hull to the 'Quarterly Journal of Science' for January 1868, from which the following Table of results has been condensed:—

	Depth, in feet.	Temperature at bottom, in degrees Fahr.	Average rate of increase.
			° feet.
Puits de Grenelle, near Paris	1794·6	81·95	1 for 59
Boring at Neu Salzwerk, Westphalia.	2281	91·04	1 " 54·68
Boring near Geneva	....	....	1 " 55
Boring at Mendorff, Luxemburg	2394	....	1 " 57
Monkwearmouth Colliery	1499	....	1 " 60
Rose Bridge Colliery, near Wigan ..	1800	80	1 " 58·3
Astley Pit, Dukenfield, Cheshire	2040	75·5	1 " 83·2

Mr. Hull strongly insists on the necessity of observations at greater depths. He gives reasons for maintaining that, at depths exceeding 2000 feet, no water would be found in ordinary Coal-measure strata, and offers a recommendation in the following terms:—

"After much consideration, the plan which we venture to recommend, in case of experiments being undertaken by the British Association, or any other scientific society, would be, not to commence at the surface, but at the bottom of a coal-mine, of not less depth than 600 yards.

"There are several collieries, particularly in Lancashire and Cheshire, sufficiently deep for the purpose. It would be an easy matter to excavate a chamber in the coal and its roof, where the borings might be carried on. The chamber ought to be a short distance from the bottom of one of the shafts, and out of the way of mining-operations. As the process of boring progressed, observations should be taken at every 10 yards, and at every change of strata, from sandstone to shale or coal. The boring might be carried down at least to a total depth of 1000 yards from the surface, and having been completed under proper supervision, could not fail to give results of value to science. It is also probable that a proprietor of some colliery of the required depth would willingly afford the facilities for carrying on the experiment, for the sake of the information he would derive regarding the minerals underlying the coal-seam then being worked."

With respect to this recommendation, I may say, in the name of the Committee, that they consider it very valuable, and would gladly avail themselves of any opportunity of carrying it out, so far as the funds at their disposal permit.

Fifth Report of the Committee for Exploring Kent's Cavern, Devonshire. The Committee consisting of Sir Charles Lyell, *Bart., F.R.S.*, Professor Phillips, *F.R.S.*, Sir John Lubbock, *Bart., F.R.S.*, John Evans, *F.R.S.*, E. Vivian, George Busk, *F.R.S.*, William Boyd Dawkins, *F.R.S., and* William Pengelly, *F.R.S.* (*Reporter*).

Before commencing the Report of their researches during the last twelve months, the Committee beg to call attention to a few facts connected with branches of the Cavern explored in previous years.

In their Third Report, presented to the Association at Dundee in 1867, they stated that in a part of that branch of the Cavern termed the "Vestibule," there was *beneath* the Stalagmitic Floor, and generally in direct contact with its nether surface, a layer of black soil, known as the "Black Band," which varied from 2 to 6 inches in thickness, covered an area of about 100 square feet, and at its nearest approach was 32 feet from the northern entrance of the Cavern. They also stated that this Black Band contained a large amount of charcoal, and that in it had been found 366 flint implements, flakes, cores, and chips; a bone harpoon or fish-spear, and a bone awl; and numerous bones and teeth of extinct and recent animals, some of which were partially charred. They further remarked that were they to speculate respecting the probable interpretation of the Black Band—bearing in mind its very limited area, its position near one of the entrances of the Cavern and within the influence of the light entering thereby, its numerous bits of charcoal and of burnt bones, its bone tools and its very abundant, keen-edged, unworn, and brittle chips and flakes of whitened flint,—they might be tempted to conclude that they had not only identified the Cavern as the home of an early British family, but the Vestibule as the particular apartment where they enjoyed the pleasures of their own fireside, cooked and ate their meals, and fashioned flint nodules and bones into implements for war, for the chase, and for domestic use*.

To the foregoing description of the Black Band and its locality, it may be added that, even during very wet seasons, that part of the Cavern is very little exposed to drip from the roof.

It may not be out of place to state here that, in order to ascertain to what extent the light penetrating the entrance of the Cavern was available, one of the Superintendents of the exploration placed himself near the centre of the Black-Band area, and found that without any artificial light he could distinctly see to write a letter and to read ordinary print.

But whilst the Committee have seen no reason to abandon or to modify their interpretation of the Black Band, and whilst it has been generally accepted by those who by personal inspection have made themselves familiar with the phenomena of the Cavern, they have found that by one very able and experienced observer it has been regarded with some amount of scepticism, on the ground that the smoke of a fire in the Cavern would either suffocate or expel the inhabitants; that, in short, the interpretation was inconsistent, since it supposed the Cavern to have been inhabited under conditions which would render it uninhabitable.

To test the force of this objection, six large faggots of wood were piled in a heap and set on fire, as nearly as possible on the centre of the area which the Black Band had occupied. The fire burnt brilliantly and threw out large tongues of flame, which licked the roof, whilst a party of five persons, without the least inconvenience from smoke or any other cause, sat on the rocky sides of the Cavern and watched the experiment. They were unanimous in the opinion that the objection that was thus put on its trial was utterly invalid. It may be mentioned, too, that the temperature of the Cavern is permanent, and stands by night and by day, in summer and in winter, at about 52° Fahr., or half a degree above the mean annual temperature of the district in which Kent's Hole is situated. Hence it may be concluded that, unless the Black Band represents a period when the mean temperature of South Devon was considerably below that which at present obtains, large fires would not have been needed. Artificial heat would have been required, not to make the Cavern tenantable, but perhaps for culinary purposes only.

Before quitting this subject, it may be stated that the smoke drifted towards the interior of the Cave, and that one of the party, who from time to time passed all round the fire and to various distances from it, reported that in the narrower adjacent ramifications it was oppressive.

Soon after the Meeting at Norwich in 1868, Mr. Boyd Dawkins, a member of the Committee, intimated his intention of visiting Torquay for the purpose of examining and naming the remains of the Cave-animals which had been collected during the exploration. It has been stated in previous Reports that, from the beginning, a separate box has been appropriated to the specimens found in each distinct "yard" of deposit, that is, in each parallelopiped of Cave-earth a yard in length and a foot in breadth and in depth, that with each set of specimens was packed a numbered label, and that the Secretary recorded in his daily Journal full information respecting the precise position of the objects thus numerically defined, as well as the date on which they were exhumed. It may be added that, as soon as the specimens

* Report Brit. Assoc. 1867, p. 32.

were cleaned and packed, the boxes were stowed away in a room set apart for them, the door was locked, and the Secretary never parted with the key. It is obvious that the number of boxes of specimens waiting for examination was equal to the number of "yards" in which fossils have been found. On the 31st of December, 1868, this number was 3948; and though it is true that some of the boxes contained no more than a single bone, it is also true that in many of them there were upwards of a hundred; hence it will be seen that the task Mr. Dawkins had before him possessed Herculean dimensions. When he began his examination, there must have been in store for him more than 50,000 bones; and though many of them were unidentifiable chips merely, every one had to pass under review.

In order that this gigantic labour might be somewhat facilitated, the Secretary commenced to unpack each box, and to write on every specimen it contained the number written on the accompanying label. While thus engaged, on the 24th of September, 1868, with the box labelled 1847, he found amongst its contents what appeared at first to be merely a very small bone, the greater part of which was covered with a film of stalagmite. On being touched, the investment fell off (a very common occurrence in the case of similar specimens after having been washed and dried), and the object proved to be a portion of a bone needle, having its point broken off but retaining its perfect and well-formed eye. This part had been concealed and, happily, protected by the calcareous covering. The remnant is about ·85 inch long and is slightly taper. Its section at right angles to its longest axis is subelliptical, resembling that of a modern bodkin rather than that of a needle. Its greater diameter at the larger end is about ·075 inch, and at the smaller ·05 inch; hence, assuming it to have been symmetrical in form and to have terminated in a point, its original length must have been 2·55 inches. There are numerous fine longitudinal striæ on its surface, suggesting that it had been scraped into form. The Secretary's daily journal shows that it was exhumed on the 4th of December, 1866, and that it belonged to the Black Band *beneath* the Stalagmitic Floor.

Since its discovery it has unfortunately been broken, the line of fracture passing through the eye. Before the accident it had been seen by several members of the Committee and by many other persons. The parts have been very carefully and firmly reunited. The eye was capable of carrying a thread about three-eightieths of an inch in diameter, or about the thickness of fine twine.

On November 26th, 1868, while still engaged in preparing the specimens for Mr. Boyd Dawkins, the Secretary had the good fortune to detect, under precisely similar conditions, in the box labelled 2206, a bone "harpoon" or fish-spear barbed on one side only. When dug out of the deposit it was in two pieces, one of which was almost, and the other completely, encrusted with stalagmite. Indeed the latter was regarded as a pipe of stalactite, and as such was preserved. It is recorded in the Secretary's journal that it was disinterred on the 7th of March, 1867, in the Vestibule, in the first or uppermost foot-level of Cave-earth, beneath the Black Band, which was 4 inches thick, and which was covered with a Stalagmitic Floor varying from 12 to 20 inches in thickness, and that this, again, was overlaid with Black Mould containing pre-Roman and Romano-British objects.

The fact that remains of the extinct Cave-bear, Hyæna, and Rhinoceros have been met with not only *in* the Stalagmitic Floor just mentioned, but quite at its upper surface, must be borne in mind when attempting to form an estimate of the chronology of the needle and "harpoon" just described.

Besides the foregoing, there was found during the preparatory examination, in the box numbered 2067, a canine of a Badger, the fang of which had been cut or otherwise reduced to a wedge-like form, and perforated obliquely as if for the purpose of being strung. It was exhumed on February 4th, 1867, in the "Vestibule" in the second foot-level of Cave-earth, which is believed to have been intact; but as the overlying Stalagmite had been broken up and removed by the earlier explorers, the Superintendents do not feel perfect confidence in the trustworthiness of its position.

The foregoing are the only objects of peculiar interest which have been recently detected among the specimens collected by the Committee, prior to the last Meeting of the Association, from the deposits beneath the Stalagmitic Floor.

There have been found, however, two noteworthy objects, among those which had been met with in the Black Mould overlying the Stalagmite, and which, therefore, can have no pretensions to great antiquity. The first is a bone needle, by no means so elegantly designed or so highly finished as that just described. Its proportions also are such as to secure for it great strength, and to enable it to carry a thread or cord of considerable size.

The second object is a ring, apparently of Kimmeridge Coal, or some kindred substance. The diameter of the greater circle is upwards of an inch, and of the inner one about half an inch. The annulus is about ·2 inch thick at its inner edge, and both surfaces are uniformly bevelled to a line at the outer edge. Its breadth is not uniform, as the circles are not concentric.

Researches during the year 1868–69.—During the year which has elapsed since the Meeting at Norwich in 1868, the Committee have, with very slight modifications to be noticed hereafter, conducted the excavation on the method described in detail in their First Report (Birmingham, 1865); the Superintendents have continued their daily visits to the Cavern; the Secretary has recorded in his daily journal such facts as have presented themselves; monthly Reports have been regularly forwarded to the Chairman of the Committee; the workmen have continued to be interested in their work, which they have performed with great zeal and integrity; the interest felt by the general public in the progress of the investigation has suffered no diminution; and the arrangements for the admission of visitors, which in previous years worked so satisfactorily for all parties, have in all cases been carried out.

Since the last Report was sent in, the Superintendents have had the pleasure of showing the Cavern and explaining the operations to the Queen of the Netherlands and her suite, the Right Honourable Sir George Grey, the Right Honourable John Bright, and several Members of the British Association, including Sir W. Tite, Mr. G. Griffith (Assistant General Secretary), Professor Tyndall, Mr. W. A. Sanford, Mr. W. Froude, Mr. J. E. Lee, Mr. S. R. Pattison, and others.

Mr. Everett, who is about to proceed to Borneo to explore some of the caverns in that island under the auspices of the Raja of Sarawak, recently spent two days (July 31st and August 2nd) in Kent's Hole, accompanied by one of the Superintendents, for the purpose of studying the operations in detail. It may be hoped that the British Association has in this way been able to render valuable aid to the Committee who have undertaken the important work of cavern exploration in the far east.

The South-west Chamber.—In the Fourth Report (1868) the Committee stated that they were occupied in excavating that portion of the Cavern termed the "South-west Chamber," which, so far as was then known, was the last or most south-westerly branch of the Eastern Series of Chambers and Galleries.

They added that the portion of the Chamber which they had reached was completely closed with an enormous accumulation of Stalagmite, so that it was not possible to form a correct estimate of the size of the apartment, that it was probably much larger than was then supposed, that the only known communication between the Eastern and the Western Divisions of the Cavern was the Vestibule at its opposite or north-eastern end, and that the Superintendents inclined to the opinion that a passage would be found opening out of the South-west Chamber, which would form a second channel of communication between the two Divisions. Respecting the deposits, the Fourth Report stated that, in the eastern part of the Chamber, they were :—first, or uppermost, Stalagmitic Floor, commonly of granular structure; second, the ordinary Cave-earth, with flint implements and the usual Cave-mammals; third, an Old Floor of Stalagmite of great thickness, and of a peculiar crystalline structure; fourth, or lowest, a Rock-like Breccia, in which fragments of grit, not derivable from the Cavern hill, were abundant, and which, though replete with remains of the Cave-bear, had neither bones nor any other indications of Hyæna, Rhinoceros, or other prevalent Cave-species. It was added that in proceeding westward the Cave-earth had thinned out and entirely disappeared, so that the two Stalagmites, between which was its proper place, rested one immediately on the other.

Soon after that Report was presented, the Committee found that a few feet beyond the point where they had lost the Cave-earth, it once more appeared in the section, occupying its accustomed position between the Stalagmites, resting on the Old crystalline mass, and overlaid with that which is granular and comparatively modern. It proved to be merely an insulated patch in contact with the northern wall of the Chamber, along which it extended for a distance of 11 feet. Its maximum breadth was $6\frac{1}{2}$ feet, and depth 32 inches. No sooner did it enter the section than it brought with it the characteristic flint and chert implements, teeth of hyæna, mammoth, and fox, and gnawed bones.

Three of the implements deserve more than a brief mention, as they are very fine specimens, belong to different types, and can scarcely be said to be represented by any previously met with in the Cavern.

The first (No. $\frac{1}{3912}$*) is of a dull light grey colour on the surface, but of an undecided black within. In form it is a trapezoid closely approaching a rectangle, but having the angles somewhat rounded off. It is about 4 inches in length, $2\frac{1}{2}$ inches in breadth, and ·8 of an inch in greatest thickness. It is worked to an edge along the entire margin, and has apparently seen some service as a scraper. With it were found a portion of a chert implement, a molar of bear, molar of hyæna, four other teeth, a gnawed bone, and several small fragments of bone.

The second implement (No. 3918) is a beautifully white flint of porcellanous aspect. Its form is not easy to describe, but it may perhaps be said to be rudely subovoid. Its extreme length is about 3·9 inches, breadth 2·5, and depth ·7 inch. It is flat on one face, and from a point near the centre of the other side is unequally fined off to an edge all round the perimeter.

The third (No. 3922) is of the same kind of flint as the second. Every part of its surface is elaborately chipped. It is flat on one side, uniformly rounded on the other, and worked to an edge all round its circumference. It may be described as a canoe-shaped implement, or a long, narrow, pointed,

* 3912, the denominator, is the number of the box or series of specimens; 1, the numerator, is the number of the specimen in the series; and so on in other cases.—W. P.

nearly symmetrical semiellipsoid, the principal diameters of which are 4·7 inches, 1·3 inch, and ·6 inch. There were found with it several teeth of hyæna, bear, and fox, and a small quartz crystal.

The Cave-earth in which these specimens were found was completely sealed up with the ordinary overlying floor of stalagmite, which, though never quite a foot thick, was at its upper surface almost everywhere in contact with the limestone ceiling of the Chamber, and was nowhere separated from it by an interspace of more than 3 or 4 inches.

The same sections, continued across the Chamber towards its southern wall, successively and uniformly showed that, beyond the patch just mentioned, they contained no Cave-earth, but were made up of one undivided huge accumulation of Stalagmite, every accessible part of which apparently belonged to the Old crystalline Floor, and rested on the Rock-like Breccia. The two, conjoined, not only filled the Chamber, but there was nothing to show that the Stalagmite did not extend upwards to the external surface of the hill. There was no trace of limestone visible; and the workmen had to hew their way through two kinds of material, each more intractable than any ordinary rock, and manfully they addressed themselves to their protracted toil, feeling some gratification in the fact that every inch they advanced was so much added to what had been previously supposed the entire extent of the Cavern.

With some reluctance, it was decided to abandon the practice of breaking up the entire mass of Stalagmite. The men were directed to remove the lower or basal portion of it only, to excavate the underlying Breccia to the depth of five feet instead of four, which from the beginning to this time had been the invariable practice, to leave the upper and greater part of the Stalagmite intact overhead, and to cut a tunnel beneath it, laying bare the limestone wall of the Cavern on each side.

The Stalagmite, as well as much of the Breccia, could only be removed with the aid of gunpowder; and considerable care and judgment were required in order that the remains of bear which both contained, and with which the latter was crowded, should be injured as little as possible.

The Committee have remarked in previous Reports that, on account of its comparatively loose texture, stalagmite is blasted with great difficulty. All, however, that the workmen had previously experienced in this way was inconsiderable in comparison with what they have encountered during the last twelve months. In addition to the usual difficulties, there were others arising from the existence of cavities in the mass, one of which had a capacity of upwards of a cubic yard, into which the boring tool would unexpectedly plunge to inform the men that their labour had been in vain. Not unfrequently a hole which had been bored with great labour, and appeared to be quite satisfactory, would prove to be incapable of being fired on account of its rapidly filling with water, which oozed through the Stalagmite as through a sponge.

The Crypt of Dates.—The Western Division of the Cavern, no part of which has yet been explored by the Committee, bifurcates towards its south-western extremity, and, so far as is at present known, terminates in two capacious chambers, termed the "Cave of Inscriptions" and the "Bears' Den." From the north-east corner of the latter, there extends a narrow gallery between almost vertical limestone walls. The greater part of it was, from time immemorial, occupied by a pool or "Lake" of water about 20 feet long, 8 feet broad, and of unknown depth. It was commonly regarded as the end of the Cavern, and was separated from the Bears' Den by a considerable mound of Stalagmite. This Lake has called forth much speculation. Mr. Northmore believed the Cavern, of which he was the earliest explorer, to have been a temple of Mithras, and he spoke of the water as "the baptismal lake of '*pellucid water*'"*. Others have occupied themselves with guesses respecting the source whence the Lake received its supply, and the mode by which it was kept from overflowing. Some held that it was fed by a small perennial spring; others that it was replenished by the drip from the roof only; whilst a third party contended that there was neither waste nor supply, and that the water ebbed and flowed synchronously with the tides of the ocean.

It is said that one adventurous visitor climbed along its northern or least precipitous side from one end to the other; but, according to the current belief, those who gained the further end usually did so by swimming. They all are said to have brought back the report that the Cavern extended "a very little way beyond the water" Mr. M'Enery, speaking of the water, says, "the Cave beyond it deserves no particular notice; Admiral Sartorius and others have swam across"†.

From the direction and length of the passages leading to them, it was obvious that the Bears' Den and Lake could not be far removed from the South-west Chamber. In this opinion the Superintendents were confirmed by the fact that when, from time to time, they visited the Den during the progress of the excavation of the Chamber, they heard the sound of the workmen's tools with great distinctness, and increasingly so as the work advanced, until at length their voices were heard, and ultimately conversation could be carried on, by means of shouting, however, rather than talking. Finally, on removing the *Modern* granular Stalagmitic Floor in the north-west corner of the Chamber, where it was in contact with the limestone roof, a hole, about 3 inches across, and extending obliquely upwards, was disclosed in the limestone, and it was observed that a current of air occasionally passed through it alternately in opposite directions. The workmen were directed to enlarge the hole by breaking away the limestone, and to ascertain whither it led. As soon as it was of sufficient dimensions, the younger workman, John Farr, ascended through it, and after a short time returned, stating that from the hole he entered a somewhat tortuous passage, having an easterly direction through the limestone, and so narrow and low that it could only be traversed by lying prostrate, and adopting a vermicular motion; that after a few feet he entered a longer passage in which it was possible to turn round and, in some places, to stand erect; that this second passage had a north and south direction, extending both ways a few feet only beyond the point at which he had entered it; that the inner or northern end was closed with stalagmite, on which he observed "writing," and that it terminated southward on the end of the Lake most remote from the Bears' Den.

Farr's report induced the other workman, George Smerdon, and one of the Superintendents, to follow his steps, when they found his description to be correct in all respects. It was further observed that the floor of the longer or north and south passage was entirely composed of stalagmite, and was, in fact, the upper surface of the mass beneath which they had begun to tunnel, and the greater part of which, on account of its enormous thickness and its intractability, they had reluctantly decided to leave intact. At the inner end this floor rose in the form of a steep irregular talus, on which, as well as on

* See Trans. Devon. Assoc. vol. ii. p. 479-495 (1868).
† Ibid. vol. iii. p. 242 (1869).

the walls of the crypt, was the "writing" of which John Farr had spoken. This proved to be a series of initials and dates, amounting, probably, to upwards of a hundred, inscribed on the Stalagmite. Amongst the dates are those of 1744, 1728, 1702, and 1618. In several cases the scribes cut the figure of a square, and inscribed their initials within it.

Inscriptions in more accessible parts of the Cavern have long been well known. The most famous is the following in the "Cave of Inscriptions:"—"Robert Hedges of Ireland, Feb. 20, 1688," which there is good reason to believe is really as old as it professes to be, thus rendering it not improbable that those discovered in the crypt are genuine also.

In looking at those dates, it seems impossible to abstain from reflecting on the facts that they are cut on the upper surface of a mass of stalagmite upwards of 12 feet thick, in a locality where the drip is unusually copious; and that two and a half centuries have failed to precipitate an amount of calcareous matter sufficient to obliterate incisions which at first were probably not more than an eighth of an inch in depth.

It is scarcely necessary to observe that if the Stalagmite had been entirely broken up, as was at first intended, the inscriptions would have been destroyed with it; or that the discovery of them confirmed the decision to remove no more of the nether surface of the floor than would suffice to give the workmen sufficient height for their labour.

The Lake.—As the workmen advanced steadily towards the south-west, every step rendered it more and more probable that a passage would be laid open, leading out of the South-west Chamber in the precise direction of the Lake, and thus furnished an additional motive for tunnelling beneath the floor, in order that the Lake-basin might be preserved.

The removal of the Breccia, and of that part of the Stalagmite immediately above it, disclosed the fact, with which, indeed, the Superintendents were already familiar, that stalagmite is by no means impervious to water. Increased proximity to the Lake rendered this not only more and more patent, but augmented the difficulty of blasting the mass, and caused the labour to be one of great discomfort. It was therefore found necessary to tap the Lake to allow the water to escape. As soon as it was sufficiently dry, the workmen were directed to remove and examine carefully such deposits as might be found lying on the Stalagmitic Floor of the basin. They proved to be, first, or uppermost, the Modern Floor of Stalagmite; second, the ordinary Cave-earth, beneath which was the Old Crystalline Stalagmite of great thickness.

The Stalagmitic Floor, overlying the Cave-earth, was from 10 to 12 inches thick. It was finely laminated, and was soil-stained throughout; but, except at the ends of the basin and along its northern side, where portions of it remained *in situ* in a coherent but brittle condition, it was everywhere resolved into an almost impalpable paste, which, on being subjected to hydrochloric acid, rapidly effervesced and left very little residuum. A heap of this paste thrown outside the Cavern has, on exposure to the weather, hardened into a coherent mass.

In this pulpy mass were found numerous objects, none of which were of much interest, as the following list shows:—

1. Extemporized wooden candlesticks, such as are commonly used by those who visit the Cavern.
2. Pieces of candle.
3. Stems and bowls of clay tobacco-pipes, one of the former being unusually large.

4. Bottles of various kinds—wine, lemonade, and ginger-beer; some entire, but most of them broken.
5. Wine and other glasses, all broken.
6. Fragments of earthenware and china cups.
7. Numerous sticks and branches of trees; many of them charred.
8. A tin sconce.
9. A small iron claw-hammer.
10. The handle of a hammer.
11. A clasp-knife, shut.
12. A two-foot rule, closed.
13. The plate of a child's iron spade.
14. A wooden ink-bottle (?).
15. An oyster-shell.
16. A pecten-shell, apparently used to hold some kind of paint.
17. A wooden spatula.
18. A wooden tally, having the initials W. R. cut on it.
19. A well-squared block of wood, above 5 inches long and broad, and $2\frac{3}{4}$ inches thick.
20. A wooden cover of a salting-pan, or of a small furnace.
21. A portion of a stout iron chain, 44 inches long, consisting of twenty-four links and a swivel, and having a padlock at one end.
22. Numerous broken stalactites, pap-like stalagmites, pebbles, and blocks of limestone.

Many of the objects (such as the candles, candlesticks, bottles, glasses, &c.) present no difficulty. They were, no doubt, thrown into the Lake in frolic, or by those who did not care to carry them further after they had ceased to be of service. Others (such as the knife, foot-rule, hammer, &c.) were probably dropped unintentionally; and the cover of a salting-pan or furnace, as well as the block of wood, may have been used to float candles by the curious. It does not seem easy, however, to account for the chain. It is not an object likely to have been useful during visits to the Cavern, nor is it such as people commonly carry about with them. The pebbles were thrown in, perhaps, in order to the formation of an opinion respecting the depth of the water; and the larger stones probably for the same purpose, or perhaps to be used as stepping-stones by those who desired to traverse the Lake.

It is perhaps worthy of remark that there are no medieval or ancient objects; nor any such as might have been cast in as votive offerings by people who regarded the water with religious veneration.

Mr. M'Enery seems to have believed that there were probably objects of interest in the Lake; he says, "We ought to rake it out" *.

In the underlying Cave-earth in the Lake there were found a fragment of an elephant's jaw containing a perfect molar, the finest specimen of the kind with which the labours of the Committee have been rewarded; a molar of a horse; several more or less perfect bones, including a humerus, an ulna, a scapula, and radii; and a fragment of a large horn-core.

That the Lake was supplied with water by infiltrations through the roof exclusively there is now no manner of doubt, and that some portion of it oozed away through the Stalagmite composing the bottom of the basin is no less certain. The mechanism, however, which rendered it impossible for the Lake to be filled to overflowing was, on examination, very patent and interesting. In its left wall, which is almost naked limestone, there is a natural tunnel

* See Trans. Devon. Assoc. vol. iii. p. 242 (1869).

or watercourse about 30 inches high and 20 inches wide, the base of which, at its junction with the Lake, is 8 inches below the highest level to which the water could rise, and forms an ascensive inclined plane, having an inclination of 3°, and a length of about $3\frac{1}{2}$ feet. Beyond this point the inclination is in the opposite direction, and is very much more rapid. Beyond a distance of 18 feet its course has not been traced, but it seems to ramify in various directions through the limestone. At the common vertex of the two planes, a diaphragm of stalagmite about 9 inches high and something more than 1 inch thick, extends quite across the tunnel from wall to wall, having its upper edge sensibly horizontal, and leaving above it a free open passage several inches high. It is obvious that whenever the water attained to this level the Lake was full, and that the surplus flowed over the diaphragm of stalagmite or natural weir. The fact that this regulated the maximum level of the water is confirmed by a corresponding and strongly marked high-water line along the entire boundary of the Lake. It is equally evident that unless there had been some other means of escape, this height, once reached, would have been permanent. During protracted droughts, however, the water has been known to fall upwards of 2 feet below this level—a fact accounted for by the slow oozing of the water through the Stalagmite.

The entire circumference of the Lake, and especially the almost vertical limestone wall on the south, is thickly studded with coralloidal tubercles of arragonite of various sizes, extending from the high-water to the low-water line. Indeed, they occur quite to the bottom of the Lake, but are less abundant than in the zone just mentioned.

Many parts of the Cavern present phenomena and problems of interest to the physicist as well as to the anthropologist and palæontologist. Thus, to go no further than the Lake, there are:—first, the facts that, at one period, the water entering through the limestone roof formed a floor by precipitating carbonate of lime, and that subsequently water, finding access through the same channel and lodging on this very floor, was capable of dissolving it and reducing it to a mere paste, apparently as calcareous as when it was in the coherent condition; second, that during the work of destruction, coralloidal masses of arragonite were formed on the naked limestone and Old stalagmitic walls, but chiefly on the former; third, that the water had slowly increased the capacity of the Lake, by building a weir of stalagmite entirely across the narrow tunnel which formed its principal outlet; and, fourth, that had time been allowed, this latter process must ultimately have closed the outlet and entirely changed the drainage of the Lake.

From the inscriptions in it, the number of persons who, from time to time, visited the Crypt of Dates, must have been very great; and every one of them must have taken the same route, namely, along the entire length of the Lake. The earliest known mention of the water is that by Polwhele in 1797, in his 'History of Devonshire'*, when its condition appears to have been identical with that in which the Committee found it. Assuming it to have existed, and in the same state when the inscriptions were cut, the scribes must have performed the journey by wading through it, by using a float, by climbing along its almost precipitous northern wall, or by swimming. The last is perhaps the most probable mode; but in either case they must have provided themselves with the requisite tools and with an adequate supply of candles. In some cases the work appears to have consumed a considerable amount of time. If, however, it is supposed that at

* The 'History of Devonshire,' 3 vols. 1797, vol. i. pp. 50, 51.

least most of the inscriptions belong to the time when the upper Stalagmitic Floor of the Lake was yet undissolved, much of the difficulty will disappear, as wading would then have been easy—the Stalagmite would have afforded firm footing, and the depth of the water would not have been very considerable, even if permanently at the overflowing level, and the weir had been as high as it is at present.

The Water Gallery.—Having completed the excavation of the Lake, the workmen resumed their tunnelling operations in the recess or passage leading out of the South-west Chamber in a south-westerly direction, and which, as had been anticipated, was found to extend beneath the floor of the basin and along its entire length. To this branch it is proposed to give the name of "The Water Gallery;" and probably no part of the Cavern surpasses it in interest or importance.

As might have been expected, the deposit it contained was made up of the same materials as everywhere else were found beneath the Old Floor of crystalline Stalagmite—dark red earth; angular, subangular, and rounded pieces of grit not derivable from the Cavern hill, but which the neighbouring and loftier Lincombe and Warberry hills can supply; angular pieces of limestone, and pieces of stalagmite (some of them of great size), which, of course, were remnants of a floor more ancient still than the Old crystalline Floor which lay *above* the Breccia and below the Cave-earth. The points in which the Breccia differed from the Cave-earth were the darker colour of the red soil forming its staple and the much greater prevalence of fragments of grit. By the latter character alone it is very easy to distinguish the materials of the two deposits when thrown into the huge mass of refuse which the workmen have lodged outside the Cavern, especially after exposure to a shower of rain. Many of the pieces of grit, both angular and rounded, were of a very dark colour, and some of them had a polished metallic aspect, somewhat like that of a black-leaded hearthstone. The removal of the smallest splinter, however, showed that both colour and polish were superficial.

Along a considerable part of the length and breadth of the Water Gallery the Breccia, instead of being in contact with the nether surface of the Stalagmitic Floor which formed the bottom of the Lake, was separated from it by a vacuous interspace, sometimes 14 inches deep. It may be described as a rudely lenticular space, as it was of greatest depth in the middle, and, if the phrase is allowable, thinned off in every direction. A correct idea of the complete insulation of this vacuity may be conveyed by stating that if any animal, however small, could have become its occupant it would have been a permanent prisoner unless it could have excavated for itself a passage by which to escape.

Here and there, moreover, the vacuity was interrupted by what may be called "outliers" of Breccia, which reached, and were firmly adherent to the Stalagmite above. In every other part, the ceiling, or lower surface of the Stalagmite, retained traces of the deposit which had once been in contact with it, and on which, indeed, it had been formed. To it there clung angular and rounded pieces of rock, blocks of "*Older*" Stalagmite, and bones, teeth, and almost entire skulls of the Bear; whilst between them, in the ceiling, were the cavities once filled by similar objects, but which had fallen out and were found on the surface of the Breccia beneath. From the ceiling, too, there shot downwards numerous thin pipes of stalactite, of the thickness and colour of goose-quills, some of which reached the Breccia. The surface of the latter deposit beneath was here and there covered with patches of modern stalagmite, occasionally incorporating pipes of stalactite, such as have been just mentioned, which by some means had been broken off. In fact a modern floor was in process of formation, vertically beneath the old one, by the agency of water filtering through the latter, and carrying with it the requisite calcareous matter.

As nothing would have been gained by their removal, the objects just described are left adhering to the ceiling—a fact which induces visitors to regard the Water Gallery as the most attractive branch of the Cavern.

All that portion of the Breccia which was not more than about a foot from its upper surface, and about a yard from the south wall of the Gallery, was invariably cemented into a firm rock-like concrete, but at all lower levels, and at greater distances from the south wall, it was perfectly incoherent. Where it was cemented it was crowded with fossils, but where it was not, there were none. The former was its almost uniform condition in the adjacent South-west Chamber and Lecture Hall, where its fossils formed a very large percentage of the entire mass.

The problem of the severance of the Breccia from the Stalagmite closely occupied the attention of the Superintendents whilst the excavation of the Water Gallery was in progress. There appear, *à priori*, to be three possible solutions,—first, that a stream of water had insinuated itself between the deposit and the floor, and had carried off the detritus which once filled the interspace; second, that, through failure of support at the base, the Breccia had sunk away from the Stalagmite to a slightly lower level; and, third, that water passing slowly through the floor had carried the finer particles of the detritus from the top of the Breccia to lower levels, lodging a portion of them in such interstices as it encountered, and perhaps carrying off the residue as colouring-matter.

The first is met by the fatal objection that there is no channel, large or small, either of ingress or egress, for the hypothetical stream, or the matter it is supposed to have removed.

Since the vacuity was both partial and discontinuous, the second suggested solution requires that the supposed failure at the base should have had the same characters, and hence that the Breccia should have been faulted. To this latter point the closest attention was given from first to last, and no trace of anything like a fault was ever detected.

The third hypothesis presupposes that both the Stalagmite and the Breccia are permeable by water. On neither of these points is there any doubt. Water has been seen oozing through this very Stalagmite, and it is well known that pools which in wet weather are formed on the Breccia disappear in a short time on the cessation of the drip. Indeed, when the Lake was tapped, the water was led to a depression in the surface of the Breccia in the South-west Chamber, and in less than a week the greater part of it had disappeared. There seems to be little doubt that the third is the true solution of the problem of the severance in the Water Gallery.

The animal remains found in that branch of the Cavern at present under notice were, so far as is known, exclusively those of Bear; and many of them are fine specimens, including some splendid canines and molars. Many of the bones were found broken, and some of them had been certainly fractured where they lay, as the parts remained in juxtaposition and, indeed, are reunited by some natural cement. When first exhumed, many of them were so soft that in cleaning them it was found that a soft brush left its traces on their surfaces. Exposure to the air hardens them. Some of the canines have obviously seen considerable service. Many of the molars are beautifully white and fresh, and it is rarely possible to detect any evidence of wear on them. This latter fact was noticed by Mr. M'Enery when speaking of the Bears' molars found in a similar deposit in the adjacent Bears' Den; and was supposed by him to "intimate that the Bears of those days were less exclusively frugivorous than the modern species, and lived partly on flesh" *.

In their Fourth Report, the Committee, speaking of the deposit under the Old crystalline Stalagmite, remarked, "Up to this time the Rock-like Breccia has been utterly silent on the question of the existence of Man; it has given up no tools or chips of flint or bone, no charred wood or bones, no bones split longitudinally, no stones suggesting that they had been used as hammers or crushers. But whilst they have before them the lessons so emphatically taught by their exploration of the Cavern, the Committee cannot but think that it would be premature to draw at present any inference from this negative fact" †.

The cautiousness inculcated in this passage received its justification on March 5, 1869, when a flint flake (No. 3991) was discovered in the Breccia in question in the Water Gallery. The particulars of this discovery were forwarded to Sir Charles Lyell, Chairman of the Committee, by the Superintendents, in the following passage in their Monthly Report, dated April 8, 1869:—"It was found with portions of the teeth of the Cave-bear, lying on a loose block of limestone, in contact with the north wall of the Gallery, in the third foot-level; that is, from 2 to 3 feet below the surface of the Breccia. A section at right angles to its longest axis would be a scalene triangle. The face of the flake represented by the smallest side is the natural surface of the flint nodule from which the specimen was struck. It required no more than three or, at most, four blows to produce it. On its larger face the bulb of percussion is well pronounced. It is partially coated with a thin ferruginous film, occasionally dendritic, and resembling that which . . . . . commonly coats the pebbles found in the Breccia. Beneath this partial envelope it is of a light buff-colour. Its aspect is unlike that of any implements or flakes found in the Cave-earth. None of its edges can be said to be keen, yet it does not appear to have been rolled. One well-rolled small flint pebble occurred in the Breccia in the Gallery.

"Though the flake cannot be regarded as a *fine* specimen, we think there is little or no doubt that it was formed by human agency, and assuming this to be the case, it appears to us to be of very great value, as it was found in a deposit not only older than the ordinary implement-bearing Cave-earth, but separated from it by the Old Floor, which in some cases was upwards of 12 feet thick, and which is certainly of great thickness immediately above the spot where the flake lay. In fact, it was found in a deposit which, so far as the Cave evidence goes, was laid down before the introduction of that in which were entombed the first traces of the Cave-hyæna, Cave-lion, Mammoth, and their contemporaries.

"Being impressed with the probably great importance of the discovery, we carefully addressed ourselves to the question, 'Did the flake originally belong to the comparatively modern Cave-earth in the Lake above and find its way through some crevice in the Old Floor which forms the ceiling of the Gallery?' To this important question we are prepared to give a negative reply; for—

"1st. No crevice or hole of any kind is discoverable in either the upper or lower surface of the ceiling or *Old* Floor.

* See Trans. Devon. Assoc. vol. iii. p. 366 (1869).

† Brit. Assoc. Report, 1868, p. 54.

"2nd. The flake was not found vertically beneath any part of the Lake, but fully a yard beyond its nearest margin.

"3rd. It did not lie on the surface of the deposit, but from 2 to 3 feet beneath it.

"4th. If the flake was originally lodged in the Cave-earth found in the Lake, it must have been the only one deposited there; for when we carefully and completely emptied the Lake no flint implement was met with.

"5th. If the flake had found its way through the Stalagmite, it might have been expected that some such bones as were found in the Lake (Horse and Mammoth, for example) would have descended through the same crevice; but instead of this, the remains of the Cave-bear alone are met with in the Breccia, and teeth of this animal were found in contact with the flake itself.

"In short, there is no crevice through which the object could have passed; if it descended through the floor, it descended alone; and if it did so descend, it ought not to have been where it was found. We have no hesitation in stating that the flake is of the same age as the Breccia which contained it; and that if our opinion of its human origin is confirmed, it is anthropologically by far the most important object the Cavern has yielded."

On June 3rd, 1869, the flake was submitted to Mr. John Evans, F.R.S., a Member of the Committee. He drew up the following statement, with the intention that it should be inserted in the present Report:—"No. 3991 is undoubtedly of human workmanship. It is a flake of flint from the Chalk, one of the smaller facets of which shows the natural crust of the nodule from which it was struck. The other external facet shows the characteristic depression arising from the bulb of percussion on the flake previously removed to form this facet. The flat or internal face of the flake shows a well-developed bulb, and the large but-end where the blow was struck has been fashioned by two or three blows. It has therefore taken four or five blows, each administered with a purpose in view, to produce this instrument.

"Not only, however, has it been artificially made, but it carries upon it evidence of having been in use as a tool; for the edge produced by the intersection of the two principal artificial faces is worn away along its entire length, and exhibits the slightly jagged appearance produced by the breaking off of the sharp edge, such as I find by experience to result from scraping bone or other hard substances with the edge of a flint flake.

"(Signed) John Evans, June 3, 1869."

Besides the above, a small perfectly angular piece of coarse-grained white flint (No. 4037*a*) was discovered in the first foot-level of the Breccia in the Water Gallery on Friday, April 23, 1869. It has all the aspect of having been struck off in making an implement.

Having ascertained by careful measurements that a very few feet would take the workmen into the Bears' Den, it was decided to excavate the Water Gallery no further, as it was deemed undesirable to commence the investigation of the Western Division of the Cavern so long as any branch of the Eastern Division remained unexplored.

The South Sally-Port.—Two long, comparatively narrow, and approximately parallel galleries extend in a south-easterly direction into the eastern wall of the Eastern Division of the Cavern, one from the Great Chamber, the other from the Lecture Hall. They were termed "The Sally-Ports" by Mr. M'Enery, who believed that they ultimately led to external openings in the eastern side of the Cavern hill. On the discontinuation of the excavation of the Water Gallery, the exploration of the South Sally-Port, opening out of the Lecture Hall, was commenced, and at present has been completed to upwards of 40 feet from the entrance.

For the first 15 feet there was the ordinary granular Stalagmitic Floor overlying the typical Cave-earth, but beyond that point there was no stalagmite, except a thin and very limited patch in one or two places. At the junction with the Lecture Hall the floor was 21 inches thick, but it became rapidly thinner as it extended inward; and for some feet it did not exceed an inch in thickness.

No part of the Cavern is at present less than this exposed to drip. It may not be out of place to state here, as a fact of, at least, large generality, and to which there is no known exception, that in those branches of the Cavern where the drip is at present very copious the Stalagmitic Floor is of great thickness; and where the drip is but little, there is either no floor or an extremely thin one; that, in short, the present amount of drip in any locality affords a good index of the thickness of the floor there, so that the external drainage of the Cavern hill appears to have undergone no change for a very lengthened period.

The South Sally-Port presented phenomena having no parallel in the experience of the Committee during the present exploration, but for which Mr. M'Enery's "Cavern Researches" had prepared them. Speaking of the Sally-Ports, or "Long Tongues," he says, "their entire area is honeycombed with fox-holes, and the loam thrown up in mounds round their edges is mixed with scales of the beetle, modern and fossil bones, all of which, as well as the rocky contents, resembled bleached or calcined substances exposed on a common." Indeed his description of the South Sally Port is not very encouraging. He says, "In attempting to reach the extremity of the lower tongue at a point where it suddenly expands into a large grotto, the hollow floor gave way like a pitfall with my weight and sank into a cleft of the rock. I shall not dissemble my terror at my sudden descent. My efforts to escape would but cause the ground to sink still deeper and deeper into deeper abysses.

"'At subito se aperire solum vastosque recessus
Pandere sub pedibus nigraque voragine fauces.'

"The crash routed some animals from their subterranean abodes. I heard them forcing their escape towards the outside through the incumbent earth, and perceived their footmarks. The hounds frequently assemble outside about this point, and frequently earth foxes there" *.

Happily none of the present exploring party have experienced any inconvenience during their researches; but they are constantly meeting with tunnels in the Cave-earth, probably made by some burrowing animals, with ancient and modern bones commingled both on the surface and at all depths below it, with great clusters of the wing-cases of beetles exclusively on or very near the surface; and they have had impressed on them daily the important but familiar truth that unless sealed up with a Stalagmitic Floor, Cavern deposits are just as likely to be fraught with anachronisms as with a trustworthy chronological sequence.

During the present month (August 1869) one of the Superintendents has had occasion to pass frequently through "The Labyrinth," a branch of the Western Division of the Cavern. As he entered it on the 6th he observed some fresh Cave-earth lying on the floor where there was no stalagmite, and he directed the attention of the workmen to it. They had all passed along

* See Trans. Devon. Assoc. vol. iii. p. 302 (1869).

the same route the day before, and they were all satisfied that the earth was not there then. On examination it was found to have been thrown out of a newly made hole, in all respects resembling those made by rats, and extending from the edge of a slab of limestone obliquely through the Cave-earth beneath*.

In the South Sally-Port, the Black Mould, which in most of the other branches of the Cavern was found continuously overlying the Stalagmitic Floor, did not extend many feet within the entrance. Beyond the point at which the Stalagmite ended, the entire deposit was Cave-earth from top to bottom of the section, and in all probability every part of it had been introduced before the formation of the calcareous floor began. In previous Reports the Committee have recorded the fact that in the Stalagmite itself are lodged remains of the Cave-bear, Hyæna, and Rhinoceros. Indeed the only fossil found in the scanty floor in that branch of the Cavern now under consideration was a tooth of the last-named species, which is not only in quite the upper part of the stalagmitic sheet, but, instead of being completely covered, projected above its surface. Obviously, then, *Ursus spelæus*, *Hyæna spelæa*, and *Rhinoceros tichorhinus* outlived the era of the Cave-earth, and therefore it would not be surprising if their remains, together with palæolithic flint implements, were found lying on the surface of this deposit; nor, if they were left unprotected, would there be anything inexplicable or strange if they were found mixed with objects belonging to more recent periods, or even to the present day. Such a commingling might or might not be the result of disturbance and rearrangement when occurring on the surface, but could not be otherwise explained when met with below it.

Be this as it may, it is undeniably the fact that in this, but in no other branch of the Cavern which the Committee have explored, ancient and modern bones, and unpolished flint implements and rude pottery, have been found lying together. Remains of the extinct brute inhabitants of Devonshire are mixed confusedly with those of the present day, and the handiwork of the human contemporary of the Mammoth is found inosculating with the product of the potter's wheel.

It is worthy of remark that whilst potsherds lie on the surface, and the mouths of shafts, connected with the tunnels or burrows, stand open to receive them, instances of their having fallen in are extremely rare. The modern objects found in the body of the Cave-earth are almost without exception such as have been actually taken in by the recent animals which made their homes there.

In a sensibly horizontal tunnel about the size of a fox-earth, at a depth of 4 feet below the surface, there was found a bell, such as huntsmen are wont to suspend to the neck of a terrier when sent in after a fox—a fact which in all probability explains its presence in the spot it occupied.

In other and smaller burrows bundles of moss, each about the size of a man's fist, have been met with and supposed to be the nest of some animal.

Compared with the phenomena of every other branch of the Cavern explored by the Committee, those of this Sally-Port are no doubt anomalous;

* The visits of rats to the Cavern and their habit of carrying off candles have long been well known. In January 1867 the workmen observed a rat in the Cavern on several successive days. At length he made his presence felt in a very disagreeable manner. At 9 a.m. the principal workman placed his dinner, carefully lodged in a bag, in a stout wicker basket. At the dinner-hour (1 p.m.) he found that the rat had eaten a hole through the basket, another through the bag, and carried off every particle of his meal. Poisoned food was at once prepared for the intruder, and nothing further was seen of him until a few days after his dead body was found.

but regard being had to the condition of the deposit in which they occur, they are certainly such as might have been looked for, and they present no difficulty whatever.

Notwithstanding the obvious disturbance of the Cave-earth, the same method of exploration has been followed here as elsewhere; and the specimens found in each "level" and "yard" have been kept apart in separate boxes as heretofore.

Scarcely any branch of the Cavern has surpassed this Sally-Port in the number of the fossils it has yielded, and in no part have finer or more perfect specimens been found. They are the remains of all the common Cave-mammals, with a greater number of the teeth of the Mammoth than have been met with by the Committee within an equal space elsewhere. The bones are generally of less specific gravity, softer, and more brittle than those found in the Cave-earth in other branches of the Cavern—a fact perhaps ascribable to the absence of a calcareous drip. Many of them are gnawed, some have entirely escaped this ordeal, and a few have marks on their surfaces apparently unlike those produced by teeth. Most of them on being cleaned retain impressions of the brush used for that purpose. The surfaces of several are more or less covered with rudely circular punctures of various sizes—a fact observed occasionally in those found elsewhere, but much less frequently than in these in this branch of the Cavern. Lumps of fæcal matter are by no means rare.

The flint and chert implements and flakes are ten in number, three of which were met with on the surface, one in the first foot-level, three in the second, two in the third, and one the position of which is somewhat uncertain.

Four of them only need description. The first (No. 4155) is a splendid heart-shaped chert implement. It was found June 12, 1869, lying on the surface of the Cave-earth, beneath an overhanging ledge of limestone which it almost touched, on the west side of the Sally-Port. It was wrought from a chert nodule apparently selected from the supracretaceous gravel of Milber Down between Torquay and Newton Abbot. It is about $4\frac{1}{4}$ inches long, 3 inches in greatest breadth, and $1\frac{3}{4}$ inch thick at $1\frac{1}{4}$ inch from its broad end. The but-end only retains the original surface of the nodule. It is the only implement of the kind found by the Committee, and none of those figured by Mr. M'Enery at all resemble it.

The second (No. 4259) is of fine-grained silvery grey flint. It is symmetrically canoe-shaped, 3·6 inches long, 1·2 inch broad, and ·4 inch in greatest thickness. It is flat on one side, somewhat rounded on the other, worked to an edge all round the margin, and considerably chipped on both surfaces. It belongs to the same type as the implement (No. 3922) previously described, but is much less rounded on the outer surface. It was found on the Cave-earth, July 5, 1869.

The third (No. 4263) is formed of rather coarse white cherty flint. It is flat on the inner surface, carinated on the outer, and is not highly finished. It is about 4 inches long, 1·3 inch broad, ·6 inch in greatest thickness, and was found July 6, 1869, 2 feet deep in the deposit.

The fourth is strongly carinated on the outer surface; the inner is very concave longitudinally, and slightly convex transversely. It is 3·4 inches long, 1·2 inch broad, and ·5 inch where thickest. It is chiefly remarkable from having a square tang at one end, ·8 inch long and ·6 inch broad, as if for fastening into a haft. Its opposite end is rounded, it is fined off to an edge all round, and it appears to have been used as a scraper. It was found August 5, 1869, 40 feet from the entrance of the Sally-Port, in a small mass of Cave-earth which, without being observed, had slipped off the face of the section; hence its exact position is uncertain.

Charcoal has been found somewhat plentifully on the surface, where a few burnt bones occurred with it. It has also been met with at all depths in the deposit, though in no great quantity.

A few marine shells of common species were met with on the surface.

The fragments of pottery differ in colour and in finish, and probably belong to more than one period. Two or three of them are rather longer than those commonly found in the Cavern.

During the last twelve months Mr. Boyd Dawkins, assisted by Mr. Ayshford Sanford, has made considerable progress in identifying and naming the fossils. He has prepared and sent in a Catalogue of a large number of specimens, accompanied by the following Report.

In the determination of the following animals from Kent's Hole Cavern I have been aided by my friend Mr. Ayshford Sanford. By far the greater portion of the labour has been undergone by him. We have examined upwards of four thousand specimens, or rather less than one-tenth of the whole accumulation of the remains in the hands of the Committee. No bones of birds or fish have been catalogued; the latter Dr. Günther has kindly undertaken to name before our Report is concluded. The results of our work are contained in the following catalogue.

Homo.—We have met with no bones or teeth from the Cave-earth that can be ascribed undoubtedly to man. One or two much-worn or mutilated incisors, however, may be human, but they may also belong to several other animals. The human remains from the prehistoric deposit of Black Mould are exceedingly abundant, and many of them, in Mr. Sanford's opinion, bear evidence of the former existence of cannibals in the Cave. Some of them have been cut and scraped by sharp instruments, the marrow-bones are broken, and are mixed indiscriminately with the broken bones of Sheep or Goat, Red Deer, *Bos longifrons*, and other animals. In one box there are the remains of at least three individuals—a large man, a nearly full-grown woman or lad, and a child about half-grown.

Man has also left his handiwork on some very remarkable fragments of canines of Bear from the Cave-earth, which, in common with many other splinters of bone, are in a totally different mineral condition to that presented by the ordinary Cave-remains. They are much more crystalline, much heavier, and of a darker colour than the ordinary teeth and bones, and have been so mineralized that they present a fracture almost conchoidal, and strongly resembling that of a Greensand chert. One of these had been fashioned into a flake, and one of its surfaces presented the usual traces of use. It had manifestly been formed after it had lost its normal dentinal texture. It is clear, therefore, that they had become fossilized before the introduction of the present Cave-earth. Viewed in connexion with the evidence of the existence of an ancient floor that is now represented by masses of stalagmite, sometimes ossiferous, we cannot resist the idea that they are samples of the contents of the Cave which had in the main disappeared before the introduction of the present Cave-earth.

Felis spelæa.—The Cave-lion is tolerably abundant in the Cave-earth.

Felis, sp.?—A single canine from the Cave-earth indicates an animal of the size of *Lynx cervaria*.

Felis catus?—A lumbar vertebra from the Cave-earth corresponds in size with that of the Wild Cat.

Hyæna spelæa.—The Cave-hyæna is very abundant in the Cave-earth.

Canis lupus.—The Wolf, on the other hand, is comparatively rare.

Canis domesticus.—The remains of the Dog are sparingly met with in the Black Mould, and indicate the presence of more than one variety.

Canis vulpes.—The Common Fox is found in the Black Mould, and sparingly in the older subjacent deposit.

Canis vulpes (var. *spelæus*).—Vulpine bones, on the other hand, from the Stalagmite and Cave-earth indicate an animal larger and stouter than the English Fox. These are not found in the Black Mould.

Canis (size of *C. isatis*).—With the larger bones there are a few much smaller than those of the Common Fox, that correspond most closely with those of *C. isatis*. The vulpine skulls, however, in the Taunton Museum, from the Mendip Caves, rather indicate a species closely related to *C. isatis* than a specific identity, since the true molars are somewhat broader. It is well to mention that Mr. Sanford has identified a portion of a skull found along with the remains of Hyæna, in a cave on the opposite side of Torbay, as belonging to *Canis isatis*.

Gulo luscus.—A single os innominatum of a nearly full-grown Glutton indicates the presence of this rare mammal in the Cave-earth. Although it belonged to an animal not quite adult, it agrees almost exactly in size with that of a fully grown male from Sweden.

Meles taxus.—The remains of the Badger are abundant in the prehistoric Black Mould, rare in the Cave-earth. In the latter case we doubt the truly fossil condition of the bones.

Ursus spelæus.—The bones and teeth of the Cave-bear from the Cave-earth indicate greater variation of size than those of any other wild animal with which we are acquainted.

Ursus priscus=ferox.—This species, which has been proved by Mr. Busk to be undistinguishable from those of the North-American Grizzly Bear, occurs abundantly in the Cave-earth, as it does also in the caves of the Mendip Hills. The short stout bones of *U. spelæus* are represented by flatter, longer bones of *U. ferox*, that are for the most part distinct from the rounder bones of *U. arctos*. We therefore have attributed the isolated flat long bones to the second of these species. Bones of intermediate form, however, occur which appear to connect the two forms. They are more constant in size than those of the other two bears.

Ursus arctos.—Teeth and bones of the Brown Bear, still living in Europe, occur, but not very commonly, in the Cave-earth. Some of those from the Black Mould are evidently derived from the lower and older beds; but others, from their condition, apparently belong to animals that lived at the same time as *Bos longifrons* and the Sheep or Goat of the Black Mould.

Elephas primigenius.—The Mammoth is but sparingly met with in the Cave-earth.

Rhinoceros tichorhinus.—The remains of the Woolly Rhinoceros are abundant in the Cave-earth.

Equus caballus.—The Horse is the most abundant fossil in the Cave-earth. Many of the teeth are more or less plicident, but we are unable to draw any sharp line separating the *Equus plicidens* of Prof. Owen from the recent species. They present almost endless variations in this respect, and were apparenly in a state of transition from the plicident to the common type in the postglacial times.

Bos primigenius.—The Urus exists somewhat sparingly in the Cave-earth.

Bison priscus.—The Bison, on the contrary, is much more common in the same deposit.

Bos longifrons.—Bones and teeth of the Celtic Shorthorn occur in the Black Mould. The small bones in the Cave-earth belong to the preceding species.

Cervus megaceros.—The Irish Elk is not uncommon in the Cave-earth.

Cervus elaphus (=*Strongyloceros spelæus*, Owen=*C. destremii*, Serres).—We have come to the conclusion that the Red Deer was more variable in size during the postglacial period than at the present day. Some teeth are not larger than those of a small hind from the Hebrides, while others surpass in size those of the largest Haddon or Horner Hart. Some even almost rival those of the smaller specimens of the Irish Elk. The animal occurs both in the superficial Black Mould and in the Cave-earth.

Cervus tarandus.—The Reindeer is abundant in the Cave-earth.

Cervus capreolus.—We have met with the Roedeer only in the Black Mould; it was evidently a common article of food.

Ovis aries, Capra hircus.—The Sheep and the Goat are abundant in the Black Mould.

Sus scrofa.—The Pig occurs in the Black Mould only; it is small in size, and was evidently an article of food.

Lepus timidus.—The remains of the common Hare are abundant in the Black Mould, but are rare in the Cave-earth and Stalagmite. In these deposits they are for the most part replaced by larger and stouter bones, which may perhaps be referred to *Lepus diluvianus* of the French naturalists. These stout bones are very rare in the Black Mould.

Lepus cuniculus.—Bones of the Rabbit are abundant in the Black Mould; a single bone has occurred apparently from the Modern Stalagmite, but none from the Cave-earth.

Lagomys spelæus.—We have met in the Cave-earth with a lower jaw of the Cave Pika. It is rather smaller than the type, and is closely related to that of *Lagomys pusillus.*

Arvicola amphibius.—The Water-rat, or one of the closely allied varieties, we have met with, but not abundantly, in the Cave-earth and Black Mould.

Arvicola agrestis.—There are one or two specimens from the Cave-earth of this species that show the same variation in the direction of *A. ratticeps* which Mr. Sanford has remarked in jaws from the Mendip Caves.

Arvicola glareola (=*A. pratensis*).—We have met with a single lower jaw from the Cave-earth.

Arvicola Gulielmi.—This new species of Vole, discovered lately by Mr. Sanford in the caves of Mendip, is represented by a jaw from the Cave-earth. It may be recognized by its uniting a size which nearly approaches that of *A. amphibius* to the dentition of *A. subterraneus.*

Castor fiber.—We have met with five specimens of the Beaver from the Cave-earth.

Phocæna communis.—A solitary scapula of this cetacean has been furnished by the Black Mould.

In this list we have merely noticed the species that have passed through our hands, without reference to the previously published list of animals from the Cave.

Report of the Committee on the Connexion between Chemical Constitution and Physiological Action. The Committee consists of Dr. A. Crum Brown, Dr. T. R. Fraser, *and* Dr. J. H. Balfour, *F.R.S. The investigations were conducted and the Report prepared by* Drs. A. Crum Brown *and* T. R. Fraser.

Drs. Brown and Fraser communicated to the Section, at the Norwich Meeting, the results of some experiments (the details of which have since been published in the Transactions of the Royal Society of Edinburgh) on the connexion between change of chemical constitution and change of physiological activity.

They have since that time continued their investigations by applying the method described in the above communication to the alkaloids, atropia, conia, and trimethylamine. The substances which they have compared in reference to their physiological action are, atropia and the salts of methylatropium, conia, methylconia, and the salts of dimethylconium, salts of ammonia, trimethylamine, and tetramethylammonium. They have made in all about 120 experiments, and give in the accompanying Table the results of thirty-six, in which the dose was not much above or below the minimum fatal. It will be seen that these results confirm the conclusions at which they formerly arrived, viz. that the action of compounds of triatomic nitrogen is different from that of compounds in which the nitrogen is stably pentatomic, and that salts of ammonium bases act on the peripheral terminations of the motor nerves in the same way as curara. This action, and the absence of convulsant action, appear to be generic characters of the salts of ammonium bases. Besides this, the salts of the ammonium bases frequently retain certain of the special (specific) actions of the nitrile bases from which they are derived.

Tabular Summary of Experiments with Doses that are about the minimum fatal.

Number of experiment.	Substance employed.	Animal and its weight.	Method of exhibition.	Dose.	Effect.
1.	Iodide of methyl-atropium.	Rabbit, 3 lb. $13\frac{1}{2}$ oz.	Subcutaneously.	2·5 grs.	Dilatation of pupils; slight and then decided paralysis; faint tremors; and *recovery* (in more than two hours and ten minutes).
2.	Do.	Rabbit, 3 lb. 10 oz.	Do.	3 grs.	Ditto; and *death* (in fifty-eight minutes).
3.	Do.	Dog, 8 lb. 6 oz.	Do.	10 grs.	Dilatation of pupils; rapid and decided paralysis; very faint tremors; and *death* (in thirty-two minutes).
4.	Do.	Frog, 392 gr.	Do.	0·005 gr.	Paralysis; complete suspension of reflex excitability (motor-nerve conductivity being retained); and complete *recovery* (in less than two hours).

TABLE (*continued*).

Number of experiment.	Substance employed.	Animal and its weight.	Method of exhibition.	Dose.	Effect.
5.	Iodide of methyl-atropium.	Frog, 455 gr.	Subcutaneously.	0·025 gr.	Complete paralysis, with suspension of motor-nerve conductivity; and *recovery* (in less than twenty-four hours).
[a]6.	Do.	Frog, 422 gr.	Do.	0·1 gr.	Complete paralysis, with suspension of motor-nerve conductivity, during first, second, third, and fourth days; and *recovery* on fifth day.
7.	Do.	Frog, 260 gr.	Do.	0·3 gr.	Complete paralysis, with suspension of motor-nerve conductivity in thirty minutes; muscular contractility was retained until the sixth day; loss of muscular contractility and some *rigor* (*death*) on seventh day.
8.	Do.	Rabbit, 3 lb. 12 oz.	by stomach.	30 grs.	None.
9.	Sulphate of methyl-atropium.	Rabbit, 3 lb. 7½ oz.	subcutaneously.	2 grs.	Dilatation of pupils; decided paralysis; faint twitches; and *recovery* (in about thirty minutes).
10.	Do.	Rabbit, 2 lb. 7 oz.	Do.	2 grs.	Ditto; and *death* (in forty minutes).
11.	Do.	Frog, 460 gr.	Do.	0·1 gr.	Complete paralysis, with suspension of motor-nerve conductivity in about forty minutes; retained muscular contractility until fifth day; loss of muscular contractility with some *rigor* (*death*) on sixth day.
12.	Iodide of ethyl-atropium.	Rabbit, 3 lb. 8½ oz.	Do.	2 grs.	Dilatation of pupils; decided paralysis; faint tremors; and *death* (in about thirty minutes).
[b]13.	Sulphate of atropia.	Rabbit, 4 lb. 10 oz.	Do.	5 grs.	Dilatation of pupils, and no serious symptom.
14.	Do.	Do.	Do.	10 grs.	Ditto.
[b]15.	Do.	2 lbs. 5 oz.	Do.	15 grs.	Ditto, diuresis, catharsis, and languor, followed by *recovery*.

[a] No symptom of exaggerated reflex activity occurred during this experiment.
[b] Same rabbit at intervals of several days.

TABLE (*continued*).

Number of experiment.	Substance employed.	Animal and its weight.	Method of exhibition.	Dose.	Effect.
[c]16.	Sulphate of atropia.	Dog, 8 lb. 6 oz.	subcutaneously.	10 grs.	Dilatation of pupils; decided paralysis; frequent tetanus; and *recovery*.
17.	Sulphate of atropia.	Frog, 447 gr.	Do.	0·4 gr.	Incomplete paralysis first day; spasms second day; tetanus fourth to sixth days; stiff reflex movements seventh day; and *recovery* eighth day.
18.	Do.	Frog, 404 gr.	Do.	0·4 gr.	Complete paralysis first and second days; tetanus third to ninth day; spasmodic movements tenth and eleventh days; and *recovery* twelfth day.
19.	Hydrochlorate of methylconia.	Rabbit, 3 lb. 14¼ oz.	Do.	0·1 gr.	No obvious effect.
20.	Do.	Rabbit, 2 lb. 10½ oz.	Do.	0·2 gr.	Exaggeration of reflex activity; decided paralysis; and *death* (in twenty-two minutes).
[d]21.	Do.	Frog, 175 gr.	Do.	0·2 gr.	Proof of paralysis of motor endorgans at early stage.
22.	Iodide of dimethylconium.	Rabbit, 3 lb. 6½ oz.	Do.	2·5 grs.	Slight paralytic symptoms and *recovery*.
23.	Do.	Rabbit, 4 lb.	Do.	3 grs.	Decided paralysis; faint tremors; and *death* (in about one hour and fifteen minutes).
[e]24.	Do.	Frog, 225 gr.	Do.	0·1 gr.	Complete paralysis for three days; and *recovery*.
[f]25.	Hydrochlorate of conia.	Rabbit, 3 lb. 6½ oz.	Do.	0·2 gr.	Tremors and decided paralysis; exaggerated activity; and *death* (in about thirty-two minutes).
[g]26.	Do.	Frog, 364 gr.	Do.	0·1 gr.	Paralysis of motor nerves, and *death* on fourth day.
[h]27.	Hydrochlorate of trimethylamine.	Rabbit, 3 lb. 2½ oz.	Do.	7 grs.	Very slight paralysis &c.; and *recovery*.

[c] Same dog as used in experiment 3.
[d] Some evidence of reflex exaggeration.
[e] No evidence of exaggerated reflex activity.
[f] Dr. Christison's preparation ; a specimen from Mr. Morson was found to be less active.
[g] Some evidence of exaggerated reflex activity.
[h] Strong odour in breath of trimethylamine in a few minutes.

TABLE (*continued*).

Number of experiment.	Substance employed.	Animal and its weight.	Method of exhibition.	Dose.	Effect.
28.	Hydrochlorate of trimethylamine.	Rabbit, 3 lb. $7\frac{1}{2}$ oz.	Subcutaneously.	11 grs.	Slight sleepiness, salivation for a few minutes, defæcation and urination, decided paralysis, spasms, and *death*.
29.	Do.	Frog, 345 gr.	Do.	0·5 gr.	Tonic spasm in anterior and left posterior extremities (right cut off from poisoning by ligature of its vessels); complete paralysis of left sciatic nerve (right remaining active); and *death*.
30.	Iodide of tetramethylammonium.	Rabbit, 3 lb. $1\frac{1}{2}$ oz.	Do.	0·7 gr.	Salivation (very profuse and long continued); lachrymation; decided paralysis; slight tremors; and *recovery*.
31.	Do.	Rabbit, 2 lb. 14 oz.	Do.	12 grs.	Ditto; and convulsions; and *death*.
	Do.	Frog, 497 gr.	Do.	0·04 gr.	Tonic spasm, and motor endorgan paralysis; and *recovery*.
33.	Do.	Frog, 425 gr.	Do.	0·05 gr.	Ditto; and *death*.
34.	Chloride of ammonium.	Rabbit, 3 lb. 12 oz.	Do.	12 grs.	Partial paralysis; frequent tetanus; and *recovery*.
35.	Do.	Rabbit, 2 lb. 8 oz.	Do.	15 grs.	Decided paralysis; frequent tetanus; and *death*.
[1]36.	Do.	Frog, 435 gr.	Do.	0·5 gr.	Partial paralysis; starts and other symptoms of reflex exaggeration; complete paralysis of motor nerves and muscles; and *death*.

[1] Evidence of motor nerves being paralyzed before muscles.

Of the various substances included in this Table, atropia possesses the most remarkable special (specific) actions, viz. a dilating action on the pupils and a paralyzing action on the cardiac inhibitory branches of the vagi nerves. It will be seen from the two following experiments that the salts of the methyl derivative of atropia retain these special actions:—

Experiment 37. One minim of a solution of 1 grain of sulphate of methyl-atropium in 100,000 minims of distilled water ($=\frac{1}{100000}$ of a grain of sulphate of methyl-atropium) was placed on the right eyeball of a rabbit.

Before the application the right pupil measured				$\frac{15}{50}\times\frac{14}{50}$, and the left		$\frac{15}{50}\times\frac{14}{50}$	of an inch.
39 mns. after the application	,,		,,	$\frac{16}{50}\times\frac{15}{50}$	,,	$\frac{15}{50}\times\frac{14}{50}$	,,
1 hour	,,	,,	,, ,,	$\frac{17}{50}\times\frac{15}{50}$	,,	$\frac{15}{50}\times\frac{14}{50}$	,,
1 hr. 30 ms.	,,	,,	,, ,,	$\frac{18}{50}\times\frac{17}{50}$	,,	$\frac{15}{50}\times\frac{14}{50}$	,,
2 hs. 10 ms.	,,	,,	,, ,,	$\frac{18}{50}\times\frac{17}{50}$	,,	$\frac{15}{50}\times\frac{14}{50}$	,,
22 hrs.	,,	,,	,, ,,	$\frac{15}{50}\times\frac{14}{50}$	,,	$\frac{15}{50}\times\frac{14}{50}$	,,

Experiment 38. The two vagi nerves were exposed in the neck of a rabbit, and on separately subjecting the trunk of each nerve to galvanic stimulation of a certain strength (obtained by the use of Du Bois-Reymond's induction-apparatus), it was found that stoppage of the heart's contractions resulted on each occasion during the five seconds the galvanic stimulation was applied. A solution containing half a grain of sulphate of methyl-atropium in fifteen minims of distilled water was then injected under the skin of the abdomen.

5 minutes....	after the injection	the heart was contracting	28 times in 10 seconds.
7 "	" "	" "	28 " "
7 mns. 10 secs.	" "	the right vagus was galvanized for 10 seconds, and the heart continued to contract during the galvanism..........	28 times in 10 seconds.
10 minutes....	after the injection	the heart was contracting	29 " "
19 "	" "	" "	30 " "
20 "	" "	the left vagus was galvanized for 10 seconds, and the heart continued to contract during the galvanism..........	30 times in 10 seconds.
20 mns. 20 secs.	after the injection	the heart was contracting	30 " "
26 " 0 "	" "	" "	30 " "
26 " 20 "	" "	the right vagus was galvanized for 10 seconds, and the heart continued to contract during the galvanism..........	30 times in 10 seconds.

It was also found that the special actions on the pupils and on the cardiac inhibitory branches of the vagi nerves are possessed by the ethyl derivative of atropia.

Report of a Committee, consisting of Lieut.-Col. Strange, *F.R.S.*, Professor Sir W. Thomson, *F.R.S.*, Professor Tyndall, *F.R.S.*, Professor Frankland, *F.R.S.*, Dr. Stenhouse, *F.R.S.*, Dr. Mann, *F.R.A.S.*, W. Huggins, *F.R.S.*, James Glaisher, *F.R.S.*, Professor Williamson, *F.R.S.*, Professor Stokes, *F.R.S.*, Professor Fleeming Jenkin, *F.R.S.*, Professor Hirst, *F.R.S.*, Professor Huxley, *F.R.S.*, *and* Dr. Balfour Stewart, *F.R.S.* *, *appointed for the purpose of inquiring into, and of reporting to the British Association the opinion at which they may arrive concerning the following questions:—*

I. *Does there exist in the United Kingdom of Great Britain and Ireland sufficient provision for the vigorous prosecution of Physical Research?*

II. *If not, what further provision is needed? and what measures should be taken to secure it?*

Your Committee, having sought the counsel of many of the most eminent men of science of the United Kingdom upon these questions, so far as it was found practicable to do so, and having carefully deliberated thereon, have arrived at the following conclusions:—

I. That the provision now existing in the United Kingdom of Great Britain

* The following names have since been added to the Committee:—Alfred Tennyson, F.R.S.; Lyon Playfair, F.R.S., M.P.; J. Norman Lockyer, F.R.S.

and Ireland is far from sufficient for the vigorous prosecution of Physical Research.

II. It is universally admitted that scientific investigation is productive of enormous advantages to the community at large; but these advantages cannot be duly reaped without largely extending and systematizing Physical Research. Though of opinion that greatly increased facilities are undoubtedly required, your Committee do not consider it expedient that they should attempt to define categorically how these facilities should be provided, for the following reason:—

Any scheme of scientific extension should be based on a full and accurate knowledge of the amount of aid now given to science, of the sources from which that aid is derived, and of the functions performed by individuals and institutions receiving such aid. Your Committee have found it impossible, with the means and powers at their command, to acquire this knowledge. A formal inquiry, including the inspection of records to which your Committee have not access, and the examination of witnesses whom they are not empowered to summon, alone can elicit the information that is required; and, as the whole question of the relation of the State to Science, at present in a very unsettled and unsatisfactory position, is involved, they urge that a Royal Commission alone is competent to deal with the subject.

Your Committee hold that this inquiry is of a character sufficiently important to the nation, and sufficiently wide in its scope, to demand the use of the most ample and most powerful machinery that can be brought to bear upon it.

Your Committee therefore submit, as the substance of their Report, the recommendation that the full influence of the British Association for the Advancement of Science should at once be exerted to obtain the appointment of a Royal Commission to consider—

1. The character and value of existing institutions and facilities for scientific investigation, and the amount of time and money devoted to such purposes.
2. What modifications or augmentations of the means and facilities that are at present available for the maintenance and extension of science are requisite; and,
3. In what manner these can be best supplied.

On Emission, Absorption, and Reflection of Obscure Heat. *By* Prof. Magnus*.

There was a time when heat was considered to be very different from light. Now, however, we are persuaded that the only difference between them is the length of the waves by which they are produced and propagated. Therefore I thought that the well-known laws of the radiation and absorption of light must also exist for heat. I followed in these thoughts Mr. Balfour Stewart, who, ten years ago, and several years before Kirchhoff and Bunsen had propounded their theory, published a paper in which he developed nearly the same ideas for heat as these philosophers did for light.

I will endeavour to give some of the results at which I arrived; but

* A communication ordered to be printed *in extenso* among the Reports.

before doing this, I must mention that for these experiments it was necessary to obtain the rays from the body examined unmixed with those of the flame or of any substance by which the body is heated. I succeeded in this by making use of a stream of heated air in which the body was suspended.

I found that different substances heated to 150° C. emit different kinds of rays; some only one kind, or waves of one length, and others waves of many different lengths. To the first class belongs pure Rock-salt. There is an analogy between the heat emitted by this body and the light produced by its vapours, or rather of the Sodium it contains. The light from this substance gives only one line in the spectrum, and the heat also is only of one wave-length. It is monothermic, as its vapour is monochromatic.

Rock-salt absorbs the heat given out by Rock-salt, while it absorbs almost none of that given out by other substances.

There is another crystallized substance, the chloride of potassium, called Sylvin, very like rock-salt in its behaviour; but it is not monothermic, because it absorbs the heat from different substances, not in a very high degree, but to a greater extent than rock-salt does.

If our eyes would allow us to see the dark heat as we see light, and we could project a spectrum of the heat of rock-salt, we should see but one line. But in making use of the heat emitted by chloride of potassium a longer space would be illuminated, but not so long as from lampblack or from a flame.

Here also is an analogy between the heat and light given off by chloride of potassium.

I then made experiments on the reflection of heat, and I found that Silver, Glass, Rock-salt, Sylvin, and Fluorspar reflect nearly the same quantities of heat coming from a flame, from Lampblack, Glass, or from other substances. But of the heat from Rock-salt, the Fluorspar reflects five times as much as of that from other substances. Of the heat from Sylvin the Fluorspar reflects three times as much.

It follows from these experiments that if obscure heat were visible, and if Rock-salt were used as the source of heat, we should see the Fluorspar brighter than all other bodies, as far as I know at present. With Sylvin as the source of heat we should see the Fluorspar bright, but not so bright as in the heat from Rock-salt.

Although invisible to the eye there are millions of rays of heat passing between different substances, being partly absorbed and partly reflected; and although we are surrounded by these motions, we cannot observe them but by special experiments.

The analogy between light and heat seems to me to be complete.

Report on Observations of Luminous Meteors, 1868–69. *By a Committee, consisting of* James Glaisher, *F.R.S., of the Royal Observatory, Greenwich, President of the Royal Microscopical and Meteorological Societies,* Robert P. Greg, *F.G.S., F.R.A.S.,* E. W. Brayley, *F.R.S.,* Alexander S. Herschel, *F.R.A.S., and* Charles Brooke, *F.R.S., Secretary to the Meteorological Society.*

The Catalogue of the Tenth Report of this Committee contains the results of assiduous observations of shooting-stars, directed principally to the periodical dates when shower-meteors are usually expected to occur. Many observations are, besides, recorded from the published accounts, and privately communicated descriptions of observers on the large meteors which have appeared with more than ordinary frequency during the interval of the year elapsed since the presentation of the last Report.

The general insufficiency of some of the observations, for the purpose of determining approximately the real distance of the meteors, is not greater than must always be expected to arise, when a due allowance is made for the unprepared condition of observers at the moment of the appearance of such unusually large and brilliant meteors as have during the past year been seen in some abundance. The comparison of some of the accounts contained in the present list has, nevertheless, led to satisfactory conclusions regarding the real height and course of some of the splendid fireballs recorded in the paragraphs of this Report. Among those which principally appear to have afforded elements of strict mathematical calculation may be mentioned the observations made in France on the large fireball of the 5th of September, and those at Cambridge and in Paris on the detonating meteor of the 31st of May last.

Some interesting communications on the same subject, bearing especially on the extent, velocity, and direction of the currents observed to exist in the loftiest regions of the atmosphere, are included with the heights of certain persistent meteor-streaks determined by Professor Newton, in the United States, on the 14th of November last. These observations, with the last-mentioned descriptions of bright meteors seen at the same time in England and on the Continent, are contained in the first Appendix of the Report.

The occurrences of new aërolites and of other large meteors are described in detail, and frequent minor notices of similar appearances from foreign sources are placed in the second Appendix; to which is added a Catalogue of recent fireballs, completing up to the present time the very comprehensive list of such appearances which, since their first Report, Mr. Greg has continued with unfailing industry to collect for the Committee.

The observations reported in the next Appendix show that the periodical star-shower of August, in the past and present years, has been made the subject of increasing attention in England and on the Continent. The systematic observation of the rate of frequency, time of maximum, and apparent position of the radiant-point has not yet cleared up some of the perplexities which surround the exhibition of this well-known but not yet thoroughly explained phenomenon. The possible prevalence of several maxima, and an apparent oscillation of the radiant-point in successive years between tolerably wide limits in the constellations Perseus and Cassiopeia, are features of this meteoric current which especially call for further investigation. The characteristic appearances of the meteors, both as to magnitudes and to the abundance and duration of their luminous streaks, are also points of principal and recurring interest.

Owing to the exceptionally overcast state of the sky in England during the whole of the winter and summer months of the past year, the number of observations of the ordinary shower-meteors of October, December, January, and April last have not only been unusually deficient, but observers in England were unfortunately deprived of more than partial views of the great star-shower of the 14th of November last. Several interesting notices of the bright display, from transatlantic and continental stations, will, however, be found in the third Appendix; and that and previous reappearances of the star-shower are further illustrated by papers in the fourth Appendix of the Report. Some insight into the physical structure of the November meteoric cloud has, it will thus be seen, been derived from the simultaneous observations of its recent principal displays at places as far apart in longitude as Shanghai, Calcutta, Greenwich, and the observatories of the United States. It appears that the central and most compact portion of the stream was twice encountered in the years 1866 and 1867, while in the years 1865 and 1868 respectively, two outlying currents of greater width, but of less considerable density, were crossed, one on either side of the central stream, and separated from it, the former in front of, and the latter behind its margin, by an equally broad well-defined space comparatively devoid of meteors. This curious circumstance, first pointed out by Mr. Marsh, of Philadelphia, is drawn from observations at the conclusion of Appendix IV.

A review of several important papers published, and received by the Committee, during the past year, occupies the whole of the fourth and last Appendix of the Catalogue. The consideration now generally bestowed upon observations of luminous meteors is sufficiently rewarded by the occasional perusal of such papers of eminent scientific interest in the special branches of aërolitic and meteoric astronomy; while the present zeal of observers is evinced by their association together in France and Italy to record in a regular and systematic form, under the direction, at Metz, of a luminous meteor committee like that of the British Association, the transitory phenomena of meteors and falling-stars. In consequence of the combination of observers to observe shooting-stars together on stated nights, it cannot be doubted that a great accession to the present state of knowledge of this class of bodies will thus, in the course of a few years, be obtained. The star-showers of April last, which, on account of the unfavourable state of the weather, were unperceived in this country, were yet conspicuously seen at Moncalieri near Turin, and at Urbino, and the radiant-points of these meteoric epochs of the 10th, 20th, and 30th of April, already previously established by the British Association, received an unexpected confirmation.

With the object of furthering the views, and assisting the progress of meteoric science in its most highly productive sphere of observation, the Committee, in presenting this their Tenth Annual Report, express the hope that the same success may continue to attend their future efforts which has rewarded them in the first period of their existence, and which was originally bequeathed to them by the great and talented author of the annual Reports to the British Association on observations of luminous meteors, when, in the year 1860, after compiling the present Catalogue alone and presenting it unassisted to the British Association for fifteen years, he for the first time placed the preparation of these Reports, and the annual collection of observations of luminous meteors, in the hands of a committee.

A CATALOGUE OF OBSERVATIONS

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m s 5 52 p.m.	Between N. Foreland and Broadstairs.	Apparent diameter about one-fifth that of the full moon.	Rather deep blue.	6 seconds ...	First appeared ver[y] close to Mar[s]. Passed about 6[°] under the moo[n] and disappeare[d] under Altair [,] at an altitu[de] of about 1[0°] above the h[o]rizon.
1866. Sept. 17	10 22 p.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	From η Dracon[is] α= δ= to 224° +48[°]
17	10 22 30 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ½ (ζ, [η]) Draconis to Cygni.
17	10 55 p.m.	Ibid	=1st mag.*, then =♃.	Deep yellow and ruby.	2·5 seconds ...	From α Persei to Aurigæ.
17	11 0 p.m.	Ibid	=1st mag.*	Yellow	2 seconds......	α= δ= From 9° −18[°] to 348 −27
17	11 22 p.m.	Ibid	=3rd mag.*	Blue	1 second	α= δ= From 90° +27[°] to ε Geminoru[m]
Oct. 28	10 46 p.m.	Ibid	=1st mag.*.........	Blue	0·75 second ...	α= δ= From 346° − 5[°] to 333 −16
Nov. 18	5 40 p.m.	Wadhurst (Sussex).	Splendid meteor ...	....	....	Appeared near t[he] moon.
1867. Aug. 19	9 27 p.m.	Birmingham ...	=2nd mag.*	Red	1·5 second ...	α= δ= From 49° +48° to α Pegasi.
20	9 15 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ζ Aquilæ [to] θ Serpentis.
21	11 30 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From κ Boötis t[o] Lyræ.
21	11 52 p.m.	Ibid	=Sirius	White	1 second	From ε Caprico[rni] to λ Piscis A[us]tralis.
27	11 3 p.m.	Ibid	=1st mag.*	White	0·75 second ...	α= δ= From 305° +20[°] to 291 − 8
27	11 3 p.m.	Ibid	=3rd mag.*	Blue	1 second	Through the bo[dy] stars of Came[lo]pardus.

OF LUMINOUS METEORS.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ıe nucleus was followed by a flame-coloured tail about 2° long. It was twice nearly extinguish-ed in its course, but both times regained its luminosity.	....	Inclining towards the earth.	The horizon itself was invisible.	James Chapman.
....	....	From Radiant $R_{1,2}$	....	W. H. Wood.
....	....	From Radiant V	....	Id.
t a tail 12° long or one second. Ruby-coloured sparks issued rom the meteor.	....	From Radiant $R_{1,2}$	Beautiful colours.........	Id.
t a train for 1½ second	....	From Radiant U	....	Id.
....	....	From Radiant $T_{2,3,4}$ ...	Meteors five or six per hour.	Id.
....	....	From Radiant R_3........	....	Id.
l not leave much train	....	....	Though the moon was brilliant, the meteor was yet very bright; even brighter than those of November 14th, 1866.	Communicated by A.S.Herschel.
a streak	....	From Radiant ε Cassio-peiæ.	....	W. H. Wood.
....	....	From Radiant ε Cassio-peiæ.	....	Id.
....	....	From Radiant M G_5 ...	....	Id.
a streak	....	From Radiant Q G	....	Id.
....	....	From Radiant ε Cassio-peiæ.	This meteor nearly si-multaneous with the next.	Id.
....	15°	From Radiant ε Cassio-peiæ.	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1867.	h m					
Aug. 27	11 20 p.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	From α Delphini t α Pegasi.
27	11 20 p.m.	Ibid	=Sirius	Orange colour	1·5 second ...	α= δ= From 329°−13° to 310 −19
27	11 35 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	From ε to δ Aquil
27	12 0 p.m.	Ibid	=3rd mag.*	Blue	2 seconds......	α= δ= From 336°−21° to 348 −18
28	12 1 a.m.	Ibid	=2nd mag.*	Blue	1·5 second ...	From α Aquarii α Equulei.
28	12 7 a.m.	Ibid	=1st mag.*.........	Blue	1 second	From ι to β Ceti.
28	12 18 a.m.	Ibid	=1st mag.*.........	Blue	0·5 second ...	From π Andromed to γ Pegasi.
Sept. 3	10 40 p.m.	Ibid	=3rd mag.*	Blue	1 sec.; slow motion.	α= δ= From 335°+18° to 350 +15
3	10 42 p.m.	Ibid	>1st mag.*	White	0·3 sec.; rapid	From α Triangu α= δ= to 40°+32°
3	10 45 p.m.	Ibid	=1st mag.*	Yellow	0·5 second ...	α= δ= From 347°− 7° to 353 −18
3	10 50 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From α Delphini α Equulei.
22	10 15 p.m.	Ibid	=3rd mag.*	Blue	1·5 second ...	α= δ= From 0°− 6° to 335 14
24	10 20 p.m.	Ibid	=2nd mag.*	Blue	0·75 second...	α= δ= From 121°+61° to 196 +71
28	9 20 p.m.	Ibid	>1st mag.*	Blue, then white.	0·5 second ...	From α Lyræ to Ophiuchi.
Oct. 3	10 3 p.m.	Ackworth, Pontefract (Yorkshire).	=2nd mag.*	Bright white..	2 secs.; rapid	α= δ= From 12°+12° to 13 + 8
8	10 10 p.m.	Birmingham ...	>1st mag.*	Deep blue ...	0·75 second...	α= δ= From 298°+30° to σ Aquilæ.
18	9 57 p.m.	Ackworth, Pontefract (Yorkshire).	=1st mag.*	Yellowish ...	3 secs.; slow motion.	α= δ= From 70°+50° to 310 +60 Rather north the zenith.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	From Radiant $Q_3 a$	This meteor followed at a brief interval by the next.	W. H. Wood.
....	....	From Radiant R_3........	Average rate of frequency 12 per hour; fine clear night.	Id.
....	....	From Radiant V	Commencement of this meteor-shower not seen; but meteors came in groups between $9^h 30^m$ and 11^h p.m., with nearly a quarter of an hour's interval of repose.	Id.
....	....	From Radiant ζ Capricorni.	....	Id.
....	....	From Radiant β Ceti ...	....	Id.
....	....	From Radiant B_4........	....	Id.
....	....	From Radiant ε Cassiopeiæ.	....	Id.
....	....	From Radiant Q_3	Path curved laterally ...	Id.
....	....	From Radiant T_1........	Meteors four in ten minutes. Clouds prevented further observations.	Id.
....	....	From Radiant B_5........	A severe thunderstorm..	Id.
....	....	From Radiant B_3........	....	Id.
....	....	Vertically down. From Radiant R G.	The last 10° of its path curved.	Id.
t a train for 2 seconds	....	From Radiant G	One meteor in an hour; fine night.	Id.
t a streak	....	From Radiant ε Cassiopeiæ.	Fine nights on the 10th, 19th, and 25th; no meteors seen. Night of the 28th overcast.	Id.
ghtest in the middle of s course.	$4\frac{1}{2}$°	.... 	....	J. E. Clark.
t a smoky streak	....	From Radiant B_4........	....	W. H. Wood.
a fine train which did ot last.	50°	Directed from Capella...	Two small meteors about 9 o'clock.	J. E. Clark.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1867. Oct. 18	h m s 9 57 3 p.m.	Ackworth, Pontefract (Yorkshire).	=1st mag.*	Yellowish ...	$1\frac{1}{4}$ sec.; slow	α= δ= From 60°+50° to 35 +47
18	10 16 p.m.	Ibid	=2nd mag.*	Red	2 secs.; very slow.	From 296·5°+1° to 289 −3
19	10 11 p.m.	Ibid	=Sirius	Red	2 secs.; very slow.	Near Rigel ......
19	10 20 p.m.	Ibid	=1st mag.*	Red	$2\frac{1}{2}$ seconds ...	Disappeared ve near Jupiter.
19	10 33 p.m.	Ibid	=1st mag.*	White	0·75 second ...	In the south; the left of Jupit
20	10 4 p.m.	Ibid	=$2\frac{1}{2}$ mag.*	Red	$3\frac{1}{2}$ secs.; very slow.	In the south; the left of Jupit
20	10 14 p.m.	Ibid	=3rd mag.*	White	1·5 second ...	In the direction wards and n Jupiter.
20	11 17 p.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	From τ to ε gasi.
20	11 20 p.m.	Ibid	=1st mag.*	Orange colour	0·75 second ...	From α Orionis of the way tc Tauri.
Nov. 3	About 9 0 p.m.	Ackworth, Pontefract (Yorkshire).	....	....	....	....
16	6 10 to 6 40 p.m.	Ibid	=1st to 4th mag.*	....	....	In the E. ......
17	8 37 p.m.	Ibid	=1st mag.*	White	1·5 second ...	α= δ= From 295°+48° to 283 +37
21	8 20 p.m.	Ibid	Half as bright again as ♃.	Yellowish ...	1 sec.; rapid motion.	First appeared n η Pegasi, disappeared clouds near piter.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left no streak		From Capella, towards S.W.	Another meteor at 10^h 12^m p.m.	J. E. Clark.
Left a fine thin train	11°		Very distinct. Another meteor appeared at 10^h 25^m p.m.	Id.
Left a fine train of a greenish tinge.	10°		Very oscillating motion	Id.
Left a red train of varying brightness.	15°		Two meteors about simultaneous with this.	Id.
Left a dull train	5°		From the same Radiant as the last.	Id.
Left a slight train	10°		Almost disappeared during its course.	Id.
Left a slight train	10°		Opposed in its direction to the last. Another at 10^h 16^m p.m.	Id.
		From Radiant $R_{1, 2}$		W. H. Wood.
		From Radiant S_1 (?)		Id.
			On this night and the following five meteors were observed.	J. E. Clark.
			Eight meteors were seen	Id.
	14°		Fluctuated in its course. Another meteor appeared near Aquila at 8^h 28^m p.m.	Id.
Left a bright train for 3 seconds.	40°	Moved along a line parallel to β, α Pegasi. 	The observer's back being turned to the meteor, his attention was drawn to it by the reflected light, and its course was marked by the persistent streak.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1867. Nov. 21	h m s About 8 25 p.m.	Ackworth, Pontefract (Yorkshire).	=3rd mag.*	White	0·5 second ...	α= δ= From 272° +38° to 267 +39
21	10 8 p.m.	Ibid	=2nd mag.*	White	Almost instantaneous.	About 1½° to righ[t] of Rigel.
22	About 7 20 p.m.	Ibid	=3rd mag.*	White	2 seconds......	2° to left of α Cen[-] tauri [?].
26	10 2 p.m.	Ibid	About 4′ apparent diameter.	Brilliant white	3 seconds......	α= δ= From about 48° −3[.] to about 65 −5[.]
26	10 34 p.m.	Ibid	=3rd mag.*	Red	1·5 second ...	α= δ= From 55° −13° to 55 −20
27	8 50 p.m.	Ibid	=2nd mag.*	White	0·25 sec.; rapid	First appeared almost in th[e] zenith, near [.] Persei.
28	7 17 p.m.	Ibid	=3rd mag.*	Red	0·5 sec.; rapid	Centre of pat[h] midway betwee[n] the head of Arie[s] and the Pleiades
1868. Feb. 4	7 35 p.m.	Ibid	=♃	White	1 second	In the W.S.W. from about 30[°] to 22° above th[e] horizon.
July 14	10 50 p.m.	Street (Somerset).	=1st or 2nd mag.*	....	....	In Draco ....
15	10 35 p.m.	Ibid	=2nd mag.*	White	....	Commenced at [.] Draconis.
30	5 55 50 a.m. (local time).	Italaya Observatory, Brazils.	Apparent diameter about 43′ of arc.	Colour of the electric light.	17 seconds ...	Commenced 30[°] from the meridian in the east which it crossed at S. Decl. 65[°] (Zen. dist. 42[°] 32′), and disappeared behind a hill 50° 15′ west of south.
Aug. 10	10 51 p.m. (local time).	Rome	Large meteor	....	....	From the head of Boötes, across the hand of Hercules to the hand of Ophiuchus.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ke a small molten drop falling out of Vega Lyræ.	11°	Perpendicular to the horizon. 	Ten meteors seen from 8^h to 8^h 30^m p.m.	J. E. Clark.
....	$\frac{1}{3}$°	.... 	....	Id.
first scarcely visible ...	2°	....	....	Id.
e nucleus was followed by a short bright red tail, and proceeded by three successive jerks, apparently gradually fading.	25°	....  	Seen through light clouds, which obscured the smaller stars. A large halo of light surrounded the meteor, which sensibly illuminated the landscape.	Id.
adually faded out	7°	Almost perpendicularly down.	....	Id.
....	3°..........	Moving towards Cassiopeia.	Another meteor appeared above Orion at 8^h 45^m p.m.	Id.
....	7°..........	Directed from α Persei 	....	Id.
ed gradually from sight	10°	.... 	....	Id.
o meteors appeared bout the same time.	....	....	....	Id.
....	10°	Towards Corona Borealis.	....	Id.
bular, followed by a ain 9° long, oval and preading at the end. oth tail and nucleus ere as bright as the ectric light, emitting minous drops and very sparks.	Length of visible path 77° 41′.	[? Apparent] motion inclined 17° 40′ to the ecliptic; retrograde.	At the appearance of the meteor, the compass-needle oscillated 15° from the north towards the west; six minutes later, a detonation was heard in the south-west.	'Anglo-Brazilian Times,' August 7th, 1868. Dr. F. Massena and Messrs. Arsenio and Veija.
a large meteor of the ovember shower.	....	....	Seen also at Civita Vecchia by Professor Pinelli.	Mme. Scarpellini, 'Annales de l'Observatoire de Bruxelles' for 1868–69, p. 164.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Aug. 15	h m 10 13 p.m.	Primrose Hill, London.	=$1\frac{1}{2}$ mag.*	White	....	α= δ= From 337°+45° to 316 +30
15	10 36 p.m.	Ibid	=2nd mag.*	White	....	From 23°+43° to 360 +20
23	10 12 p.m.	Ibid	> ♃	Bright orange, then fiery red.	$2\frac{1}{2}$ seconds; moved slowly.	From 310°+44° to 335 +34
25	9 33 p.m.	Ibid	=3rd mag.*	White	Moved slowly	From 301°+29° to 335 +31
25	10 7 p.m.	Ibid	=2nd mag.*	White	....	From 328°+32° to 345 +29
25	10 49 p.m.	Ibid	=3rd mag.*	White	Moved very swiftly.	From 11°+87° to 245 +33
25	10 54 p.m.	Ibid	=$2\frac{1}{2}$ mag.*	....	....	From 30°+65° to 126 +61
25	10 57 p.m.	Ibid	=$1\frac{1}{2}$ mag.*	Orange colour	....	From 221°+78° to 259 +50
Sept. 5	Between 7 and 8 p.m.	Pic de Sancy, France.	Large meteor	....	Between 4 and 5 seconds.	Disappeared ex- actly at β Urs Majoris.
5	About 8 0 p.m. (Paris time)	Clermont, France	Large meteor	....	12 seconds ...	Started from th mountains of F rez, in the eas passed north Clermont, a disappeared b fore reaching t mountains of Puy de Dôme, the west.
5	8 18 p.m. (Paris time)	Geneva..........	Many times larger than Jupiter.	Colourless, or reddish.	Moved slowly; about 20° or 30° per sec.	The meteor pass close by η Ur Majoris.
5	A few minutes before 8 30 p.m., Turin time.	Aosta, Piedmont	Many times brighter than a 1st mag.*	Brilliant white; with yellowish or pinkish tinge.	Moved slowly, as if resisted in its flight.	Appeared in t east; travers the whole visi horizon of t valley of Aos towards the W.N.W., a disappeared hind the hills that direction.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
eft a long tapering streak	....	From Radiant, near B Camelopardi.	This and the next very much alike. One more meteor from α Aquilæ.	T. Crumplen.
eft a streak like the last	....	From the same Radiant as the last.	....	Id.
eft a train on two-thirds of its course. Threw off a few small sparks.	....	....	A splendid meteor with perceptible disk.	Id.
eft a slight train	....	Downwards to left. From Radiant, near β Cygni.	....	Id.
....	10°	From the same Radiant as the last.	....	Id.
eft a faint train which faded instantly.	....	....	....	Id.
....	....	....	Imperfect view	Id.
eft a train on about half its course.	25°	....	Very fine meteor; colour very marked.	Id.
ne whole length of the meteor from the head to the point of the rocket-like tail 10°. It neither changed colour nor form during its passage, and went suddenly out.	Not less than 45°.	Direction exactly parallel to the horizon.	The time of its appearance was about half an hour before the moon rose; a very imposing meteor both for magnitude and steadiness of movement. Another large meteor was seen at Ashford (Kent) on the same evening (The Times, Sept. 10).	B. F. Smith; 'The Times,' Sept. 8th, 1868.
ne meteor gradually decreased in volume as if by the loss of sparks, which remained without descending to the earth along the bright luminous streak. This remained visible on the whole of its course for some time.	....	From due E. to W........	A most brilliant meteor. No sound was heard after its disappearance. (See a calculation of its path in Appendix I.)	'Comptes Rendus,' Sept. 21st, 1868.
ew a long tail, but left no distinct streak on its course. It did not burst, but disappeared gradually in the distance.	....	Its path was horizontal	The commencement not seen, but the light as it passed caught the observer's eye.	E. Jones.
llowed by a long tapering tail of smaller width than the nucleus, and losing itself at last in a faintly luminous vapour.	....	Horizontal	At the same time and in the same direction (from E. to N.W.) a meteor of the same appearance was observed at Moncalieri. A splendid meteor was also observed at the same time (9^h p.m., *Roman time*) at Florence.	F. Denza; 'Stelle Cadenti del Periodo di Agosto Osservati in Piemonte nel 1868,' p. 55.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868.	h m					
Sept.10	10 11 p.m.	Tooting, London	=3rd mag.*	White	Very brief ...	α= δ= From 222°+40° to 226 +28
10	10 33 p.m.	Birmingham ...	=2nd mag.*	Blue	0·5 second ...	From ρ Pegasi to Aquari.
10	10 50 p.m.	Tooting, London	=3rd mag.*	White	½ second	α= δ= From 180°+70° to 188 +57
10	10 51 p.m.	Birmingham ...	=1st mag.*	Yellow	0·25 second ...	From 270°+29° to 270 +10
10	11 1 p.m.	Ibid	=3rd mag.*	Reddish	0·5 second ...	From 325°− 2° to 321 −11
10	11 16 p.m.	Ibid	=3rd mag.*	Blue	1 second	From 270°+10° to 267 + 5
12	About 11 0 p.m.	Pitlochrie (Perthshire).	=1st mag.*.........	Reddish white	2 seconds ...	After pursuing one third of its cours it passed over α Lyræ.
12	About 11 0 p.m.	Ibid	=2nd mag.*	White	0·75 second ...	Close to L Camelopardi.
13	Between 9 15 and 10 5 p.m.	Ibid	=3rd mag.*	Reddish	0·5 second ...	Commenced near Persei.
13	Between 9 15 and 10 5 p.m.	Ibid	=3rd mag.*	Dull reddish...	1 second	Near δ Boötis .....
13	Between 9 15 and 10 5 p.m.	Ibid	=2nd mag.*	White	0·75 second ...	Commenced near Andromedæ.
13	Between 9 15 and 10 5 p.m.	Ibid	=1½ mag.*	White	0·75 second ...	Commenced nea and below α Andromedæ.
13	10 31 p.m.	Birmingham ...	=2nd mag.*	Blue	0·5 second ...	Midway between Pegasi and Arietis.
14	About 10 30 p.m.	Pitlochrie (Perthshire).	=1½ mag.*	White	Slow motion; 2 seconds.	Commenced in Custos Messium Disappeared 5 below α Persei.
14	About 10 30 p.m.	Ibid	=3rd mag.*	Dull	....	Commenced in th square of Camelopardus.
23	9 26 p.m.	Ackworth, Pontefract (Yorkshire).	=3rd mag.*	White	0·3 second ...	α= δ= From 280°+87° to 245 +78
26	3 26 a.m.	Ibid .... (lat. 53° 40′ W., long. 1m 20s·5.)	=1st mag.*	White	0·2 second ...	From 52°+10° to 48 + 9
26	3 27 a.m.	Ibid	=2nd mag.*	White	0·3 second ...	Near ρ Eridani ...

ppearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ɛft a streak which instantly disappeared.	....	Slightly curved path ...	Sky clear; no moon; careful observation.	W. Jackson.
ucleus followed by an adhering tail.	....	From Radiant $T_{2,3,4}$...	Fine clear night	W. H. Wood.
ɛft a streak which was nmediately extinguished.	....	....	Stars brilliant; carefully observed.	W. Jackson.
....	....	From Radiant $N_{12,13}$ ...	....	W. H. Wood.
....	....	From Radiant B_5	....	Id.
....	....	From Radiant B_5	....	W. Jackson.
....	More than 25°.	Directed from α Cygni	....	R. P. Greg.
....	About ½° ...	Directed towards Ursa Major.	....	Id.
ɩcleus phosphorescent and trained.	....	....	....	Id.
ke a small nebulous body	5°	Directed from Ursa Minor.	....	Id.
ft a streak	7°...........	Directed towards α Persei.	From Radiant T_2.........	Id.
....	....	Fell vertically	From Radiant E in Lacerta.	Id.
....	More than 10°.	Directed from Radiant Q G or T_1.	....	Id.
....	12°	Directed from Radiant N 15 (?).	....	Id.
....	10°	Fell vertically, nearly from the direction of Cygnus.	....	Id.
....	10°	....	....	J. E. Clark.
t a train which lasted or 4 seconds.	4½°	 Directed from α Tauri... 	....	Id.
; a train for 5 seconds	3° or 4° ...	.... 	Apparently directed from the same Radiant-point as the last meteor.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Sept. 29	h m Evening ...	Troy, U. S. America.	Large meteor	Bright rose and red.	10 seconds ...	First appeared an altitude about 50° in t N.E.
Oct. 7	About 10 15 p.m. (Paris time).	Chirac, Lozére, France.	As bright as the full moon.	Like moonlight; bluish.	About 3 secs.	Disappeared ne Ursa Minor.
7	At night ...	Liskeard (Cornwall).	20′ or 30′ in diameter.	Red and blue..	....	....
7	About 11 30 p.m.	Sandwich (Kent).	Large meteor	....	....	....
7	About 11 45 p.m.	Leytonstone ...	Large meteor	....	3 or 4 seconds	It started from t centre of t heavens and tc a southerly rection.
7	About 11 45 p.m.	Walworth, London.	Large meteor	Purple and red	....	Descended to right of cluster of st known as C siopeia's Chai
7	11 48 p.m.	Wolverhampton	About the apparent size of full moon.	Colours of the train orange, yellow, and blue.	....	Disappeared a f degrees ab the northern h rizon.

ɔearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
:owed by a very brilliant train. When half way on its course it exploded and threw out a great quantity of brilliant white sparks, the meteor still pursuing its course.	Length of the bright streak 30°.	Inclined to the horizon at an angle of between 70° and 80°.	A magnificent meteor; seen by many observers.	'The Troy Whig,' Oct. 1st, 1868.
; a train of brilliant ɔarks in the form of an longated cone, with its ase at Ursa Minor.	....	From S. to N.	The sudden flash of the light was like that of the full moon emerging from behind a cloud. The meteor itself not seen. No detonation heard. Time certainly before 10^h 30^m p.m.	Abbé Trueize and Abbé Boiral; 'Les Mondes,' 2nd ser., vol. xviii, p. 332.
first an ordinary shooting-star, expanding almost instantaneously to a deep red ball; followed by a stream of vivid red light, pale bluish near the ball, 1° wide, and 20° in length. Before disappearing, the ball became bright blue, and ultimately burst, emitting numerous luminous fragments, which were instantly extinguished.	....	....	....	'The Times,' Oct. 13th, 1868.
ɪrisingly grand and illiant appearance.	....	From S. to N.	The heavens appeared for a moment to be a mass of fire.	'Daily Telegraph,' Oct. 9th.
ɪeteor of remarkable illiancy, which disapared suddenly.	....	From N. to S. [?]	The observer's attention was first drawn to the meteor by an unusual and startling light.	W. H. L. (Ibid).
....	....	....	The night was very fine and clear, and the meteor cast an immense glare around. Doubtless the largest meteor ever seen.	H. R. (Ibid).
rst it was just like star, and in its course increased in a startg manner, until at t it reached the aprent size of the moon l exploded, scattering s of light in all dions.	About 15° or 20°.	From nearly S. to N. ...	No meteor seen on the 14th of Nov. 1866 was equal to it in magnitude. The light with which objects were illumined was sufficient for the observer to have picked up a pin.	W. H. Wood; 'Midland Counties Express.'

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Oct. 7	h m s About 11 50 p.m.	Brighton (Sussex).	Large meteor	Blue, then red	....	....
7	About 11 50 p.m.	Ramsgate (Kent).	A great fireball ...	The body white, and the tail of all the colours of the rainbow.	Lasted fully half a sec.	....
7	About 11 50 p.m.	Wimbledon	Very large meteor	Red	Lasted several seconds.	....
7	About 11 53 p.m.	Gordon Square, London.	Large meteor	....	Lasted only a moment.	....
7	About 11 55 p.m.	Sandown, Coast-guard Station, Isle of Wight.	At first a small fire-ball, gradually enlarging.	Various	2 or 3 seconds	First appeared considerable height above horizon, due
7	11 59 54 p.m. (Paris time)	Belleville, Paris	Apparent diameter 30′.	At first white, then red. The fragments blue, yellow, and green.	7 seconds......	Passed from s of α Cephe north of η Minoris, and wards betwe and γ Ursæ noris.
7	About 12 0 p.m. (local time).	Angers, France...	Large meteor	....	About 1·5 sec.	At an appa altitude of above the rizon.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
e meteor itself not seen. The whole heavens seemed to be a mass of bright blue light followed immediately by a crimson hue of equal brilliancy.	....	....	The night was clear and frosty. The observer's attention was attracted by seeing the shadows of houses clearly thrown across the parade.	J. Fuller; 'Midland Counties Express.'
cket-like. A huge fire-ball with a flare of light ike the comet seen at London some years ince. It came silently nd collapsed suddenly.	....	Descending towards the earth.	A very startling and imposing meteor. The whole sky seemed on fire. The flash of light illumined the interior of a room, at Bekesbourne, for 4 or 5 seconds.	Adam Dickson (Ibid).
ed ball emitting bright parks, and followed by flaming tail of great ength.	....	....	The sky was clear. A vivid flash of bluish light illumined surrounding objects, overpowering the light of the moon, and casting actual shadows on the ground.	P. H. Lawrence; 'The Times,' Oct. 9th.
dden flash of light like ghtning.	....	....	A beautiful starlight night. Seen also in several parts of the metropolis.	T. F. P. (Ibid).
increased from a small ball, so as, in about two seconds, to obscure the moon; and burst into "variegated stars, springing from a body which assumed the shape of a huge luminous diving-bell; I can liken t to nothing else."	....	Descended in an easterly direction at an angle of about 45° towards the horizon.	During twenty-eight years' night-watching, and twelve more spent at sea, no meteor was before seen so large and brilliant.	John Burt; 'Daily Telegraph,' Oct. 10th.
dually increased until, n crossing Ursa Minor, burst; the fragments reading in a cone, 15° de at the base, which as turned towards the rth. The meteor at e same time turned d, and the fragments re blue, yellow, and een.	....	From S. to N.	About 5^m 28^s after its disappearance, a loud explosion like the bursting of a mine in the neighbourhood was heard. The explosion was heard at Paris also by M. Le Bacilly [Ibid.]; and the meteor was seen at Düsseldorf, in Germany ['Les Mondes,' Second Series, xviii, 282].	Mons. Tremechini; 'Comptes Rendus,' vol. lxvii, p. 771, Oct. 12th, 1868.
....	....	Directed towards N.E...	An extremely bright meteor. No sound of an explosion was heard.	Mons. Morren (Ibid).

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Oct. 7	h m 12 0 p.m. (local time).	Tilloy les Conti, Somme, France.	Large meteor	....	Very brief duration.	....
7	About 12 0 p.m. (local time).	Brussels, Belgium.	Large meteor; brighter than the moon.	....	Very rapid ...	Disappeared in the N.W.
10	11 10 p.m.	Birmingham ...	=2nd mag.*	Blue	1·5 second ...	From $\alpha=0°$ $\delta=+25°$ to π Pegasi.
10	11 17 p.m.	Ibid	=2nd mag.*	Dull white ...	2 seconds......	From $\alpha=4°$ $\delta=+15°$ to 358 +15
11	12 45 a.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ϕ_2 to β Orionis.
11	12 52 a.m.	Ibid	=1st mag.*.........	Blue	0·2 second ...	From $\alpha=75°$ $\delta=-3°$ to 74 −7
11	1 0 a.m.	Ibid	=3rd mag.*	Dull...........	0·5 second ...	From $\alpha=60°$ $\delta=+22°$ to φ Aurigæ.
11	7 1 p.m.	Ackworth, Pontefract (Yorkshire).	=♃..................	Red	1·5 sec.; very slow speed.	In the west; 10 above the horizon.
15	9 22 p.m.	Tooting, London	About=3rd mag.*	White	1 second	From $\alpha=269°$ $\delta=+30°$ to 260 +15
15	9 22 p.m.	Ibid	About=3rd mag.*	White	1 second	From ½ (α, γ) to (ε, ζ) Cygni.
16	7 45 p.m.	Whitby (Yorkshire).	....	....	....	From the st[ar] to the we[st] [? α] of Andro[meda], to abo[ut] the star Alg[e]rith [? α] Taurus.
17	12 1 a.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	From α Arietis to Pegasi.
17	11 58 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From o_2 Orionis ν Ceti.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
……	……	Moving from E. to W…	The meteor cast a vivid light. A few moments after its disappearance there was heard a dull rumbling sound like that of a carriage rolling over a pavement.	Mons. Roze; 'Comptes Rendus,' vol. lxvii. p. 771, Oct. 12th, 1868.
eft a luminous streak on its course.	……	From S.E. to N.W… …	The meteor threw a strong light. Seen also at Louvain, Liége, and Antwerp. According to the description at Paris, a violent explosion was heard a few minutes after its disappearance.	M. Marchal; 'Annales de l'Observatoire de Bruxelles' for 1868–69, p. 168.
……	……	From Radiant, γ Ceti; or $R_{1,2}$.	……	W. H. Wood.
……	Foreshortened course.	From Radiant $T_{2,3}$, …	……	Id.
……	……	From Radiant F_2……	……	Id.
……	……	From Radiant F_2……	……	Id.
……	……	From Radiant, γ Ceti or U.	……	Id.
ft a slight streak……	2°……	…… 	……	J. E. Clark.
ft a streak which was extinguished at once.	……	……	This and the next two meteors were observed within a quarter of a minute of time.	W. Jackson.
ft a streak which lasted rather longer than that of the previous meteor.	……	……	No moon; stars very bright. Another minute meteor was seen, almost simultaneous and nearly in the same position, with this one.	Id.
……	……	Directed from the Radiant O in Orion.	Two other meteors appeared at about 11^h p.m. from the bright star in the head of Petus [? α Ceti] to the head of Capricornus.	B. Livingstone; 'Daily News.'
……	……	From Radiant R_3 ……	……	W. H. Wood.
t a streak ……	……	Directed from Radiant O	……	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Oct. 17	h m s 10 5 p.m.	Ackworth, Pontefract (Yorkshire).	=1st mag.*	White	0·4 second ...	α= δ= From 5°−17° to 3 −25
17	10 50 p.m.	Somerton (Somersetshire).	About=1st mag.*	Bright white...	....	Disappeared near α Draconis.
18	12 8 a.m.	Birmingham ...	=3rd mag.*	Dull	0·5 second ...	From α to ε Orionis.
18	12 9 a.m.	Ibid	>1st mag.*	Green and red	1·5 sec.; slow speed.	α= δ= From 55° 0° to γ Eridani.
18	12 23 a.m.	Ibid	=3rd mag.*	Reddish	0·5 second ...	From η Eridani α= δ= to 47°−22°
18	12 23 30 a.m.	Ibid	=2nd mag.*	Blue	1 second	From β to θ Arietis
18	12 25 a.m.	Ibid	=1st mag.*.........	White	0·5 second ...	Shot from μ Eridani towards α Leporis.
18	Between 9 15 and 9 35 p.m.	Tooting, London	About=3rd mag.*	Dull white ...	2 or 3 seconds	Just beyond and parallel with the south edge of the Milky Way; near the zenith.
18	9 54 p.m.	Birmingham ...	=3rd mag.*	Blue	1 second	From the Pleiades to α Trianguli.
18	About 10 0 p.m.	Tooting, London	Rather bright meteor.	....	Moved slowly	About halfway between the 'Pointers' (α, β Ursa Majoris) and Capella.
18	10 21 p.m.	Hornsey Road ...	Large meteor	Bright white...	4 to 6 seconds	It passed from a little south of α Cassiopeiæ to ½ (γ, δ) Cygni and onwards ¼ of the way to the horizon.
18	10 26 p.m.	Tooting, London	=3rd mag.*	....	½ second	From between Pleiades and Aldebaran, a little nearer the former than the latter to ½ (α, λ) Orionis.
18	10 47 p.m.	Ibid	=2nd mag.*; larger and brighter than the last.	....	1 second	It began under Pleiades and ended between β and γ Arietis.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left no streak	8°...........	....	....	W. H. Wood.
Left a slight train which vanished immediately.	....		....	Id.
....	....	From Radiant O	....	Id.
Left a streak	....	From Radiant A_{16}	....	Id.
....	....	From Radiant $A_{14, 15}$ ...	....	Id.
....	....	From Radiant $R_{1, 2}$......	....	Id.
....	More than 10°.	From Radiant A_{16}	Intercepted view.........	Id.
Passed slowly, giving out a broad but not very bright streak which was instantly extinguished.	60°	....	Probably the same meteor as that seen at Hornsey Road at 10^h (? 9^h) 21^m p.m.; no moon; stars less bright than on the preceding night.	W. Jackson.
....	....	From Radiant O	One meteor in 15 minutes; sky hazy; overcast at 10^h 45^m p.m.	W. H. Wood.
....	Its course curved thus—  about half a degree.	Almost horizontal, towards Ursa Major.	Between 10^h and 11^h p.m. three small meteors moved on a line a few degrees below and parallel to Pleiades and Jupiter, the second below the first, and the third below the second; all of the same length of course as that line.	W. Jackson.
Left a bright sheet of light on its course for 1 or $1\frac{1}{2}$ minute.	....	....	Very fine meteor and fine streak.	T. Blunt; 'Daily News,' Oct. 1st.
....	....	....	....	W. Jackson.
Left a bright streak which was at once extinguished.	....	In a direction parallel to a line from η Tauri to α Arietis.	Careful observation......	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Oct. 18	h m s 10 58 p.m.	Tooting, London	=3rd mag.*	....	....	Commenced a litt below ½ (β Au rigæ, Castor).
19	7 33 p.m.	Birmingham ...	=3rd mag.*	Pale blue......	1 sec.; slow speed.	From κ Cygni to Draconis.
19	10 52 p.m.	Ibid	=1st mag.*	Yellow	2 seconds ...	From ½ (Pleiade ζ Persei) $\alpha=$ $\delta=$ to 0°+24°
19	11 7 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From 80°+90° to the Pleiades
19	11 10 p.m.	Ibid	=2nd mag.*	Blue	0·75 second...	From ζ to β Tau
19	11 21 p.m.	Ibid	=1st mag.*.........	Pale blue	0·5 second ...	From β to θ A rigæ, and 2° fu ther.
19	11 35 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	Commenced at Aurigæ.
19	11 40 p.m.	Ibid	=2nd mag.*	Yellow	1 second	$\alpha=$ $\delta=$ From 94°+18° to 96 +20
19	11 42 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	From γ Orionis σ Eridani.
19	11 42 30 p.m.	Ibid	=1st mag.*	Yellow	1 second	From ζ Tauri to Persei.
19	11 48 p.m.	Ibid	=Sirius	White, orange, dull red.	4 seconds......	From π_1 Orion $\alpha=$ $\delta=$ to 148°+80°
20	12 4 a.m.	Ibid	=2nd mag.*	Yellow	0·5 second ...	From ξ Ceti to Piscium.
20	12 11 a.m.	Ibid	=3rd mag.*	Dull	0·25 second ...	Appeared at $\alpha=$ $\delta=$ 85°+15°
20	12 12 a.m.	Ibid	=Sirius	White	1 second	From 120°+49° to 139 +45
20	12 17 a.m.	Ibid	=2nd mag.*	Orange	0·5 second ...	From 105°+37° to 129 +51
20	12 29 a.m.	Ibid	=1st mag.*.........	Orange	1 second	From θ Geminor $\alpha=$ $\delta=$ to 128°+56°
21	8 12 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	Appeared at $\alpha=$ $\delta=$ 20°+5°
21	9 25 p.m.	Tooting, London	=2nd mag.*	White	3 seconds......	From near τ to (ζ, ε) Herculis

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	From the direction of α Orionis.	....	W. Jackson.
....	....	From Radiant U, or $T_{2,3,4}$.	....	W. H. Wood.
Left a green train 25° in length.	....	From Radiant O	....	Id.
....	....	From Radiant L II or O	....	Id.
Left a streak	....	From Radiant O	....	Id.
....	....	From Radiant F_2........	From $10^h 30^m$ to $11^h 30^m$ p.m. four meteors seen.	Id.
....	20°	Towards Polaris, from Radiant O.	....	Id.
Left a green streak.........	....	From Radiant O	....	Id.
....	....	From Radiant O	....	Id.
Left a red streak...........	....	From Radiant O	....	Id.
Meteor showed two maxima and minima. Changed colour from white to red, nearly disappearing, and progressing some distance as a dull object. Left a streak of 30° in length, the first half green, the last red, which lasted five seconds.	The first 5° foreshortened; whole path 80°.	From an unknown southern Radiant.	....	Id.
....	....	From Radiant G	....	Id.
....	10°	Directed towards π_1 Leonis.	From Radiant O	Id.
....	....	From Radiant F_2........	....	Id.
Left a red streak	....	From Radiant O	For remarks on this meteoric shower see Appendix III.	Id.
Left a red streak	....	From Radiant O	From $11^h 30^m$ p.m. to $12^h 30^m$ a.m. ten meteors.	Id.
....	25°	Directed towards θ Ceti, from Radiant A_{10}.	The night of the 20th was overcast.	Id.
Left a broad streak for 2 seconds.	....	....	Moon set; sky clear; stars very bright; two faint lightning-flashes in the east between $9^h 45^m$ and 10^h p.m.	W. Jackson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Oct. 21	h m s 9 49 p.m.	Tooting, London	=3rd mag.*	White	1 second	From near γ Cygni to $\frac{1}{4}$° south of γ Lyræ.
21	Between 10 33 and 10 52 p.m.	Primrose Hill, London.	=4th mag.*	Like α Aurigæ	Steady speed..	In the N.E. or E...
21	10 38 p.m.	Ackworth, Pontefract (Yorkshire).	=2nd mag.*	White	0·5 second ...	α= δ= From 322°+12° to 317 + 8
21	10 57 p.m.	Birmingham ...	=3rd mag.*	Orange.........	1 second	From 258°− 7° to 335 −12
21	10 57 15 p.m.	Ibid	=4th mag.*	Orange.........	0·5 second ...	From φ to θ Aquarii
21	11 10 p.m.	Ibid	=3rd mag.*	Blue	0·25 second...	α= δ= From 77°+26° to 84 +24
21	11 13 p.m.	Ibid	=4th mag.*	Reddish	0·75 second ...	Appeared at 87°+17°
21	11 18 p.m.	Ibid	=Sirius	White	2 secs.; slow speed.	Appeared at σ Ceti
21	11 44 p.m.	Ibid	>1st mag.*	White	1 second	α= δ= From 95°+20° to κ Geminorum.
22	12 44 a.m.	Radcliffe Observatory, Oxford.	At first=1st mag.*, then=♃.	Nucleus bright white, then green.	....	Shot from α Pegasi past a group of stars in the constellation Pisces.
22	10 32 p.m.	Ackworth, Pontefract (Yorkshire).	=3rd mag.*	White	0·3 sec.; rapid speed.	α= δ= From 12°−13° to 2 −17
22	10 33 p.m.	Ibid	=3rd mag.*	White	0·5 sec.; very slow.	From 352° −7° to 351·5−8
23	9 50 p.m.	Ibid	=♃	White	2 seconds......	From 354°+22° to 331 +21

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
eft a bright streak for a second or two.	Length of a line from γ Cygni to β Lyræ.	Parallel to a line through γ Cygni and β Lyræ.	....	W. Jackson.
ive small meteors seen, leaving unusually persistent streaks.	$2\frac{1}{2}°$ to 15°..	Radiant-point about 5° below, and 2° west of β Persei.	A bright auroral glare visible all over the north and north-eastern sky.	T. Crumplen.
....	8°.........	.... 	....	J. E. Clark.
eft a red streak for 2 seconds.	....	From Radiant O	....	W. H. Wood.
eft a red streak...........	....	From Radiant O	....	Id.
....	....	From Radiant R_3.........	....	Id.
....	2°...........	Directed towards ν Orionis; Radiant O.	Close to Radiant-point..	Id.
....	....	Fell vertically, from Radiant $A_{11, 15}$.	View of the path intercepted 4° above the horizon.	Id.
....	....	From Radiant O	From 10^h 45^m to 11^h 45^m p.m. six meteors seen. Night of the 22nd cloudy.	Id.
ie nucleus was arrested for a moment in its flight and burst. It then advanced with increased brightness until it disappeared. It left a luminous cloud at the point of retardation for twenty seconds.	....	....	On the same night seventeen other meteors were observed.	B. Lucas; communicated by R. H. Alnatt, in the 'Sussex Mail.'
lft a slight train	12°	.... 	....	J. E. Clark.
first scarcely visible, brightened gradually.	1°...........	.... 	....	Id.
t a streak 1° in length	22°	.... 	Another meteor at 9^h 47^m p.m. moved at right angles to this one, near β Andromedæ.	Id.

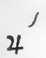
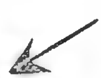
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Nov. 2	h m 8 20 p.m.	Primrose Hill ...	=3rd mag.*	....	Very brief ...	From 358°+33° to 355 +10
3	About 3 15 p.m.	Bilston, Staffordshire.	Large meteor	White and red	....	In the S.E. ....
3	About 3 15 p.m.	Leamington......	As large as a rocket	....	Moved slowly	....
3	About 3 15 p.m.	Rugby	Very large meteor	White, like ignited magnesium.	Very rapid motion.	Descended in the S.E., and disappeared on the verge of the horizon.
3	About 3 15 p.m.	Birmingham ...	Appeared as large as the crescent moon.	....	....	Shot across the sky, and disappeared behind buildings in the E.S.E.
3	About 3 15 p.m.	Ibid	Large and brilliant meteor.	White and red	....	In the S.E. Fell apparently between the spectator and Yeardley church, *i. e.* nearly in the E.S.E.
3	3 17 p.m.	Ibid	Shorter axis $\frac{1}{2}$; longer axis $\frac{3}{4}$ of the moon's apparent diameter.	Vivid white, and red.	3 seconds......	Commenced at azimuth 33° E. of S., alt. 32°; disappeared at azimuth 60° E. of S., alt. 10° or 12°. Positions measured from observed fixed landmarks.
4	8 5 p.m.	Ibid	=3rd mag.*	Pale blue ...	2 secs.; slow motion.	$\alpha=$ $\delta=$ From 23°+ 9° to 20 +14

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a train on its whole course which faded instantly.	20°	From Radiant N_{14} (?)...	....	T. Crumplen.
A white fireball with comet-like smoky tail following it. At Alcester it resembled a long streak of fire emitting much light and sparks in its course.	....	....	The sun shone, and the sky was almost cloudless. Seen also at Sarsden, Chipping Norton, and at Notting Hill, in London, as a large bright meteor in the south, going from west to east. An explosion was heard at the latter place.	'British Daily Post' and 'Times.'
In its course it appeared to have a zigzag form.	....	Descended towards the earth.	[The meteor was also seen at Northampton, in full sunshine, emitting bright flames, and lasting a few seconds. 'The Times.']	'The Morning Star.'
....	....	Rushing downwards ...	[Seen also at Hartlebury, as a shining silvery light descending in the south-east; and at Edmonton, moving from the south-west towards the east. Mr. Wood's M.S.]	'The Times.'
Meteor of a crescent form, like the moon a few days' old.	....	....	The wind was high, and clouds were passing quickly.	'Birmingham Daily Post.'
....	....	Directed from the same quarter as the wind, or about W.S.W. to E.N.E., descending at an angle of 45° to the horizon.	The meteor appeared during a strong gale.	'Birmingham Daily Gazette.'
The crescent was bright white; the rest, near the tail, ruby-red; red flames issued from the rear, and merged into the tail for about 1°. The latter 15° in length, like smoke in sunshine, lasted only a moment. The meteor flickered in transit; diminished, and changed colour towards extinction, as if burnt out.	....	....	Notwithstanding the bright sunshine, the meteor was intensely luminous. Had it appeared at night, it would have equalled that of the 7th of October. A strong gale from W.S.W. blowing at the time, prevented any sound from being heard. See figure in Appendix II.	W. H. Wood.
....	....	....	....	Id.

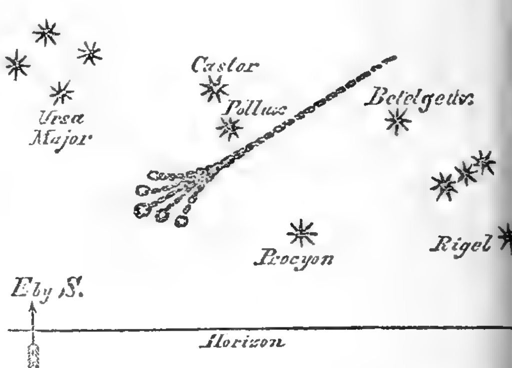
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868.	h m s					
Nov. 6	7 35 p.m.	Primrose Hill, London.	$=2\frac{1}{2}$ mag.*	....	....	α= δ= From 310°+33° to 293 +23; beginning at ε Cygni.
8	6 27 p.m.	Ackworth, Pontefract (Yorkshire).	=1st mag.*.........	Red	1 secs.; slow	From about α= δ= 313°−20° to about 275 −30
8	6 56 p.m.	Primrose Hill, London.	$=1\frac{1}{2}$ mag.*	Bluish	....	α= δ= From 290°+37° to 261 +11; ending near α Ophiuchi.
8	8 18 p.m.	Ibid	$=3\frac{1}{2}$ mag.*	Bluish	....	α= δ= From 315°+16° to 293 +12; passing through Delphinus.
8	10 51 p.m.	Ibid	$=2\frac{1}{2}$ mag.*	White	....	α= δ= From 50°+23° to 33 +14·5
8	10 55 p.m.	Ibid	=2nd mag.*	White	0·8 second ...	From 56°+26° to 58 +28
9	7 22 p.m.	Ackworth, Pontefract, (Yorkshire).	=1st mag.*.........	Red	1 second	From about 78°+35° to about 81 +33
13	10 16 p.m.	Primrose Hill, London.	=1st mag.*	White	....	From 55°+46° to 91 +29
14	2 33 a.m.	Madrid Observatory (Spain).	Large fireball	....	Rather more than 1 sec.	First appeared between λ and μ Ursæ Majoris.
14	9 57 40 p.m.	Ackworth, Pontefract, (Yorkshire).	....	Red	3 or 4 seconds	Passed from a little above ζ Tauri, through the Hyades, above α Ceti to 1° beyond 20 Ceti (under Jupiter).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a streak on its whole course which faded instantly.	17°	....	....	T. Crumplen.
Left no streak	40°	....	Oscillated in its flight...	J. E. Clark.
Left a very fine streak on its whole course which faded instantly.	Very long path.		A fine swift meteor ...	T. Crumplen.
Left a momentary streak..	....	....	....	Id.
Left a faint streak on its whole course.	....	This meteor and the next evidently radiated from Pleiades.	....	Id.
Left a bright train for half a second which faded gradually. Kite-shaped, thus— 	$2\frac{1}{2}$°	Upwards towards α Persei. A short path close to the Radiant-point.	....	Id.
eft no streak. Brightest in the middle of its course.	3°	....	On the night of the 13th clear for ten minutes, at 9^h 45^m p.m.; no meteors seen. The rest of the night overcast.	J. E. Clark.
eft a fine bright streak...	....	 Downwards towards the left.	Sky clear about this time for 15 minutes. *No Leo meteors !*	T. Crumplen.
eft a bright luminous cloud which quickly expanded to a width of 6° or 8°, and faded in the centre so as to form a ring. It remained visible ten minutes.	4° or 5° ...	Towards α Ursæ Majoris	....	M. Aquilar.
o distinct nucleus. A shapeless mass 2° long and 10′ broad.	Seen for about 80°.	.... 	Emerged at appearance from behind a house.	J. E. Clark.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Nov. 14	h m s 1 12 a.m. (New York time).	Newhaven, U. S. America.	Large meteor	[Nucleus white; train greenish blue :—at Pallisades, T. P. Gillman.]	[0·5 second; at Pallisades.]	Centre of the persistent luminous streak 2° to the right of Jupiter.
14	5 6 45 a.m. (Newhaven time).	Ibid	Large meteor	....	....	Passed 1° S. of β Geminorum.
15	12 20 a.m. (local time).	Madrid Observatory (Spain).	Large meteor	....	....	Between β and ψ Ursæ Majoris.
15	1 30 a.m. (local time).	Bahia, Brazils, S. America.	Large meteor	....	A few seconds	Passed a little N. of the equator, from E.S.E. to W.N.W.
15	6 22 p.m.	Ackworth, Pontefract (Yorkshire).	=2nd mag.*	White	4 seconds......	α= δ= From 297°−13° to 314 − 9
15	6 51 p.m.	Ibid	=1st mag.*	Yellow	0·5 second ...	From 55°+23° to 64 +22

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a nearly vertical streak 5° or 8° in length which became crooked, the upper part towards the right, and the lower part towards the left, thus—  It finally became horizontal, and was still faintly visible when the clock struck two.	[50° or 60°; at Pallisades.]	Apparently conformable to the Radiant-point in Leo.	The meteor itself was not seen. Also observed at Poughkeepsie, Pallisades, Washington, &c. See Appendix I.	H. A. Newton; American Journal of Science, for May, 1869.
The central part of the train was visible six minutes, and moved towards a little east of north, 5° in three minutes.	....	....	For the height of this, and other meteor streaks observed in the United States on the same date, see Appendix I.	Id.
The nucleus was not seen; but it left a cloud of cometic light of varying shape, three or four times the apparent diameter of the moon.	....	....	Before a telescope could be directed to it, it disappeared. Probably the streak of a meteor as large as that which appeared at 2^h 33^m a.m. on the preceding morning. Until 4^h a.m., when the sky became overcast, the number of meteors observed was very small.	M. Aquilar; 'Les Mondes' for Dec. 3rd.
Burst. Left a well-defined streak which remained unchanged for five minutes; then gradually faded, and rolled itself from W. to E. into a luminous cloud, brighter than the Milky Way, which gradually disappeared, without moving, in fifteen minutes.	....	....	The night was clear and calm, with a slight breeze from the east. Several other meteors were seen on the same night, 24 hours later than the predicted time of their occurrence.	'Glasgow Daily Herald.'
....	19°	.... 	Curved path, thus— 	A. K. Brown.
Left a momentary train 3° in length.	11°	Directed from Pleiades 	....	S. Thomson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Nov. 15	h m s 8 40 p.m.	Ackworth, Pontefract (Yorkshire).	=2nd mag.*	White	0·3 second ...	α= δ= From 347°+11° to 335 + 4
15	9 0 p.m.	Primrose Hill, London.	=3rd mag.*	Bluish	Moved swiftly	From 72°·5+50° to 55 +23
Dec. 5	About 10 30 p.m.	Manchester	=3rd mag.*	Dull white ...	A rapid flash...	From ζ Geminorum to the hind paws of Ursa Major.
5	10 45 p.m.	Wilmslow (twelve miles S.S.E. from Manchester).	Large meteor	Blue	About 4 secs...	Plan of the meteor's course among the stars.



Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
10	9 32 p.m.	Ackworth, Pontefract (Yorkshire).	= ♀	White	2 seconds......	From about α= δ= 57°+13° to 41 + 3
10	10 8 30 p.m.	Ibid	=2nd mag.*	White	0·1 second ...	From 40°+8° to 40 +7
10	10 19 p.m.	Ibid	=2nd mag.*	White	1 second	From 71°+17° to 66 +13
10	10 30 p.m.	Ibid	=2nd mag *	White	1·5 second ...	From 55°+7° to 45 −2
10	10 44 30 p.m.	Ibid	=1st mag.*	White	1 second	From 71°+14° to 67 +10

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	16°	.... 	....	J. E. Clark.
Left a faint streak	....	To right; almost horizontal.	A very fine blue meteor was seen on the 23rd.	T. Crumplen.
....	15°	....	....	R. P. Greg.
Like the largest kind of sky-rockets. Left a fine line of fire, and burst into five or six splendid blue fire-balls like Roman-candles. (See the sketch of its apparent course.)	20° or 25°	From about S.W. to N.E. Inclining slightly downwards.	A magnificent object ...	G. H. Greg.
Disappeared suddenly; left no streak.	22°	Directed from Aldebaran 	A brilliant meteor. Path not quite straight.	J. E. Clark.
....	1°	.... 	Evidently not from the same Radiant-point as the last meteor.	Id.
....	$6\frac{1}{2}$°	.... 	From the same direction as the meteor at 9^{h} 32^{m} p.m.	Id.
....	14°	.... 	From the same direction as the last meteor.	Id.
....	$5\frac{1}{2}$°	.... 	Almost parallel in direction to the meteor recorded before the last.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Dec. 10	h m s 10 51 30 p.m.	Ackworth, Pontefract (Yorkshire).	=3rd mag.*	White	1 second	α= δ= From 83°+16° to 77 +13
10	10 57 p.m.	Primrose Hill, London.	=♃	White	Moved slowly	From 165°+60° to 165 +40
10	10 58 p.m.	Ackworth, Pontefract (Yorkshire).	=♃	White	2 seconds......	From 69°+ 7° to 50 − 1
11	6 5 p.m.	Primrose Hill, London.	=3rd mag.*	....	Swift	From 81°+45° to 95 +70
12	12 7 a.m.	Birmingham ...	=2nd mag.*	Blue	0·5 second ...	From θ to π_1 Can Majoris.
12	12 15 a.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ν Androm dæ to μ Pegasi.
12	12 15 15 a.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	α= δ= From 6°+15° to 2 + 9
12	12 18 a.m.	Ibid	=♃	White	2·5 seconds ...	From 20°+13° to 2 0
12	12 22 a.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ½ (α Andr medæ, γ Pegas to α Pegasi.
12	12 25 a.m.	Ibid	=1st mag.*	White	0·5 second ...	α= δ= From 78°+36° to 62 +35
12	Between 12 30 and 1 0 a.m.	Manchester	=3rd mag.*	....	....	From β Canis M noris to the clust of stars in Cance
12	Between 12 30 and 1 0 a.m.	Ibid	=3rd mag.*	....	....	From near γ Orioni halfway to γ Er dani.
12	Between 12 30 and 1 0 a.m.	Ibid	=3rd mag.*	....	A rapid flash..	From η Aurigæ δ Persei.
12	12 32 a.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	From π Androm dæ to η Pegasi.
12	12 34 a.m.	Ibid	=1st mag.*	Deep red	3 secs.; slow	From ½ (α, δ) Ce to ζ Eridani.
12	12 43 a.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	Commenced at Canis Minoris.
12	12 46 a.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From λ Orionis γ Eridani.
12	12 47 a.m.	Ibid	>Sirius	White and red	2·5 seconds ...	From η to δ P scium, and beyond.
12	12 52 a.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	α= δ= From 99°−10° to Sirius.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	7°	....	....	J. E. Clark.
				
A large nucleus; faded slowly.	....	Radiant doubtful; probably from near Polaris.	Path probably as stated. End only well observed.	T. Crumplen.
....	21½°	....	....	J. E. Clark.
				
Left a long thin train which faded instantly.	15°	Directed from α Aurigæ.	....	T. Crumplen.
Left no streak	....	From Radiant G	A few meteors were seen on the night of the 10th.	W. H. Wood.
....	....	From Radiant G	On the night of the 11th the sky was overcast until 11^h 30^m p.m.; afterwards clear.	Id.
....	....	From Radiant G *a*	....	Id.
Left a faint streak	....	From Radiant G	....	Id.
Left no streak..............	....	From Radiant R_3........	....	Id.
Left no streak..............	....	From Radiant G	....	Id.
....	....	From Radiant V (?)........	....	R. P. Greg.
....	10°	From Radiant G	....	Id.
....	....	From Radiant G	....	Id.
eft no streak..............	....	From Radiant G	....	W. H. Wood.
eft a streak	....	From Radiant T, near γ Ceti.	Path curvilinear	Id.
....	6°	Towards α Hydræ	From Radiant R G	Id.
....	....	From Radiant L G......	....	Id.
icleus white, with a red crescent. Left a faint streak (?).	....	From Radiant R_3, or *g*...	....	Id.
....	....	From Radiant G	....	Id.

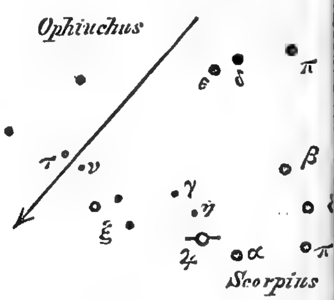
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1868. Dec. 12	h m 12 53 a.m.	Birmingham ...	=2nd mag.*	White	0·5 second ...	α= δ= From 99°+10° to 99 + 3
12	1 2 a.m.	Ibid	=1st mag.*	White	0·75 second ...	From 275°+55° to 272 +49
12	1 4 a.m.	Ibid	=2nd mag.*	White	0·75 second ...	From 185°+76° to ι Draconis.
12	1 34 a.m.	Ibid	=1st mag.*	White	0·5 second ...	From η to β L[eo]poris.
12	11 56 p.m.	Manchester	=2nd mag.*	....	A rapid flash..	Passed through th[e] Pleiades.
13	12 21 a.m.	Ibid	=3rd mag.*	....	....	Passed through th[e] Pleiades.
13	12 28 a.m.	Ibid	=2nd mag.*	Rose colour ...	0·4 second ...	From ζ to α Taur[i]
16	6 4 p.m.	Primrose Hill, London.	=3½ mag.*	....	....	α= δ= From 199°+41° to 198 +32
24	3 33 a.m.	Glasgow	=2nd mag.*	White	0·8 second ...	Commenced at Tauri.
1869. Jan. 1	....	Sweden	Large meteor	....	....	....
10	7 35 p.m.	Aberdeen, Scotland.	Half the apparent diameter of the moon.	Reddish tinge	About 1 sec...	Passed close to J[u]piter.
Mar. 27	9 55 p.m. (Paris time).	Paris	One-sixth of the apparent diameter of the full moon.	Red, enveloped in a white atmosphere.	Not more than 4 or 5 secs.	First appeared b[e]tween Cape[lla] and the const[el]lation Gemi[ni]. Crossing the la[t]ter, and Canc[er], and passing a[]bove Procyon, disappeared ne[ar] the head [of] Hydra.
Apr. 3	Between 4 0 and 5 0 a.m.	Carlisle	....	....	Travelled at a quick speed.	Passing over t[he] city.
11	10 1 p.m. (Turin time)	Moncalieri, Turin, Piedmont.	Nearly as bright as Jupiter.	Greenish	Slow speed ...	From φ Leonis t[o] Corvi.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	From Radiant G	....	W. H. Wood.
....	....	From Radiant G*a*	Twenty meteors per hour were counted by one observer. Observations discontinued at 1^h 10^m a.m.	Id.
....	....	From Radiant G.........	On the nights of the 12th and 13th the sky was overcast.	Id.
....	....	From Radiant L*g*	....	Id.
....	12°	Directed from β Tauri...	From Radiant G	R. P. Greg.
....	3°...........	Directed from β Tauri...	From Radiant G	Id.
....	....	From Radiant G	A bright meteor	Id.
Left a streak which faded instantly.	10°	Directed from near Polaris.	....	T. Crumplen.
Increased gradually in brightness; drew a short tail of sparks after it. Left no streak.	4°	Directed from δ Persei	Clear sky; no moon. No other meteor seen in twenty minutes.	A. S. Herschel.
Stonefall at Lake Malar, in the Upland.	....	....	....	'Association Scientifique de France,' No. 105.
The meteor burst, and terminated in what appeared to be three globes of light, each about one-third the apparent diameter of the full moon.	10° or 15°.	From N.N.E. to S.S.W.	A very brilliant fireball	'Glasgow Evening Citizen,' Jan. 12th.
At first as bright as Mars, it increased to one-sixth of the apparent diameter of the full moon, which was near its path; numerous sparks, issuing from it, produced a luminous appendage; and it shone brightly through clouds, which dimmed the stars.	Not less than 40°.	From N.W. to S.E. ...	A large and brilliant meteor. First appeared at $\alpha = \delta =$ 98°+36° crossed the ecliptic at 114 +21 disappeared at 126 0	M. Laussedat; 'Comptes Rendus' for Mar. 29th, 1869; vol. lxviii. p. 784.
Resembled a sheaf of fire, with connected streamers of light, which at last burst and cast a great light around.	....	From E. to W............	Cast a lurid glare on the landscape, and lit up the heavens with a singular brightness. [The meteor was seen at the same hour at Manchester.]	'Glasgow Daily Herald,' April 5th.
....	....	Course not quite straight; undulating.	....	Francesco Denza; 'Bulletins de l'Académie de Belgique,' vol. xxvii. p. 633.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. Apr. 11	h m 10 1 p.m. (Turin time)	Bergamo, Italy..	Bright meteor......	....	....	From Regulus to a point between υ and κ Hydræ, at α= 144°·5 δ= −13°
11	10 35 p.m. (Turin time)	Moncalieri, Turin, Piedmont.	Appeared about as large as Jupiter.	Red and green	Slow speed ...	From near η Ursæ Majoris to near χ Boötis.
11	About 10 34 p.m. (Turin time)	Bergamo, Italy..	Bright meteor ...	....	....	First appeared between γ and ζ Leonis. Disappeared at a point in Cancer, at α= 136° δ= +17°
May 5	About 11 30 p.m. (Turin time)	Moncalieri, Turin, Piedmont.	= ♃	Reddish	Moderate speed.	From near Spica Virginis to near γ Hydræ. Disappeared very near the horizon.
15	3 20 p.m.	Oxford	Large meteor	Pale red; sparks purple.	About 12 secs.	Disappeared shortly before it reached the horizon.
22	About 9 45 p.m. (Paris time)	Vannes, France...	Large meteor	....	....	Left a long streak. Stonefall at Cléguérec.
29	11 20 p.m.	Regent's Park, London.	Very large meteor..	Like the electric light.	Slow and stately motion.	From between η Ursæ Majoris and α Coronæ, it passed 10° or 12° to the left of Saturn, below which point it burst.
29	11 22 p.m.	Hurstgreen (Sussex).	As bright as Mars or Jupiter.	Orange-red ...	Slow speed ...	From altitude about 20° in the south-west to about 5° above the horizon, one point more towards the south.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	Possibly identical with the last.	M. Zezioli; 'Bulletins de l'Académie de Belgique,' vol. xxvii. p. 633.
urst, with sparks. Left a very bright persistent streak.	....	....	Two other bright meteors on this evening cast such a strong reflected light as to attract the attention of observers who were looking in the opposite direction.	Francesco Denza (Ibid.).
....	....	....	Possibly identical with the last.	M. Zezioli (Ibid.)
ollowed by a tail of sparks. At a point about two-thirds along its course ($\alpha = 197°$ $\delta = -14°$), it appeared to descend below, and be visible through a dark cloud.	....	....	Rocket-like. Appeared suddenly.	Francesco Denza; Ibid. p. 632.
ike a large shooting-star. It burst into what seemed to be myriads of purple sparks, which gradually vanished.	....	From W. to E.	....	'The Standard,' May 16th.
....	....	....	Stones fell at Cléguérec, Vendée, south of France. [Seen also at L'Orient, by Mons. Bourdillon.]	M. Arrondeau; 'Association Scientifique de France,' No. 123.
ucleus kite-shaped. Burst like a rocket, the fragments burning out gradually.	More than 30°.	....	Intensely luminous, lighting up the heavens. Commencement of the meteor's course not seen.	Communicated by T. Crumplen.
isappeared gradually. No sparks or streak.	15°	Descending obliquely towards the left. 	The sky in that direction was quite clear.	Communicated by A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. May 31	h m 10 52 p.m.	Christ College, Cambridge.	Large meteor	Deep yellow, then orange, then light blue.	2 or 3 seconds	From ½ (λ, σ) ½ (ν, τ) Oph uchi, and further. Disa peared behi houses.



31	About 11 0 p.m.	Battle (Sussex)..	Larger than any of the planets.	Bright flame-colour.	....	....
31	About 11 0 p.m.	Hurstgreen (Sussex).	Appeared nearly as large as the full moon.	Yellowish ...	Moderate speed.	From some heig above the S.S. horizon to ve near the east h rizon.
31	About 11 0 p.m.	Horsemonden, Brenchley (Kent).	Large fireball	Yellow, red, and purple.	About 8 secs.; slow speed.	First seen at alt tude 35° or 4 in the E.S. Disappeared b hind trees 3° 4° above t E.N.E. horizon.
31	About 11 0 p.m.	Wrotham, Maidstone (Kent).	As large as the full moon.	....	Proceeded slowly.	....

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
he shape of the meteor was rounded in front, throwing off flakes of flame behind.	About 30°	Directed nearly from α Serpentis.	The view of the last part of the meteor was intercepted by houses.	A. T. Atchison.
ocket-like. Nucleus as bright as the Drummond light, brightly defined in front, drawing behind to a short tail with sparks. Disappeared gradually. Left no streak.	....	....	The light cast was sufficient to have picked up a pin. A clear night.	J. Harmer; communicated by A. S. Herschel.
round ball, which gradually disappeared without leaving any streak or sparks.	About 50°..	From W. to E.	About four minutes and a half after its disappearance a report was heard as of a distant explosion.	Communicated by A. S. Herschel.
ke a mass of fire: pear-shaped.	45°	From W.S.W. to E.N.E.	Positions carefully observed by landmarks. Five minutes after the disappearance a report was heard which shook the earth and made the windows rattle. [The flash of light and the report were perceived within doors at Horsemonden, and at Hawkhurst, with an interval of four or five minutes between them. Both the flash and the report were double.—A.S.H.]	H. Marriot; communicated by A. S. Herschel.
....	....	From S.W. to N.E.......	Shortly after its disappearance three reports were heard as of distant cannons. The houses shook at Meopham. Seen generally around Wrotham.	W. E. Hickson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. May 31	h m 11 2 p.m.	Llandudno, N. Wales.	Large meteor	Intense green. Tail red with red sparks.	....	Passed a little below Arcturus: Disappeared behind Little Orme's Head (nearly due east).
31	11 4 p.m.	Torquay (Devonshire).	Appeared as large as the full moon.	Bright red, with red tail. Reflected light green.	....	First appeared about 30° above the horizon, a little south of east, and disappeared below the east horizon.
31	11 4 p.m.	London	Very large meteor..	Yellowish ...	Moving with great velocity.	First appeared 30° above the horizon.
31	11 5 p.m.	Ibid	Large fireball	....	....	Appeared over the houses, moving eastwards.
31	11 5 p.m.	Rickmansworth..	Large meteor; half as bright as the moon.	White, like the magnesium light. Tail red.	About 1 sec.; motion not very rapid.	Disappeared about 6° or 8° above the horizon.
31	About 11 5 p.m.	Ormskirk (Lancashire).	Large fireball	Blue, red, and yellow.	....	Disappeared at the horizon.
31	11 14 p.m. (Paris time)	Paris	Half the apparent diameter of the full moon.	White, then red.	5 or 6 seconds	Commenced in Camelopardus, 6° or 8° west of due north, at the same altitude as the three lowest stars of Cassiopeia, and crossed the constellation Perseus towards Taurus. Disappeared before reaching the horizon.
31	About 11 15 p.m. (Paris time)	Place du Carousel, Paris.	Large fireball	....	....	In the direction of the Buttes Montmartre.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
large luminous body, drawing behind it a streak of red light 5° or 6° in length, from which red fire seemed to drop.	....	....	Immediately after its passage two bright flashes of light followed which illumined the whole sky. Seen by many persons on the Parade.	Communicated by J. B. Dancer.
he bright red body left behind it a tail of considerable length, and of the same colour as the head. All the sky and the landscape was lighted up with a pale green light.	....	From W. to E.	It did not describe a perfect arc, but about halfway through its course it made a sudden rise, when the light flashed out with far greater brilliancy; after that it again tended downwards.	H. T. Mackenzie.
'hen within 20° of the horizon it broke up.	....	From due W. to E.......	No sound of an explosion was heard. [Seen also from the bridge in St. James's Park, descending apparently into the water; like a firework at the Crystal Palace. —A. S. H.]	L.; 'The Times,' June 3rd.
rilliant ball of fire and train of sparks like a comet. Burst into several balls, like those of Roman candles.	....	....	Cast shadows as bright as those of sunlight.	'Morning Herald,' June 3rd.
haped like a Tadpole. The body elongated and well defined. The tail, which was fiery-red, shook, as if violently contorted.	....	From W. to E.; parallel to the horizon.	The night was bright with starlight; and the meteor appeared to fall in a neighbouring field.	T. J. Buckton.
ke a ball of blazing tow, emitting flames of blue, red, and yellow light.	....	Fell obliquely downwards, from right to left.	....	W. Newsam.
its first appearance it ncreased, almost stationary, to half the apparent width, and at least he full brightness of he moon. As it advanced, it drew behind t a white tail, and changed its colour to bright red.	....	....	The houses and all surrounding objects were brilliantly illumined by its light.	Mons. Robinet; 'Association Scientifique de France,' Nos. 124 and 126.
bolide, drawing a long iery tail, and scattering sparks on its ourse.	....	Fell vertically downwards.	The same meteor was also seen at Havres.	'Le Temps,' June 2nd.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. May 31	h m About 11 15 p.m. (Brussels time).	Brussels	Half the apparent diameter of the full moon.	Nucleus yellowish white. Tail red and green.	....	Appeared in t W.S.W., at al tude about 45 and disappear behind trees, d west, at altitu about 35°.
31	About 11 15 p.m.	Ightham (Sussex).	Large and brilliant meteor.	....	....	Appeared in easterly dire tion.
June 5	8 55 p.m.	Greenwich Park.	Brighter than Jupiter.	White	About 1 sec...	From near t zenith to ne Arcturus.
6	1 29 a.m.	London	=3rd mag.*	White	0·5 second ...	Commenced at Draconis.
10	11 0 p.m.	Hawkhurst (Kent).	=1st mag.*	White	0·3 sec.; very swift.	From τ_1 Serpent two-thirds of t way to z Virgin
July 2	Morning ...	Littlehampton (Sussex).	Large meteor	....	....	At an altitude 45°.
7	10 55 p.m.	Hawkhurst (Kent).	=1st mag.*.........	White	1 second	From ε to 2° fo lowing α Boötis
9	11 0 p.m.	Ibid	=1st mag.*.........	Yellow	1 second	Commenced at Aquilæ.
10	10 56 p.m.	Ibid	=3rd mag.*	Yellow	0·8 second ...	From χ Herculis t η Ursæ Majoris
10	11 7 p.m.	Ibid	=α Lyræ...........	White	1·4 second ...	Commenced at Serpentis.
10	11 22 p.m.	Ibid	=3rd mag.*	Yellow	0·8 second ...	From A Dracon to ζ Ursæ M noris.
10	11 26 p.m.	Ibid	=2nd mag.*	White	0·5 second ...	Centre of path at (ζ, η) Herculis.
11	10 44 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From ¼ to ¾ of th way from θ Ca siopeiæ to ι Tr randi.
11	10 49 p.m.	Ibid	=1st mag.*	Yellow	0·5 second ...	Commenced at Boötis.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Elongated nucleus, drawing a tail of sparks, which was at first red, and afterwards of a greenish tinge.	....	....	The glare which it cast was so bright that a person standing at a window, facing towards the north, thought that it lightened. Seen also at Verviers, Tournay, Stavelot, &c.	'Bulletins de l'Académie de Belgique' for June 1869, vol. xxvii. p. 631.
....	... .	From W. to E.	Some who saw the meteor heard a loud report follow its appearance.	'Sussex Express,' June 4th.
eft no streak or sparks...	About 15°	....	In twilight. Arcturus the only star visible in the sky, which was quite clear.	Communicated by A. S. Herschel.
eft no streak..............	4°	Directed towards ζ Ursæ Minoris.	No other meteor in an hour, in a fifth part of the sky. Clear; no moon. Dawn beginning to appear.	A. S. Herschel.
eft no streak..............	....	Curved path, thus— 	Turned in the middle of its path towards Ophiuchus. No other meteor seen in thirty minutes. Sky half clear; no moon.	Id.
urst with the appearance of a rocket.	....	Passed from S. to N. ...	A very brilliant meteor..	'Sussex Express,' July 6th.
rightest at the middle of its course. Left no streak.	....	....	No other meteor seen in forty-five minutes. Sky hazy; no moon; one observer.	A. S. Herschel.
rightest at the middle of its path. Left no streak.	8°	Directed from θ Serpentis.	No other meteor seen in forty-five minutes. Sky hazy; no moon.	Id.
eft no streak	....	....	....	Id.
eft a streak at the middle and brightest part of its course for half a second.	30°	Down the division of the Milky Way.	....	Id.
eft no streak.............	....	....	....	Id.
rightest at middle of its course. Left no streak.	4°............	Directed from ε Herculis.	Four meteors seen in forty-five minutes. Very clear sky; no moon.	Id.
eft a streak at the middle and brightest part of its course for half a second.	....	....	....	Id.
rightest at middle of its course. Left no streak.	4°............	Directed from ζ Boötis	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. July 11	h m s 11 5 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1·2 second ...	From γ Lyræ to Herculis, and further.
11	11 10 p.m.	Ibid	=2nd mag.*	Yellow	0·5 second ...	Commenced at Camelopardi.
11	11 15 p.m.	Ibid	=3rd mag.*	Yellow	0·6 second ...	From θ Draconis $\frac{1}{2}$ (ν, τ) Urs Minoris.
11	11 17 p.m.	Ibid	=3rd mag.*	Yellow	0·7 second ...	From A Dracon to $\frac{1}{3}$ (ζ, β) Urs Minoris, and 4 further.
14	11 7 p.m.	Ibid	=3rd mag.*	Yellow	0·6 second ...	From $\frac{1}{3}$ (ϵ, γ) to Cygni.
15	10 42 p.m.	Ibid	=2nd mag.*	White	0·5 second ...	From $\frac{1}{3}$ (o, π) to Draconis.
15	10 42 30 p.m.	Ibid	=1st mag.*.........	White	0·5 second ...	From o to $\frac{1}{2}$ (η, H Draconis.
15	10 56 p.m.	Ibid	=Sirius, then =1st mag.*.	White, then orange-yellow.	3·5 seconds ...	From $\frac{1}{2}$ (β Aquila ϵ Delphini) to 2 following χ Cephei.
15	11 20 p.m.	Ibid	=1st mag.*.........	White	0·5 second ...	From ξ to υ Cygn
15	11 20 30 p.m.	Ibid	=1st mag.*.........	White	0·6 second ...	From ι Draconis t θ Boötis.
15	11 32 p.m.	Ibid	=3rd mag.*	Yellow	0·2 second ...	From g to A Draconis.
16	About 9 30 p.m.	Ibid	Large meteor	White	About 2 secs...	Disappeared abou 10° above th horizon, due S.
16	11 35 p.m.	Ibid	>♀	White	0·8 sec. while in sight. Total duration 2·5 secs.	From 4° above Delphini to 2 west of ϵ Pegas

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
eft a streak for 1 second	....	....	....	A. S. Herschel.
eft no streak	6° while in sight.	Fell vertically. Directed from $\frac{1}{2}$ (ω, γ) Cephei.	A side view, only, of the meteor was seen.	Id.
eft no streak	....	....	....	Id.
eft no streak	....	....	Six meteors seen in forty-five minutes. Very clear sky; no moon; one observer.	Id.
eft no streak	....	....	No other meteor seen in forty-five minutes. Clear sky; no moon.	Id.
rightest at the middle of its course. Left no streak.	....	....	Two very similar meteors following each other, almost immediately, in the same part of the sky.	Id.
rightest at the middle of its course. Left no streak.	....	....	....	Id.
the first half of its course a bright white meteor equal to Sirius, leaving a slight streak; then collapsed to a yellow first-magnitude star, drawing a short tail of red sparks; it disappeared suddenly.	45°	Almost vertically upwards to the zenith.	A very striking meteor	Id.
rightest at the middle of its course. Left no streak.	....	....	This meteor and the next followed each other in quick succession.	Id.
ightest at the middle of its course. Left no streak.	....	....	....	Id.
ft no streak	....	....	....	Id.
sparks or streak; disappeared gradually.	15° or 20°	Nearly horizontal	In twilight. Very bright meteor; seen by several persons.	Communicated by A. S. Herschel.
obular nucleus, with very quickly intermittent light. Disappeared suddenly. No streak or sparks.	8° or 10° while in sight.	Directed from near η Cygni. Radiant B_3, in head of Draco.	Two rapid white flashes in one second drew the observer's attention to the meteor. The final part, only, of the meteor's course was seen, in a clear space between clouds.	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. July 16	h m 11 35 p.m.	Kensington, London.	Splendid meteor ...	Light of intense white-heat.	Immensely rapid.	Shot from th zenith towar the S.S.E.
16	11 35 p.m.	In the north of London.	Large meteor	Nucleus quite white.	Rapid motion..	....
16	11 36 p.m.	Beckenham (Kent).	....	Reddish-yellow.	1 or 2 seconds	Disappeared abo $\frac{1}{2}°$ to the rig of ε Pegasi.
17	10 34 p.m.	Hawkhurst (Kent).	= 2nd mag.*	Yellow	0·6 second ...	Disappeared at Draconis.
20	9 35 p.m. (local time).	New York, United States.	Half the apparent diameter of the moon.	Emerald-green.	5 seconds......	First appeared bout 45° abo the N.E. horiz at a point north of α Cyg and disappea in a N. by direction.
21	11 40 p.m.	Ibid	= 2nd mag.*	Yellow	0·6 second ...	Disappeared at Tarandi.
Aug. 3	9 10 p.m. (Geneva time).	Brieg, Vallais, Switzerland.	= 1st mag.*.........	White	1·5 sec.; slow motion.	From ζ Cassiop to γ Persei.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
It began in a thin streak of red sparks, and rapidly increased to its greatest splendour; of an intense white heat, giving off jets or sputterings of light, on its whole course, from both sides of its body. Its disappearance was extremely sudden, as if its substance were wholly consumed. For a second there was left a train of sparks.	The whole course of the meteor was extremely short.	From N.N.W. to S.S.E.	The sky was very clear, and the meteor was well seen from first to last. No sound of a report was heard.	The Duke of Argyll; 'The Times,' July 21st.
'he meteor's path was not continuously illuminated, but appeared broken, for quite half the length of its flight, into a train of brilliant sparks. It terminated in an explosion of vivid incandescence, dividing the principal mass into smaller bodies, which were very quickly extinguished.	....	....	The atmosphere was quite clear and calm. No sound of a report was heard after its extinction.	John Spiller; 'The Times,' July 21st.
y a glance at the meteor, at the instant of its disappearance, it was of this form :— 	Very brief course while in sight.	The prolongation of the brief stage of its apparition which was visible was directed, apparently, from Aquila.	Two flashes in quick succession, with half a second between them, like faint lightning reflected upon surrounding objects, drew the observer's attention to the meteor. No sound was heard.	F. Howlett.
eft no streak	8°...........	Directed from ϵ Lyræ...	....	A. S. Herschel.
he nucleus was followed by a train of red, yellow, and blue light. Disappeared without bursting.	30°	....	The meteor cast a strong shadow, even during moonlight.	Communicated by R. P. Greg.
ightest at the middle of its course. Left no streak.	10°	Directed from σ Cephei	Sky quite clear. No other meteor in fifty minutes seen in $\frac{1}{4}$ of the sky. Full moon; one observer.	A. S. Herschel.
ellar nucleus. No train or sparks.	....	After midnight meteors frequent (one in two or three minutes in half the sky). Radiant Cassiopeia, Perseus, and Auriga.	Another meteor appeared very shortly afterwards in Andromeda. Very clear sky.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. Aug. 4	h m s Evening ...	Manchester ...	=2nd or 3rd mag.*	....	....	....
8	8 45 p.m.	Rigi, Lucerne, Switzerland.	=Sirius	White	1 second	From *g* Honorum to π Pegasi.
9	10 37 p.m.	Birmingham ...	=3rd mag.*	Pale blue......	0·5 second ...	From α= 24° δ= 52° to α Trianguli.
9	10 38 p.m.	Ibid	=1st mag.*.........	Pale yellow ...	0·75 second ...	From φ to π Cassiopeiæ.
9	10 43 p.m.	Ibid	=2nd mag.*	White	0·5 second ...	From α= 18° δ= +42° to 17 +27
9	10 48 p.m.	Ibid	>1st mag.*	Brilliant blue..	0·5 second ...	From φ to μ Andromedæ.
9	10 55 p.m.	Ibid	=2nd mag.*	White	0·75 second ...	From α Pegasi to α Aquarii.
9	10 59 p.m.	Hawkhurst (Kent).	>1st mag.*.........	Yellowish-green.	....	Passed between α and β Andromedæ; near the east horizon.
9	11 0 p.m.	Birmingham ...	>1st mag.*	Pale blue	0·5 second ...	From α Lyræ to α Ophiuchi.
9	11 5 p.m.	Ibid	>1st mag.*	Pale yellow ...	0·5 second ...	From ½ (α, δ) Ursa Majoris, to α= 186° δ= +50°
9	11 12 p.m.	Ibid	=1st mag.*.........	Blue	0·75 second ...	From γ to ½ (β, θ) Persei.
9	About 11 15 p.m.	Hawkhurst (Kent).	=1st mag.*	Bluish	....	Close to, and almost across α Andromedæ.
9	11 16 p.m.	Birmingham ...	=3rd mag.*	Blue	1 second	From λ to μ Persei.
9	11 19 p.m.	Ibid	=3rd mag.*	Blue	1 sec.; slow speed.	From ½ (γ, λ) to α Aquarii.
9	About 11 20 p.m.	Hawkhurst (Kent).	> α Lyræ	Pale yellow ...	....	From just below to ζ Pegasi.
9	11 24 p.m.	Birmingham ...	>1st mag.*	Yellow	1 second	From α= 354° δ= +3° to δ Aquarii.
9	About 11 25 p.m.	Hawkhurst (Kent).	=α Cygni	....	Swift	Commenced at Aquilæ.
9	About 11 30 p.m.	Ibid	=α Lyræ...........	Yellow	....	Passed near *d* Camelopardi.
9	11 38 p.m.	Birmingham ...	=3rd mag.*	Blue	0·5 second ...	Commenced at Piscium.
9	11 39 p.m.	Ibid	=2nd mag.*	Blue	1 sec.; slow motion.	From α= 23° δ= +22° to 29 +23
9	About 50 11 48 p.m.	Hawkhurst (Kent).	>1st mag.*	Greenish-white.	....	From *g* Honores to *g* Pegasi.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
even meteors seen in fifty minutes.	....	Two of them, only, were directed from Perseus.	Very clear sky; no moon; one observer.	R. P. Greg.
eft a streak for 1 second	....	Path curved, concave towards Lacerta.	No other meteor seen in twenty minutes, until 9 p.m. Sky one-fifth cloudy; no moon.	A. S. Herschel.
....	....	Directed from ε Cassiopeiæ.	Clear sky..................	W. H. Wood.
eft a reddish streak	....	Directed from ε Cassiopeiæ.	....	Id.
....	....	Directed from ε Cassiopeiæ.	....	Id.
eft a green streak.........	....	Directed from χ Persei..	....	Id.
eft a streak 15° long ...	....	Directed from γ Persei..	....	Id.
eft no streak	....	....	*Seen through* a massive cloud.	Communicated by A. S. Herschel.
....	....	Directed from ε Cassiopeiæ.	....	W. H. Wood.
eft a red streak	....	Directed from η Persei..	....	Id.
eft a broad green streak	....	Directed from γ or κ Persei.	....	Id.
eft no streak	2°...........	Directed towards Cassiopeia.	....	Communicated by A. S. Herschel.
eft a dense streak.........	....	Directed from η Persei..	....	W. H. Wood.
eft a streak	....	From Radiant $T_{2,3,4}$ ...	....	Id.
eft a train for 1½ second	....	....	Disappeared behind a cloud. Exact observation.	Communicated by A. S. Herschel.
ft a long streak	....	Directed from γ Persei..	....	W. H. Wood.
ft no streak	10°	Directed from γ Cygni..	....	Communicated by A. S. Herschel.
ew rapidly brighter, and left a faint streak for ½ a second.	....	Directed from γ, η Persei.	Seen through a slight cloud.	Id.
....	3°...........	Directed from η Persei..	....	W. H. Wood.
ft a streak	....	From Radiant T_1.........	Sixteen meteors counted in one hour by one observer.	Id.
ft a streak on its course as far as ι Pegasi for half a second.	....	....	Exact observation	Communicated by A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. Aug. 9	h m s 11 55 p.m.	Hawkhurst (Kent).	>1st mag.*		A sudden flash; ½ second.	Near *d* Camelopardi
10	12 3 a.m.	Ibid	Nearly=Capella	Whitish-green	Nearly 2 secs.	From γ to β Cassiopeiæ, and onwards as far as *c* Lacertæ.
10	About 12 20 a.m.	Ibid	>1st mag.*	Green		Commenced between β and η Cygni, and shot across Delphinus.
10	0 31 a.m.	Ibid	>1st mag.*	Greenish	Nearly 1 sec.	Close to the left upper side of the Cluster at χ Persei.
10	9 57 p.m.	Birmingham	=1st mag.*	Greenish		From θ Sagittæ to σ Aquilæ.
10	11 7 p.m.	Chalons, Sur Marne, France.	=1st mag.*	White	1 second	From ½ (F, K) Herculis to *p* Tauri Poniatovii.
10	11 12 p.m.	Ibid	=3rd mag.*	Yellow	0·5 second	Disappeared at θ Serpentis.
11	10 27 p.m.	Birmingham	=3rd mag.*	Blue	0·5 second	From ½ (δ Ursæ Majoris, Cor Caroli), to Cor Caroli.
11	10 30 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0·8 second	From B Herculis to ε Delphini.
11	10 31 p.m.	Ibid	=1st mag.*	White	1 second	Crossed E Psalteri.
11	10 31 p.m.	Birmingham	=2nd mag.*	Blue	0·5 second	From σ_1 to β Ursæ Majoris.
11	10 35 p.m.	Hawkhurst (Kent).	=1st mag.*	Green	1 second	Passed ε and δ towards ξ Draconis.
11	10 37 p.m.	Ibid	=2nd mag.*	White	1·2 second	From μ Cygni to ε Delphini.
11	About 10 40 p.m.	Ibid	=1st mag.*	Green	0·75 second	From ½ (Polaris, γ Cephei) to α Draconis, and some degrees further.
11	10 41 p.m.	Ibid	=2nd mag.*	White	0·8 second	From γ to κ Cephei
11	10 44 p.m.	Ibid	=3rd mag.*	Yellow	1 sec.; slow speed.	From ε Delphini halfway to β Cygni.
11	10 44 30 p.m.	Ibid	=3rd mag.*	White	0·5 second	Commenced at ε Pegasi.
11	10 45 p.m.	Ibid	=1st mag.*	White	0·8 second	From ε Herculis to α Ophiuchi.
11	About 10 45 p.m.	Ibid	>2nd mag.*			From *g* Honorum to ε Pegasi.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
rew gradually brighter...	Very short path.	....	....	Communicated by A. S. Herschel.
eft a fine train in the first part of its course, from γ to β Cassiopeiæ, for half a second.	....	....	Exact observation. Three more conformable meteors, very swift, in Aries, Delphinus, and Cygnus, were seen before 12^h 40^m a.m.	Id.
eft no streak............	10° or 12°...	....	....	Id.
eft a short but very dense and distinct streak of a greenish-blue colour for half a second.	....	Directed towards θ Cassiopeiæ.	A very well-defined and beautiful object.	Id.
eft a green streak for 2 seconds.	....	Directed from ϵ Cassiopeiæ.	....	W. H. Wood.
ft a streak for 1 second	....	....	About half of the sky overcast.	A. S. Herschel.
....	8°.........	Directed from 5 Vulpeculæ.	Five meteors seen in 30 minutes in $\frac{1}{5}$th of the sky; generally clear; no moon.	Id.
....	....	Directed from γ Persei..	A very fine night	W. H. Wood.
ft no streak............	....	....	....	A. S. Herschel.
....	8°.........	Directed from χ Piscium	....	Id.
....	....	Directed from α Persei.	....	W. H. Wood.
t a streak for half a second.	....	....	....	Communicated by A. S. Herschel.
t a streak for 1 second	....	....	....	A. S. Herschel.
t a streak in the first part of its course.	....	Towards γ Draconis ...	....	Communicated by A. S. Herschel.
t a streak for 1 second	....	....	....	A. S. Herschel.
dually faded out. Left o streak.	....	....	From a southern Radiant	Id.
....	5°.........	Directed from β Cygni.	....	Id.
a streak for 2 seconds	....	....	....	Id.
no streak	12°	....	....	Communicated by A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1869. Aug. 11	h m s About 10 45 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0·7 second ...	From δ Cygni to Lyræ.
11	About 10 45 p.m.	Ibid	=2nd mag.*	....	....	From under β Andromedæ to under γ Pegasi.
11	About 10 45 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From κ Cygni to Herculis.
11	About 10 50 p.m.	Ibid	....	....	....	Passed close to Lacertæ.
11	10 54 p.m.	Birmingham ...	=1st mag.*.........	White	0·5 second ...	Commenced at Ursæ Majoris.
11	About 10 55 p.m.	Ibid	=3rd mag.*	....	....	Centre at ½ (Cephei, c Lacertæ).
11	10 56 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	....	Shot across γ Cygni
11	10 58 p.m	Ibid	>2nd mag.*	....	....	From ½ (α Andromedæ, β Pegasi) to β Trianguli.
11	11 5 30 p.m.	Ibid	=2nd mag.*	....	....	Commenced at (α, β) Andromedæ.
11	11 10 p.m.	Birmingham ...	=3rd mag.*	Dull	1 second	From ½ (γ, φ) to Andromedæ.
11	11 17 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ..	Commenced at Pegasi.
11	11 17 30 p.m.	Hawkhurst (Kent).	=1st mag.*	....	Slow speed ...	Centre at K Herculis.
11	11 26 p.m.	Ibid	=Sirius	Green	Fully 1 second	From α Cephei to between γ and Cygni, disappearing close to Cygni.
11	11 30 p.m.	Birmingham ...	>1st mag.*	Green	0·5 second ...	α= δ= From 307°+19° to 291 +13
11	11 30 p.m.	Ibid	>1st mag.*.........	Green	0·75 second...	From β Cygni to α= δ= 278°+12°
11	11 31 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	Swift	Passed near γ Trianguli.
11	11 54 p.m.	Birmingham ...	=3rd mag.*	White	0·75 second ...	From π Cassiopeiæ to β Pegasi.
11	11 57 p.m.	Ibid	=2nd mag.*	White	0·5 second ...	From ν Cassiopeiæ to ι Andromedæ and 5° further.
11	11 58 p.m.	Ibid	=1st mag.*	Deep blue ..	0·5 second ...	Centre of path at ζ Arietis.
11	11 59 p.m.	Ibid	>1st mag.*	Deep blue ...	0·75 second ...	α= δ= From 37°+28° to 37 +22
12	12 2 a.m.	Ibid	=3rd mag.*	Blue	0 5 second ...	Commenced at (α Arietis, α Trianguli).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left no streak	....	....	....	A. S. Herschel.
Left no streak	....	....	....	Communicated by A.S.Herschel.
Left a streak for 1 second	....	....	....	A. S. Herschel.
....	....	Directed on a line from α Cygni to α Andromedæ.	....	Communicated by A.S.Herschel.
Left a streak	25°	Directed from ε Cassiopeiæ.	....	W. H. Wood.
Left a streak 2° in length	8°...........	On a line from β Cassiopeiæ to ε Cygni.	....	Communicated by A.S.Herschel.
....	....	Towards α Aquilæ	....	Id.
....	....	....	....	Id.
....	....	Fell vertically	....	Id.
Left no streak	....	Directed from η Persei..	....	W. H. Wood.
Left a streak	25°	Directed from η Persei..	....	Id.
Left a streak about 8° long	8° or 10° ...	Directed from ο Cygni...	....	Communicated by A.S.Herschel.
Left no streak	....	....	....	Id.
Left a green streak for two seconds.	....	From Radiant R_1........	This meteor and the next appeared within 3 seconds of each other.	W. H. Wood.
Left a green streak for two seconds.	....	Directed from η Persei..	....	Id.
Left no streak	6° or 8°.....	Directed from χ Persei..	....	Communicated by A. S. Herschel.
Left a streak	....	....	....	W. H. Wood.
Left a green streak........	....	Directed from η Persei, or from Radiant $T_{2,3,4}$.	....	Id.
The meteor flickered	....	....	Intermittent light	Id.
The meteor flickered	....	Directed from γ Persei..	Intermittent light	Id.
....	5°...........	Directed from α Persei..	The particulars of many minute meteors seen on this night are omitted in the present list.	Id.

APPENDIX.

I. Meteors Doubly Observed.

Several of the large meteors described in the foregoing catalogue having, from their extraordinary brightness, attracted the attention of observers at many places in England, as well as in neighbouring places on the Continent, to which the course of their aërial flight was more immediately directed, the comparison of the accounts affords, in some instances, approximate estimates of the real heights and distances of their luminous paths.

The course of the large meteor seen in central France on the evening of the 5th of September, 1868, although imperfectly determined by the English observations in Auvergne and at Geneva, must yet have been little less than 100 miles in length over the valleys of the Seine, the Yonne, and the Loire, north and west of the mountains of Côte d'Or and Auvergne, directed, apparently at no great inclination to the horizon, from north-east to south-west, at a height of upwards of fifty miles above the earth. In the absence of more complete descriptions of its apparent course, only the general direction of its real path and the nearest departments of France (Yonne and Cher) over which the meteor must have been conspicuous can be pointed out. The very distant observations of the same meteor at Aosta and Florence, however, indicate for the earlier portion of this meteor's flight a far more extraordinary length of course than is common among large fireballs. The following notice of a careful study of its real path and altitude will accordingly be read with more than ordinary interest. (See Comptes Rendus for August 2, 1869, vol. lxix. p. 326.)

"Meteors.—In a paper addressed last week to the French Academy of Sciences, M. A. Tissot examines the circumstances accompanying the passage of the remarkable bolis of the 5th of September, 1868. It was seen to pass over Belgrade, Laybach, Bergamo, Saulieu, Civray-sur-Cher, and Mettray*. At Bergamo, M. Zezioli found that in 17 seconds it described an arc, the extremities of which were respectively, in right ascension 17°, N. declin. 3°; R.A. 202°, N. decl. 27°. At Trémont, M. Magnin, while observing Jupiter, had at one moment both the planet and the fireball in the field of his telescope. M. Mugnier at Saulieu and M. Badiller at Civray-sur-Cher both saw it in the zenith. Letting alone the two latter data, which are somewhat uncertain, there is just enough left to enable us to determine the position of one point of the meteor's path, and those of two right lines between which it moved during a known space of time. From this may be obtained the *minima* of velocity with respect to the earth and the sun, and which are respectively 80 and 71 kilometres per second. Now were the orbit described elliptical, or even parabolic, the velocity could not exceed 42 kilometres; there can therefore be no doubt that the trajectory was an hyperbola. This is, we believe, the first time that the path of a fireball has been ascertained from reliable mathematical data. From this starting-point M. Tissot proceeds to correct the doubtful observation of Civray, and finds that the meteor passed over that place at a distance of 3° 12″ from the zenith. The lowest altitude of the bolis was 111 kilometres; the eccentricity of the geocentric hyperbola was 124, and its two asymptotes formed an angle of one degree

* M. Tissot states that the path of the meteor was vertically over these places; its altitude *at its disappearance* over Mettray, in Indre et Loire, 798 kilometres (496 miles) from Bergamo, being 307 kilometres (191 miles), and the lowest altitude of its course was 111 kilometres (69 miles). The meteor therefore shot upwards (!); and the whole length of its course from Belgrade, in Servia, to Mettray was nearly 1000 miles!

only. Our author now has sufficient data to calculate the orbit of its heliocentric motion, and finds its elements as follow: Longitude of ascending node 343° 28′; obliquity to ecliptic 68°; angle of transverse axis with line of nodes, 87° 32′; eccentricity 2·59; semiaxis major, in parts of mean terrestrial radius taken as unity, 0·20; period of perihelion passage, 1868, Sept. 25th, 19 hours; velocity at perihelion 100 kilometres per second. Motion retrograde. The meteor merely passed through our solar system; twenty days after it made its appearance it passed through its perihelion, the distance of which from the sun is about the same as that of Mercury. The bolis is now further away than Saturn, but has not yet got beyond Uranus."

From a comparison together of some of the principal descriptions of the detonating meteor of the 7th of October, 1868, Mr. W. H. Wood considers that its point of first appearance was between 80 and 100 miles above Avranches, in the north of France, and that it descended in about five seconds, with a luminous course of about 180 miles, to a height of not more than eight miles above the English Channel, twenty miles from Hastings, in the direction of Dieppe. The detonation distinctly heard at Paris would, in this case, arise from an earlier portion of the meteor's flight. In relation to the height and other particulars of this meteor, the following remarks of the Abbé Lecot, of Noyon (Les Mondes, vol. xviii. p. 333), proceeding upon the basis of good observations, deserve attention.

"The principal remarkable feature of the fireball of the 7th of October, 1868, was its vast volume, much larger than that of any other meteor seen for many years. Two other circumstances appeared also to be of some important interest; viz. 1st, the immense distance to which the series of detonations was heard over an area of more than eighty leagues (190 miles) in width, incomparably surpassing the distance to which the loudest claps of thunder, or the discharges of the largest cannons can be heard. If, moreover, the statements of the majority of the observers may be trusted, the interval between the bursting of the meteor and the sound of the report was so great that the phenomenon must have taken place at a prodigious height. Less than five minutes cannot be allowed, on the most moderate estimation, from the explosion of the meteor to the arrival of the first sound of the report; and this would imply a distance of more than twenty-five leagues (sixty miles). Taking into account the direction of the meteor as seen by the observers, it would be difficult to admit a height of less than twenty leagues (forty-eight miles). This height is confidently within the limits which it would be necessary to assign to it when the greater number of exact descriptions of the meteor given by competent observers are taken into the account.

"The second peculiarity which appears hitherto to have been overlooked is that the meteor was not solitary, but appears to have been connected with a long list of similar appearances, which have been more numerous than ordinary at this season of the year. Last night (October 19th), on two occasions, about 8 and 10 P.M., I saw each time, in less than two minutes, five bolides of considerable brightness, leaving behind them a persistent streak, and moving from south-east to north-west. Their apparent brightness was about that of the planet Jupiter. On every previous evening since the 8th of October, when the sky was clear, I have been astonished at the number of shooting-stars that have presented themselves, generally without my paying any particular attention to record their appearance."

By extending backwards some of the given apparent paths, Mr. Wood infers that the direction relatively to the earth, or the apparent point of radiation of this great meteor, was probably the radiant T, a general centre of divergence of shooting-stars near α and γ Pegasi during the months from July to November.

A collection of fourteen original accounts of the appearance of the great daylight meteor of the 3rd of November, 1868, was carefully examined by Mr. Wood, to determine as accurately as possible its real path. A radiant-point, or general vanishing-point of the apparent paths prolonged *backwards,* near Arcturus, is pretty clearly indicated as the most probable direction from which the meteor actually approached and entered the earth's atmosphere. Assuming this direction as established, and the apparent points upon its path observed by Mr. Wood at Birmingham as certainly very near approximations to the true positions of the meteor at its first and last appearance, the comparison of the remaining observations with these first assumptions regarding the computed path enables the latter to be at least provisionally fixed with moderate precision. The point of first appearance of the meteor was seventy miles over Cuckfield, in Sussex, and its point of disappearance twenty-five miles over Herne Bay, in Kent. The whole course of about eighty miles, performed in about three seconds of time, was directed from the west-south-west, descending at an inclination of about 35° to the horizon.

Should the real course of the meteor be assumed to be more nearly from west to east, the apparent radiant-point would be nearer to ϵ Virginis than to Arcturus; and preserving the same place of first appearance, the point of disappearance will be found to be at a height of about thirty miles over the neighbourhood of Calais.

Meteors of November 14th, 1868.—From a large number of meteors observed in the United States of America on the morning of the 14th of November last, Prof. Newton has selected several instances of meteors of conspicuous brightness, which were simultaneously observed by observers at distant places. The results, accompanied by two excellently executed plates of the persistent streaks, some of which presented peculiar features, are given in the 'American Journal of Science' for May 1869 (vol. xlvii. p. 399), and lead to the supposition, from the observed motions of translation and distortion of form of some of the streaks, that a northward current of the upper air prevailed below an altitude of about fifty-four miles, and that above this level, to a height of about sixty miles, a current of air existed moving towards the south, succeeded, at a greater height, by another current moving in a northerly direction.

The double appearance of the streaks observed with the telescope in some of the meteors of the shower suggests the conjecture, entertained by Prof. Newton, of an actual duality in the meteor itself; and a very possible analogy may thus evidently be recognized among the November shooting-stars to the double or multiple character, which is a common feature among the detonating and stone-producing meteors.

1. Meteor and meteor-streak observed at Newhaven &c. at 1h. 12m. A.M. New York time (see Catalogue). "The central point of the cloud may be regarded as fifty-four miles high, over N. lat. 40° 43′, and W. long. 76°, and its course S. 78° W., with an angle of depression of 20° upon the horizon of the places beneath it. The heights of its eastern and western ends were fifty-nine and forty-nine miles, or ninety-five and seventy-nine kilometres." In the earlier part of its course the meteor "passed the meridian of Haverford at a height of about sixty-eight miles, but may have been visible before it reached that point. . . . A note in his observation of the meteor at Pali-

sades, by Mr. Gilman, would imply a first altitude of eighty-five or ninety miles. This estimate, however, is not to be taken strictly."

2. Meteor and meteor-streak observed at Fern Lodge Observatory, Palisades, and at Stamford, Conn., at 2h. 48m. A.M. New York time. Although the base-line and the corresponding parallax are small, the two observed paths agree well together, and give an elevation of fifty-two miles for the end of the track, and sixty-five for the beginning, with a length of path of twenty-seven miles. A portion of the luminous streak, which in the field of view of a telescope magnifying forty times appeared double, and terminated by an oval cloud, was, allowing for the inclination and diameter of the field of view, 0·89 mile in length.

3. Meteor and meteor-streak observed at Portland and at Boston, U.S.A., at 3h. 51m. 30s. A.M. Portland time. A parallax of 53° upon the base-line of 121 miles gives for the height of the meteor, at a point near the beginning of its path, seventy-seven miles. The length of the luminous cloud, which gradually curled up and floated northward as it faded, remaining visible at Boston for three minutes, must have been ten miles.

4. Meteor observed at the same stations at 5h. 6m. A.M. Portland time. The altitude of this meteor at disappearance was about forty-eight miles. Its first appearance, judging from observation, was at a height of nearly 150 miles; but the track was so near to the radiant, that a difference of three or four degrees in the apparent length would reduce the first altitude below 100 miles.

5. Meteor and meteor-streak observed at Newhaven and at New York by Professors H. A. Newton and A. C. Twining, at 5h. 6m. 45s. A.M. Newhaven time (see Catalogue). The altitude of the beginning and end of the visible path of the meteor is, from these observations, eighty-five and sixty miles respectively. The motions of the train seem to indicate an upper current from the north above that from the south, which was shown by the motions of the train of the meteor of 1h. 12m. A.M. New York time.

6. Meteor and meteor-streak observed at Boston and Fairhaven, &c., U.S., at 5h. 30m. 30s. Boston time. The meteor left a streak, which at Boston remained visible for seven minutes, drifting northwards; and at Fairhaven it also remained visible as a pale cloud for five minutes, widening and becoming nearly circular and larger than the full moon. The observed paths agree very well with the necessary conditions, and indicate an altitude of about fifty-nine miles for the lower part of the cloud. The northward motion of the cloud showed that it did not penetrate through the upper into the lower current, which swept away southward the lower part of the train of the meteor at 1h. 12m. A.M. New York time.

1868, December 10th, 10h. 57m. P.M., London, and Ackworth, Yorkshire (see Catalogue). The resemblance between these two meteors in time and other particulars of their appearance, although singularly close, is only accidental, as the difference of the positions of their apparent paths at the two places does not agree with that which would be produced by the effect of parallax.

1869, May 31st, about 11h. P.M., Cambridge and Paris, &c. (see Catalogue). Among the many descriptions of this large detonating fireball, the apparent path is indicated at very few places with precision. An approximate determination of its real path by means of the reference to certain stars contained in the careful observations by Mr. Atchison at Cambridge, and by M. Robinet at Paris, leads to the result that the meteor first appeared at a height of about seventy miles above Eastbourne in Sussex, and disappeared about twenty miles above the English Channel, halfway between North Foreland and the opposite coast of France. The distance of this course, about fifty-five or sixty miles from Hawkhurst, Wrotham, and the other places in Kent where the detonation was distinctly heard at an interval of about five minutes after the meteor's disappearance, affords a verification of its correctness, while it is in good agreement with the apparent course of the meteor as observed at Brussels. The direction of the meteor from near ξ (in the spear-hand) of Boötes is probably an outlying example of the occurrence of the Radiant Q_2, in Corona, of shooting-stars during the greater part of the months of May and June.

1869, July 16th, 11h. 35m. P.M., London, Hawkhurst, and Beckenham (see Catalogue). The small parallax indicated by the observations at the two latter places of the point of disappearance of the meteor "near the star ϵ Pegasi" may partly be attributed to the great height of the meteor, which perhaps prevented any sound of its explosion from being heard, and partly to the direction of its apparent path, being at both stations nearly parallel to the straight line joining the two places of observation. The descriptions of the meteor's course at London are not sufficiently exact to afford any confirmation of this result. A similar meteor observed nearly at the same hour on the same date, in 1861, was likewise found to disappear at a great height (sixty-five miles) above the surface of the earth (see Report for 1862, p. 77).

1869, August 9th, 10h. 59m. P.M., Hawkhurst and Birmingham (see Catalogue). The resemblance of these meteors, like that of the two meteors almost simultaneously observed on the 10th of December last, is only accidental, the apparent paths at the two places not satisfying the necessary conditions of identity, although the two meteors approximate to each other very closely in their remaining features.

II. Aërolites and Large Meteors.

a. *Aërolites.*

Daniel's Kreil, Grigua Territory, South Africa, March 20th, 1868.

The fall of the meteorite was witnessed by a native, who picked it up whilst still warm. The specimen, which weighs 2 lbs. 5 oz., was brought to England by a well-known mineralogist, Mr. J. R. Gregory, and analyzed by Professor Church. In composition it is a meteoric stone, containing much free iron disseminated through its mass, together with some troilite and schreibersite. The following is Professor Church's analysis of the aërolite:—

Nickel-iron	29·72
Troilite	6·02
Schreibersite	1·59
Silica and Silicates	61·53
Oxygen &c. and loss	1·14
	100·00

A new mass of meteoric iron, from South Africa, was also noticed by Mr. Gregory. It fell in 1862 at Victoria West, and is preserved in the Museum at Cape Town. (Quarterly Journal of Science for January 1869, No. xxi. p. 133).

Pnompehu, Camboja, Cochinchina, 1868, between June 20th and 30th, about 3^h P.M. (local time).

The meteorite separated into three pieces, of which one fell at the door of the king's palace, the other two pieces were picked up at a considerable distance. The first piece, forwarded to France by M. Lafon, Naval Surgeon, residing at Pnompelu, is pyramidal, weighing about 2 lbs. (1 kilogr.). It is covered with a black shining crust $\frac{1}{50}$ inch in thickness, in which nickel-iron is scattered in fine grains. The fracture is granitic, and speckled with dark spots. The substance of the meteorite dissolved in muriatic acid leaves a residue of graphite and of crystalline silicates. A portion was sent to M. Peyremol, Professor at the medical school at Rochefort, for more exact analysis. ('Les Mondes,' 1868, Nov. 20th.)

Namur, Belgium, 1868, July 5th, $11^h 45^m$ P.M. (local time).

During a violent storm a fireball fell on the roof of a house at Namur, and broke a tile. The fall coincided with a clap of thunder. The only residue found of the ignited body was a small meteorite weighing about a third of an ounce (10 grammes); some grains of which were detached for analysis, and the remainder now weighs 137 grains. It is entirely covered with a slight crust of olive-colour speckled with bright-yellow, but not crystalline-looking points, giving evidence of its exposure to a glowing heat. The interior substance is a friable dark-grey cinder, interspersed with black and yellow crystals, but without metallic grains. The density, 3·0004, is rather less than that of ordinary aërolites. It exhibits opposite magnetic poles at the two ends of its longest axis, and is highly magnetic. Attacked by hydrochloric acid it is partly dissolved, disengaging sulphuretted hydrogen, and leaving a pretty abundant residue containing graphite and free sulphur. The solution is found by the ordinary tests to contain iron, nickel, and chromium. ('Les Mondes,' 2nd ser. vol xviii. p. 332.)

Ornans, Doubs, France, 1868, July 11th.

The following extract from a French newspaper of September last, announces the fall of an aërolite in central France.—"On the 11th of July in the present year" [1868] "a meteorite fell at Ornans in the Department of Doubs. M. Pisani has submitted it to analysis, and he finds that it contains a very small quantity of nickeliferous iron, a small quantity of chrome-iron-ore, and magnetic iron-pyrites; it is besides very rich in peridot. Its structure is friable and porous, and its general aspect is of a deeper grey colour than is commonly observed in aërolites." (See M. Pisani's analysis, in 'Comptes Rendus' for Sept. 28, 1868, vol. lxviii. p. 663.)

Sauguis, Mauléon, Basses Pyrénées, 1868, September 7th, $2^h 30^m$ A.M. (local time).

After a meteor of the usual appearance a report was heard as far as Irun, on the Spanish border, 50 miles distant from Sauguis, where a meteorite weighing 4½ lbs. (2 kilog.) fell into a small stream, 30 yards from the church, and broke into pieces. The pieces, which were further broken by those who found them in search of a supposed hidden treasure, were sent to the Museum of Geology in Paris, and analyzed by M. Stanislas Meunier. They closely resemble those of the meteorite of Casale, which fell (on the 29th February) six months and seven days before the present occurrence, appearing thereby to indicate two nodes of this meteoric orbit, intersecting the earth's orbit at 180° apart. The siliceous mass contains grains of nickel-iron, troilite, and chromite. (Report of M. A. Daubrée, 'Comptes Rendus' for Nov. 2, 1868; and 'Les Mondes,' Nov. 5th, 1868.)

1869, January 1st (morning).

Stonefall at Lake Malar, Upland, Sweden. ('Bulletins de l'Association Scientifique de France,' No. 105.)

Krähenberg, near Zweibrücken, Bavaria, May 5th, 1869, 6^h 30^m P.M. (local time).

A specimen of this stonefall is in the Mineralogical Museum of Vienna.—(Communicated by R. P. Greg. See also the Report on this meteorite by Dr. Neumayer, in the 'Proceedings of the Sections.')

Kernouve, Cléguérec, Morbihan (Vendée), S. France. (Comptes Rendus, No. 25, 1869.) May 22nd, 1869, 9^h 45^m P.M. (local time).

Stonefall after a brilliant meteor, which was seen at l'Orient, and at Vannes by M. Arondeau, leaving a long streak, and followed by a violent detonation. ('Bulletins de l'Association Scientifique de France,' Nos. 123 and 124.)

A large meteor, casting a bluish glare over the whole town, was seen in a northerly direction from Vannes, and was followed in $2\frac{1}{2}$ or 3 minutes by a violent explosion, which shook the doors and windows of the houses. A meteorite, which appears to have been of conical shape, and to have weighed about 160 lbs. (English), struck the earth, at Kernouve, a few yards from a young girl, who was the only witness of its fall, and it penetrated a little more than a yard into the ground. On the following morning it was dug out, broken in pieces, and the fragments were distributed among the villagers as mementos of a stone supposed to have fallen from the moon. Unable to disabuse its possessors of the supposed value of the relics, Professor Felix Pisani, of Paris, at considerable expense, succeeded in securing possession of almost the entire aërolite for his mineral cabinet, where the larger half is now destined for one of the European museums. A specimen weighing 32 lbs. he presented to the Paris Academy, with a careful analysis of the meteorite. The interior of the stone presents a dark grey granular mass, with iron-pyrites, and much metallic iron in bright grains, some of them a few millimetres wide, and others like thin veins or filaments scattered through it. The iron-pyrites, although magnetic, is not attracted by the magnet, and the metallic iron is thus easily separated from it. The entire meteorite is highly magnetic, and its specific gravity is 3·747. Its substance is fused by the blowpipe to a black magnetic bead, in which the spectroscope reveals the presence of sodium and calcium. It is partly attacked by muriatic acid; and a specimen thus treated offered to M. Pisani the following proximate chemical analysis:—

Nickeliferous iron	20·5
Magnetic iron-pyrites (Fe_7 S_8)	5·45
Silicates soluble in muriatic acid	34·6
Silicates insoluble in muriatic acid	40·22
	100·77

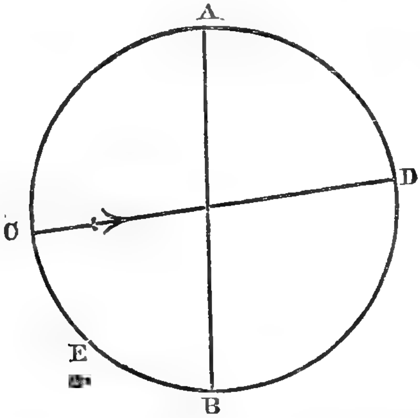
b. *Large Meteors.*

September 5th, 1868, 1^h 4^m P.M. (G.M.T.). Passage of a black body across the sun's disk.

On the same date as that of the large meteor seen at Geneva and in Central France (see Catalogue), Mr. G. Forbes communicates the following observation of a black body seen to transit the sun's disk at Pitlochrie, in Perthshire.

The sun's disk was projected on a white screen with a $2\frac{1}{4}$-inch achromatic (of the late Mr. Dolland), magnifying about 60 times. A B, in the figure, is the projection of the vertical line; C D is the path of the meteor. "It was

Fig. 1.



not round, but shaped like E, the pointed end moving first. I was at the time watching a faint spot near which it passed, and it was much blacker than the spot. It took about $1\frac{1}{2}$ second to cross. I also drew the apparent size of the meteor and of the sun at that moment. By this means I find its apparent diameter to be 27″ approximately, *i. e.* greater than the mean diameter of Saturn, and less than that of Jupiter. To have moved so slowly it must surely have been beyond the limits of visible meteors; and if at so great a distance, how great must its size in all likelihood have been!

"I have here taken for granted that it was a meteor, which some may question. Its motion was perfectly steady, quite unlike a bird crossing the field of view, which I have often seen. Another person was watching the spot with me at the time, so that there is corroborative evidence. I was enabled to take the time, position, shape, direction of flight, apparent size of the meteor (as a fraction of the sun's diameter), all except the duration, with great exactness. I may mention about the spot, that it was *quite* in focus for very distinct vision."

Kansas, U.S. America, June 6th, 1868, $11^h\ 40^m$ A.M. (local time).

At Manhattan a meteor was first seen in the western sky at an elevation of about 60°, descending at an angle of 75° to the horizon, and leaving a luminous streak which remained visible nearly a minute. The nucleus, of a vivid pink colour, was about 15′ diameter. It fell in less than one second to within 12° of the horizon, where it burst, and thence descended in a double stream of fire. About $4\frac{1}{2}$ minutes afterwards a double report, like 12-pounder cannons at a distance of a mile, was heard. A light-blue cloud remained at the point of explosion, $1\frac{1}{2}$° long and nearly 1° wide, which remained visible, without much change of shape, until it was obscured by cirro-cumulus clouds. The report was heard over an area 120 miles in width, and the meteor was seen at Topeka, Marysville, Forts Harker and Zarah, and at other very distant places. Its flight was apparently from south to north.

Height of the meteor when first seen	81 miles
Height when it exploded	12·5 ,,
Length of the luminous persistent cloud	1·44 ,,
Breadth of ditto	0·96 ,,
Diameter of the nucleus	1890 feet
Distance of the explosion from the place of observation	58 miles

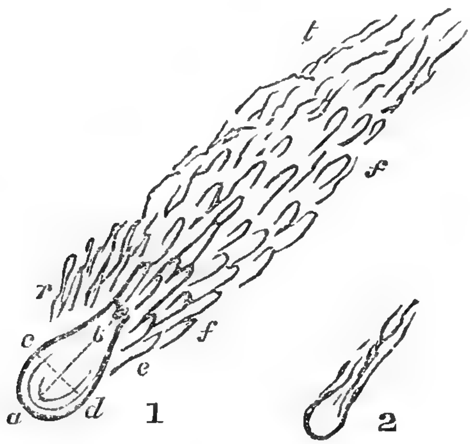
The above measures of the meteor's course are calculated by Professor Mudge, of the Agricultural College of Kansas, who adds that the meteorite must have exploded over the country halfway between the Republican and Solomon Rivers. This district has few inhabitants, and no aërolite has yet been picked up. ('American Journal of Science' for Nov. 1868, 2nd ser. vol. xlvi. p. 429.)

Birmingham.—Large meteor seen in daylight, Nov. 3rd, 1868, $3^h\ 17^m$ P.M.

Mr. Wood's description of the meteor (see Catalogue) is accompanied by the following careful drawing and explanations:—

"The meteor was pear-shaped, the rectangular diameters being $\frac{3}{4}$ and $\frac{1}{2}$ the diameter of the moon (fig. 1). The body, brilliant white in front, and ruby-red near the tail, flickered considerably in transit, and diminished towards extinction, as represented in the drawing (fig. 2). Red flames, or the substance of the meteor, issued from the nucleus, and extended towards the tail one degree, as shown in fig. 1. The tail, 15° long, resembled ordinary smoke in sunshine; only a small section of it is represented in the figure. The nucleus preserved its intensely white light until near the last 5° of its course, when there was a perceptible diminution in its lustre; its size was then about equal to Venus. At the time of collapse I thought it dark red, or non-luminous, probably from the contrast with sunlight, as the effect of the sun's presence would be to deprive the meteor of the usual bordering rays of light.

Fig. 2.



Great daylight meteor of November 3rd, 1868, as seen from Birmingham. Diameter $ab=24'$; $cd=14'$. *ff*, Red flames (or particles of the meteor)$=1°$.

Space *r b e* of nucleus ruby-red. Space *r a e* of nucleus brilliant white. *t*, portion of tail 15° long, bluish-white, smoke-like, lasting $1\frac{1}{2}$ second.

Fig. 1. Size at appearance. Fig. 2. Relative size at extinction, devoid of lustre.

"The same object at night would certainly have appeared much larger, and have produced an extraordinary illumination over England. The path appeared slightly undulating, if it were not an optical illusion produced by the fluctuation of its light.

"A few clouds were rapidly driving across from the W.S.W., and the sun shone brightly; yet the meteor stood prominently out, in bold relief, on the greyish background of the sky."

The following additional notice of this large meteor is communicated by Sir J. Herschel, Bart. Extract of a letter from H. Griesbach, Esq.

"Travelled from Worcester to Morton on Thursday last" [Nov. 4th] "with a lady and gentleman who reside at *Morton.* They told me that on Wednesday last [Nov. 3rd] about 3 o'clock, they were walking from their residence at *Morton* to call on some friends at Toddenham, when they saw a most brilliant meteor which fell to the earth about a furlong from them. They described the light from the meteor as extremely bright and white, the sun shining brightly at the same time. They did not hear any noise from the motion of the meteor. The gentleman said he thought that he should be able to find the spot where the meteor fell, and promised to take two of his men to search for some relic."

The meteor was also observed at Southam, South Warwickshire, as a large fiery body, travelling in the direction of the wind (which was from W.S.W.: see Weather Reports).—'Birmingham Gazette,' November 7th.

Bolides observed in France, 1868–69.

M. A. Guillemin, author of the French work on Astronomy 'Le Ciel,' communicates the following notes of observations of large meteors contained in the Numbers of the weekly 'Bulletins' of the 'French Association for the Advancement of Science,' of which two annual volumes, under the active presidency of M. Le Verrier, have now appeared:—

	No.
1868. Sept. 5th.—Notes by Messrs. Denza and Schiaparelli	108
1869. Jan. 1st.—Swedish aërolite, observed at Stockholm, Upsala, &c.	105
" Feb. 2nd.—Bolide at Bordeaux: M. Rousanne; " Feb. 8th. " Nancy: M. A. Tissot	108
" Feb. 24th. " Marseilles: M. Borelly; " March 2nd. " Bordeaux: M. Rousanne	110
" April 28th. " Pont Pierre (Moselle): M. Richard	120
" May 22nd.—Aërolitic meteor observed at L'Orient and Vannes. Fall of stones at Cléguérec	123
" May 22nd.—Fragments presented to the French Association	124
" May 22nd.—Details of observation at Vannes: M. Arrondeau	126
" May 31st.—Bolide at Paris: M. Robinet (see Catalogue)	124
" May 31st.—Seen also at Albert (Somme); M. Comte; and at Pontarmé, near Senlis	126
" June 17th, 8^{h} 34^{m} P.M.—Bolide at Marseilles: M. Borelly. Seen also at Narbonne and Aix-les-Bains	ibid.
" June 17th.—The same at Annecy (Savoy), at Montpellier, Perigueux, and Sarlat (Dordogne)	127
" June 18th, 1^{h} 12^{m} and 1^{h} 50^{m} A.M.—Two Bolides observed at Marseilles: M. Borelly	126

In the 'Zeitschrift der österreichischen Gesellschaft für Meteorologie,' vol. iii., large meteors are recorded as having been observed at certain places in Germany during the nights of the 17th of September and 17th and 26th of October, 1868.

In continuation of his former list, Mr. Greg has added the following supplementary Catalogue of large meteors observed in recent years to the numerous records of such occurrences contained in the Appendix of the last Report (for 1868), and collected in similar lists in the Reports for 1860 and 1867.

Catalogue of Aërolites and Meteors. By R. P. Greg.—Supplement No. III.

Year.	Day of month.	Locality.	Size &c.	Observations.
1842.	Jan. 29...	Eutin	large	
1844.	Dec. 9...	Hamburg	>Venus	
1845.	Jan. 26...	Flottbeck............	large	Whitish; 7 seconds.
,,	Aug. 9...	Bilk	....	Greenish.
1846.	April 21...	Huatasco.............		
,,	July 29...	Rhine-land		
,,	Nov. 28...	Bonn		
1847.	June 2...	Do.		
,,	Sept. ...	Piræus................	large	
1848.	Mar. 24...	Frankfort		
,,	July 13...	Bonn		
1850.	Feb. 17...	Do.		
,,	21...	Lüdenscheid		
,,	Aug. 29...	Nauplia		
1851.	Aug. 14...	Melfi		
,,	16...	Rastenburg...........		
,,	26...	Grieskirchen		
1852.	June 8...	Rastenburg		
,,	Oct. 16...	Eutin		
,,	Nov. 27...	Bonn		
,,	Dec. 2...	Jena..................	large	
,,	18...	Bonn		
1853.	Jan. 26...	Osnabrück		
,,	27...	Süchteln	....	
,,	Feb. 26...	Bonn		
,,	July 5...	China		
,,	Aug. 10...	Switzerland...........		
,,	Oct. 28...	Holland		
1854.	Jan. 3...	Wels	large	
,,	Feb. 3...	Stromboli		
,,	Mar. 1...	Aargau		
,,	Aug. 24...	Blansko		
,,	Oct. 5...	Naples................		
,,	Nov. 2...	Cronstadt	large	
,,	16...	Hamburgh	do.	
,,	Dec. 2...	Lemberg	do.	
1855.	Mar. 27...	Thurgau		
,,	May 3...	Naples................		
1856.	May 25...	Petersburg		
,,	Aug. 9...	Olmütz	....	Two seen.
,,	Oct. 19...	Triest		
,,	Nov. 15...	Troppau		
,,	Dec. 14...	Olmütz		
,,	27...	Do.		
1857.	Feb. 16...	Holland	large	
,,	Mar. 24...	Smyrna		
,,	29...	Bohemia	large	
,,	May 18...	Olmütz		
,,	June 6...	Do.		
,,	Aug. 15...	Do.	....	And other places.
,,	Sept. 13...	Wimpassing		
,,	Oct. 7...	Olmütz		
,,	Dec. 18...	Oldenburg	....	Greenish.
1858.	Jan. 15...	Troppau		
,,	15...	Navoina		
,,	20...	Olmütz	large	
,,	22...	Görnöver.............		
,,	23...	Menyhazza		

TABLE (*continued*).

Year.	Day of month.	Locality.	Size &c.	Observations.
1858.	April 24...	Van Diemen's Land.	$=\frac{1}{3}$ moon	Bluish white; 4 secs., 8 p.m.
,,	Aug. 5...	Olmütz		
,,	Nov. 12...	Oxford		
1859.	Jan. 4...	Holstein	large	
,,	4...	Athens	....	(Julius Schmidt* &c.)
,,	June 27...	Do.		
,,	Oct. 9...	Do.	....	12 secs., greenish.
,,	Nov. 2...	Do.		
,,	6...	Do.		
1860.	June 16...	Do.	....	Greenish.
,,	Dec. 23...	Do.		
1861.	April 5...	Coblenz		
,,	June 30...	Athens		
,,	July 12...	Do.		
,,	Sept. 1...	Do.		
,,	27...	Do.		
,,	Oct. 31...	Dara, Arcadia	large	5.30 p.m.
,,	Nov. 1...	Athens		
1862.	Feb. 18...	Algiers		
,,	Mar. 31...	Athens		
,,	25...	Van Diemen's Land.	$=\frac{1}{2}$ moon	Streak 10″; greenish; 10 p.m.
,,	May 16...	Athens		
,,	21...	Do.	large	Streak 20″.
,,	June 29...	Do.		
,,	July 16...	Levant?		
,,	20...	Athens	large	7 p.m.
,,	Aug. 16...	Arcadia		
,,	Sept. 16...	Athens		
,,	Oct. 12...	Do.	large	6.15 p.m.
,,	26...	Vienna		
1863.	Feb. 26...	Geneva	....	Bluish, 15 secs.
,,	Mar. 23...	Vienna		
,,	May 31...	Washington		
,,	June 6...	Oxford		
,,	Sept. 7...	Hungary		
,,	Oct. 1...	Athens		
1864.	May 12...	Psara, Greece	large	
,,	Aug. 2...	Kephissia, Greece		
,,	22...	Do.		
,,	30...	Athens		
,,	Sept. 6...	Do.		
1865.	Mar. 30...	Tyrol	....	Streak 10″.
,,	April 12...	Palermo		
,,	29...	Somersetshire	large	8.15 p.m.
,, *	July 5...	Natal	large	E. to W.; detonation in 2 seconds.
,,	Aug. 4...	Jutland		
,,	20...	Athens	....	Streak 15″.
,,	Sept. 12...	Do.		
,,	20...	Aube, France	large	Detonated in 5 minutes, after dividing into two halves; 5 a.m.
,,	24...	Kent	....	7.48 p.m.
,,	Oct. 18...	Athens		
,,	24...	Do.		
,,	Nov. 27...	Essen, Prussia		
1866.	Jan. 9...	London, &c.	....	Also at Greenwich.
,,	22...	Dantzic	=moon	7.18 p.m.
,,	Feb. 2...	Maidstone		
,,	June 2...	Eubœa		
,,	24...	Derby	$=\frac{1}{4}$ moon	$11\frac{1}{4}$ p.m.; 60° in 2″.

TABLE (*continued*).

Year.	Day of month.	Locality.	Size &c.	Observations.
1866.	July 5...	Kent	noon	In sunshine; large.
,,	21...	Athens................		
,,	Aug. 8...	Corfu		
,,	24...	South Australia	large	
,,	Sept. 9...	Athens................		
,,	Oct. 19...	Holyhead and Dublin	5′ *d*	Brilliant; S. to N.; 3 a.m.
,,	24...	Kildare, Ireland......	large	4.40 p.m.; moved slowly.
,,	Nov. 6...	Sussex	3 > Venus	Very slow; sparks.
,,	9...	Buckinghamshire ...	....	Lighted up the sky; 8.40 p.m.
,,	13–14	Athens................	....	3 very large ones.
,,	,, ...	London, England ...	$\frac{1}{8}$–$\frac{1}{3}$ moon	Several very large ones.
,, *	20...	Nashville, Tennessee.	= sun	4 a.m.; moved S.W.; detonated loudly.
,, *	Dec. 6...	Santander, Spain ...	....	Stone-fall (not Nov. 30?)
,,	8...	York	= $\frac{1}{7}$ moon	Red; 1 sec.; 18° path; 8.47 p.m.
,,	10...	Do.	= $\frac{1}{8}$ moon	
,,	12...	Kishnaghur, India ...		
,,	12...	York	= $\frac{1}{8}$ moon	
,,	12...	Ireland		
,,	12...	Constantinople; Athens.	large	
,,	15...	Brest, France.........	do.	
,, *	14...	Alderly, Cheshire ...	do.	Followed by a loud detonation. Also seen at Manchester.
,,	30	Athens.		
1867.	May 6...	London	3 > Venus	Kite-shaped, 7.50 p.m.
,, *	June 9...	Setif, Algeria	10.30 p.m.	Stone-fall; no crust; meteor and detonations.
,, *	11...	Switzerland; Paris...	= $\frac{1}{2}$ moon	Streak remained for an hour; direction N.W. to S.E., between 65 and 85 miles high; from over Dunkirk to over Cambray; detonated.
,,	Aug. 19...	Dobbs's Ferry, New York, U. S..........	....	Elongated; divided into three.
1868.*	Jan. 30...	Pultusk, Poland......	....	Stone-fall; regular shower, like that of l'Aigle in 1803.
,,	,, ...	Dantzic and Poland..	= moon	Large meteor at 6.18 p.m., same as the last.—J. G. Galle.
,, *	Feb. 29...	Alessandria & Casale; Piedmont.	11 a.m.	Stone-fall; detonation from a fiery cloud; 3 stones = 9 kilogrammes, 3·6 sp. gr.
,,	29...	Chiavary, Italy	10 a.m.	Large fireball from S.W.
,,	29...	Ditto?	11$\frac{3}{4}$ p.m.	Large meteor, S. to N., horizontal.
,, *	Mar. 20...	Iriqualand, S. Africa	....	Stone-fall (2$\frac{1}{2}$ lbs.).—Quarterly Journal of Science.
,, *	June 6...	Kansas, U. S. A.......	= $\frac{1}{2}$ sun	Fell down ver. 75°; 11.40 a.m.; heavy double explosion in 4$\frac{1}{2}$ minutes from a light blue cloud, which was seen for 17″ afterwards; report heard over 120 miles area; S. to N. Probably 12$\frac{1}{2}$ miles high when it burst.
,, *	Sept. 7...	Tardet, Basses Pyrénées.	2.30 a.m.	Stone-fall, meteor, and great detonation. N.W. to S.E.; sp. gr. of the stone 3·37.
,,	Oct. 7...	London	large	
,,	Nov. 3...	Rugby, Birmingham, &c.	= $\frac{1}{2}$ moon	Large meteor at 3$\frac{1}{4}$ p.m. In bright sunshine.

III. Star-Showers.

1. *The August Meteoric Shower in* 1868.—Signor Francesco Denza, Director of the Observatory at Moncalieri, in Piedmont, has published a pamphlet of the observations made on the nights of the 9th–12th August in Italy, comprehending some fifteen stations. It appears that the largest number to be seen by a single observer in one hour was at Florence, viz. 26·9 on the night of the 10th August, at 13^h–14^h. Three observers, under the supervision of Prof. Donati, registered :—

August.	10^h–11^h.	11^h–12^h.	12^h–13^h.	13^h–14^h.	14^h–15^h.	Totals.	
9	45	40	30	30	42	187	813
10	64	70	88	98	83	403	
11	63	46	48	31	35	223	

Of these, about 5 per cent. on each evening were sporadic, or not Perseids. Out of these 813 meteors Prof. Donati classifies 164 as large ones, 221 of ordinary size, and 428 as small. As compared with the Perseids of 1867, the result appears, as reduced for the same days and hours of observation, for a single observer :—

	Aug. 9.	Aug. 10.	Aug. 11.	Totals.
1867	67·0	104·8	79·3	251·1
1868	62·3	134·3	74·3	270·9

From whence it does not appear that there was any great difference in the richness of this shower for the two years. Signor Denza gives the positions assigned to the radiant-point of these August meteors, as determined by competent observers, at 6 out of the 15 Italian stations, and the results are remarkably accordant :—

	R. A.	N. Decl.
	°	°
Bergamo	43	57
Milan	?	57
Lodi	45	56
Moncalieri	44	57
Urbino	45	56·5
Palermo	43·4	56·7
Mean or average	44·1	56·7

The position of the Perseid radiant, as determined by A. S. Herschel in 1863, was R. A. 43°·8, N. Decl. 56°·2 (Report for 1864, p. 98).

For the fifteen stations in Italy, the horary numbers, reduced for a single observer, gave as average :—

9 August		8·2
10	,,	14·7
11	,,	10·5
12	,,	5·1

At Urbino Prof. Serpieri gives the radiant positions as follows :—

	R. A.	N. D.
	°	°
9 August	41·0	57·5
10 „	45·0	56·5
11 „	44·5	56·5
Mean	43·5	56·8

The path of one meteor, observed at Moncalieri on the evening of the 9th, at $10^h\ 5^m$, was cuvilinear (tortuosa), and the light of another, at $10^h\ 12^m$ (Turin time), was intermittent. Bolides of considerable brightness were observed on the 7th at $9^h\ 15^m$ P.M., on the 9th at $9^h\ 35^m$ P.M., and a third on the evening of the 10th at $10^h\ 49^m$ P.M. The first, brighter than Venus, of a reddish colour, made its appearance at an altitude of 40° above the S.E. horizon, between α and δ Lyræ, and descended vertically with very slow speed to η Serpentis, near the same point of the horizon; it left behind it a most brilliant-white, persistent streak. The last of the three bolides was so bright as to illumine the clouds near which it passed.

At Bra, in Piedmont, two meteors were observed, with curved paths, on the morning of the 10th, at $12^h\ 20^m$ and $12^h\ 30^m$ A.M. On the same morning, at $12^h\ 53^m$, local time, a bolide, more brilliant than Jupiter, of bright whiteness, was seen at the Observatory of the College at Rome, moving from the south towards the east. Madame Scarpellini, at Rome, saw a similar meteor on the evening of the 10th, at $10^h\ 50^m$ P.M., which was also seen by Prof. Pinelli at Civita Vecchia. The latter observed another bolide of equal brightness at Civita Vecchia on the morning of the 11th, at $1^h\ 53^m$ A.M.

At Palermo very brilliant bolides were observed by Prof. Tachini on the nights of the 5th and 6th of August, 1868 (Bulletino Meteorologico del R. Osservatorio di Palermo, vol. iv. Nos. 8 & 9).

At the Meteoric Observatory of the Luxembourg M. Chapelas-Coulvier-Gravier noticed the greatest frequency of meteors (1·3 per minute) on the morning of the 10th, between midnight and 1^h A.M. The number of meteors recorded during the night of the 10–11th was 237, of which 113 were of the 3rd magnitude, or brighter, and 49 left persistent streaks. A bolide presenting very remarkable features was observed at $11^h\ 27^m$ P.M. on the night of the 10th. The meteor was "conformable to the general direction of the meteoric current," and moved slowly, as if resisted in its course, so that, instead of the usual spherical form, it appeared internally agitated, and assumed the form of a cone, with base foremost, from which the material of the meteor fell off in red sparks along the dazzlingly bright luminous streak. (Comptes Rendus, vol. lxvii. p. 498.)

Prof. Tachini, of the Royal Observatory of Palermo, in the 'Bulletino Meteorologico' of that Institution for August and September 1868, gives a very full account of the meteor observations made at that observatory on the evenings of the 8th, 9th, 10th, 11th, 12th of August, 1868. The number of meteors seen by four observers in three hours (after 10 P.M.), on the evenings of the 8th, 9th, and 10th August, were respectively 44, 101, 195; in two hours ten minutes on the 11th August 115 meteors, and in one hour and eight minutes on the evening of the 12th August 24 meteors. This would give a relative frequency of

14·7, 27·3, 52·7, 39·7, 13·3,

and would probably indicate a *maximum* frequency on the morning of the

11th August towards 7 A.M. This result was confirmed, it appears, by the observations made by the astronomers at Rome.

In all a catalogue of 393 meteors are given for these five evenings, with the precise time of observation, apparent magnitudes, and exact positions of the paths of each observation, determined by the fixed stars; as well as colours.

In the 1st	quadrant	...........= 78
" 2nd	"	...........=112
" 3rd	"	...........= 97
" 4th	"	...........=160

Professor Tachini himself observed, with the aid of his *meteorometre*, which he had made use of for the 14th-November meteors of the preceding year, and described in the Journal of the Observatory, No. 11 of vol. iii.

His observations in R. A. and N. Decl. were then drawn upon a celestial map, and the following results are given in relation to the radiant-point:—

Palermo, August 1868.	R. A.	N. Decl.	No. of observations.
8th	=41·0	+57·6	= 8
9th	=46·0	+56·5	=21
10th	=40·8	+56·5	=35
11th	=45·0	+56·5	=19
12th	=49·7(?)	+57·0	= 4
Means...	=44·5	+56·8	Total 87

Another Table is given, showing the reductions of *all* the observations made during the five evenings by himself and the four other observers in reference to the radiant-point:—

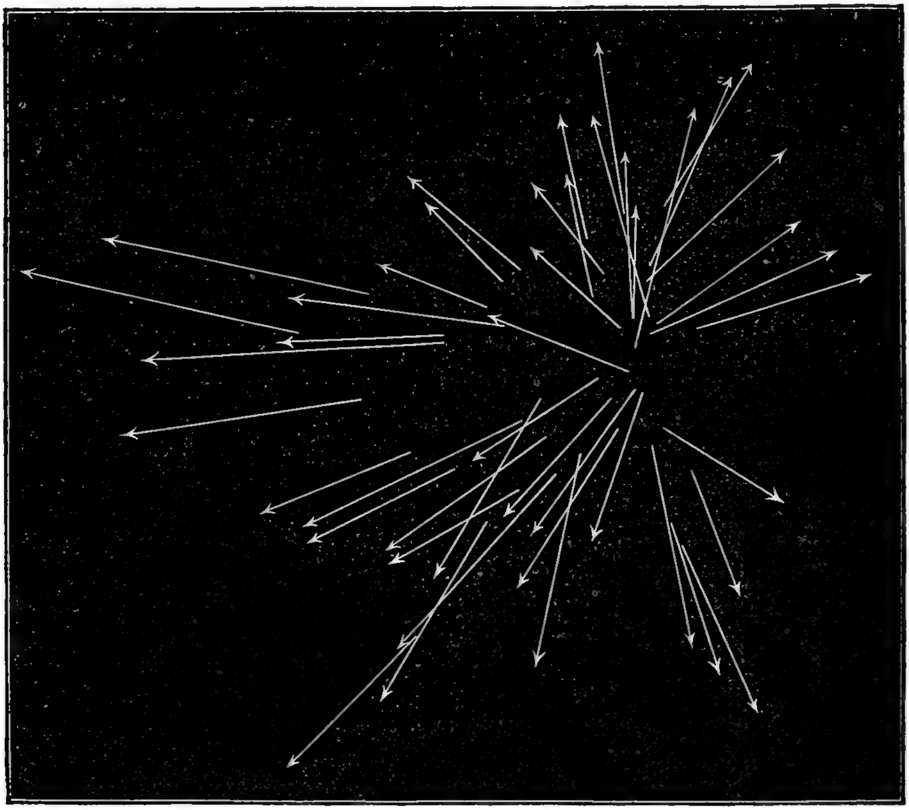
R. A.	D.
43·5	+57·0
45·0	+53·0
41·0	+57·0
40·0	+57·5
47·5	+59·0
Means..43·4	+56·7

Rejecting the observations of the evening of the 12th August, on account of their comparative paucity, we obtain as the best average result for the radiant position R. A.=43°·3, N. Decl.=+56°·8; and this is probably a pretty accurate determination.

Other meteors were seen on these evenings, which may have belonged to other radiants; *five* seen on the evening of the 10th August had a radiant-point at R. A.=3°·5, N. Decl.=+71°.

The trajectories of all were in straight lines, and the streaks of the meteors well marked, appearing as a slight or feeble residuum of the substance of the burning meteor itself, whose diameter generally appeared larger than that of the streak or train.

Prof. A. Serpieri, of Urbino, gives, in the monthly 'Bulletino Meteorologico' of the Osservatorio del Collegio Raffaello, occasional observations of meteors. On the evening of the 21st of May, 1868, the positions and times of seventeen are recorded in R. A., and N. Decl.; and a considerable number for the evenings of 23rd–26th of June.



Tracks of meteors recorded at the Royal Observatory of Palermo, on the 8–12th of August, 1868, showing the position of the radiant-point. By Professor Tachini.

Professor Serpieri, with three other observers, found that the horary numbers on the following evenings were,—

	No.
9th August	51
10th ,, ...	105
11th ,, ...	74

Each evening the chief radiant-point was near η Persei, with two minor ones near Camelopardus, at about R. A. $=40°$, Decl. $+58°{\cdot}5$, and $49°{\cdot}5$, $+58°{\cdot}5$. The meteors on the evening of the 10th August appeared finer, and gave longer paths than those of the 9th and 11th August. There appeared to be a considerable number of meteors on each evening belonging to other radiants (or sporadic), most of which, however, seemed to lie around, as it were, the sides of a polygon, with the constellation Perseus itself a centre of them.

Prof. Serpieri considers that the radiant presented itself rather diffusely, taking into account all the meteors which passed near k Persei. Projected on a chart, the tracks approximately crossed each other.

On the 9th August,	from R. A.	46° to 36°,	and Decl. 61° to 54°.
,, 10th ,,	,, ,,	50 to 40,	,, 54 to 59.
,, 11th ,,	,, ,,	49 to 40,	,, 55 to 58.

Taking the average of these positions,

		R. A.	Decl.
		°	°
for August	9	41	+57·5
"	10	45	+56·5
"	11	44·5	+56·5
The average of 3 days....		=43·5	56·8

which agrees well enough with the result of Schiaparelli's and Zezioli's observations for this year.

At Milan, Prof. Schiaparelli considered the Perseids of August 1868 more conformable than usual; the declination of the radiant-point was determined more precisely than, perhaps, its right ascension, as about 57°. Zezioli, at Bergamo, found

R. A.=43°, Decl. +57°.

Signor Zezioli, of Bergamo, has also sent to Mr. R. P. Greg particulars of about 600 meteors seen in March and April 1868, most of which Mr. Greg has reduced upon the charts prepared by Mr. A. S. Herschel for the British Association, and the results as to radiants are given in the second edition of the Atlas of Meteor Charts*.

At Rome, Mancini states the horary numbers for three observers thus,—

		No.
9th	August	25
10th	"	46
11th	"	42
12th	"	18

Mr. R. P. Greg, at Whitby, considered the principal radiant for the earlier part of the August shower (from 2nd August to 8th August) as very close to *k* Persei, or about R. A. 44°, N. Decl. +57°.

2. *The November Meteoric Shower in* 1869.—"Captain Donald of the 'Preston,' from Bombay to Liverpool, reports that on the 14th inst., when thirty-eight miles S.S.W. of Kinsale (N. lat. 51° 42', W. long. 8° 31'), from 2h. A.M. till after daybreak, meteors appeared to be bursting in every direction, like innumerable rockets flying across the heavens. The principal direction was from S.E. to N.W. The weather was rather overcast at first."—*Liverpool Mercury*, Nov. 28th, 1868.

From the logs of various vessels transmitted to him for analysis, Captain H. Toynbee, head of the Ocean-Meteorological Department of the Board of Trade, has kindly extracted, at the solicitation of the Committee, the following entries, in which the occurrence of this star-shower is noticed as having been observed at sea.

Extract from the log of the ship 'Spray of the Ocean,' Capt. P. Slaughter, from Bombay to Liverpool, "Nov. 14th, 1868, N. lat. about 15°, W. long. about 32°" [in the N.E. trades of the Atlantic Ocean].—"From midnight until daylight a continual succession of meteors; countless; many of them of great magnitude and brilliancy, their direction mostly from between N.E. and N.W. towards the latter point. Their tracks, also, mostly parallel to the horizon, at altitudes from about 10° to about 35."

Under the same date and hour, in a corresponding position of the S.E. trades, where no lightning is usually seen, an entry in the log of another vessel contains a memorandum of the appearance of constant lightning.

* These charts, containing 26 plates, can be obtained on application to Messrs. Taylor and Francis, Red Lion Court, Fleet Street, London.

In an excellent meteorological register kept on board of the ship 'Siberia,' between Boston and New York, by Captain Mostyn, there is recorded on the night of the 13th and early morning of the 14th of November, 1868, "Meteors glancing from east to west, at an average rate of five or six per minute, at times leaving a luminous track extending 15° or 20°, which remained visible 4 or 5 minutes. The night being perfectly clear gave an additional effect to the gorgeous display."

A good Weather-register kept by Captain C. T. Raymond, on board of the ship 'British India,' gives a description of the shower as it appeared to him in southern latitudes.

"November 13th, 1868, at 10h. 30m. P.M. in S. lat. 26° 3′, W. long. 27° 37′.—A perfect shower of shooting-stars commenced, and continued until the rising sun extinguished their light. It might be best compared to a shower of rockets; for, like them, they left long trains behind, moving confusedly in all directions, some falling perpendicularly, some obliquely, some horizontally describing curves, and some even slightly ascending. Some shone with a bright green light, exploding at last into many pieces, but without report; some with a dull red, and some with a faint yellow. It resembled in every respect a similar shower which I witnessed in Bombay, 14th November, 1866. At times the meteors fell as dense as snow-flakes.

"I could not detect any uniformity, either with regard to the point of the heavens whence they started, or whither they fell. Most fell perpendicularly, and with a prodigious velocity."

The following description of the meteoric shower in America, as observed at Haverford College, Pa., by Prof. Samuel J. Gummere, was received, at the time of its occurrence, by the Committee from Mr. B. V. Marsh:—

"Meteoric Shower, November 13–14th, 1868, as observed at Haverford College, Pennsylvania, ten miles west of Philadelphia. Latitude 40° 0′ 46″, longitude 5h. 1m. 13s.

"The watch commenced at 10h. 45m. P.M., November 13th. About eleven o'clock two or three very fine meteors were seen coming from the direction of Leo, which was yet below the horizon. At 11h. 17m. one directly from Leo. The train, of a spiral form, remained visible ten minutes near the constellation Perseus. Seventeen minutes later another in the south-west exhibited a train of similar form for the space of seven minutes. Persistency and brilliancy of train, with variety of colour, continued to be a marked feature of the whole display.

"At midnight about two hundred meteors had been counted. From this time the reckoning was as in the following Table:—

h	m	Meteors.	h	m	Meteors.	h	m	Meteors.
12	21	300	2	39	1900	4	38	3500
	34	400		47	2000		43	3700
	46	500		53	2100		47	3800
	58	600	3	9	2300		51	3900
1	17	800		18	2400		54	4000
	34	1000		31	2600		56	4100
	42	1100		45	2800	5	0	4200
	47	1200		51	2900		26	4700
	55	1300		58	3000		31	4800
2	1	1400	4	7	3100		36	4900
	9	1500		14	3200		41	5000
	23	1700		22	3300			
	31	1800		30	3400			

"The counting was discontinued at 5h. 41m., although several hundreds were seen between that time and sunrise.

"At 1h. 10m. the finest meteor of the night was seen. It appeared near the Pole-star, increasing in brilliancy as it approached Cassiopeia, and vanishing near κ and β Cassiopeiæ with a flash of extraordinary brilliancy. The train at first had a direction nearly parallel to the line of these two stars, and about 15° in length. Immediately it commenced to spread, and soon assumed the form of an inverted S, thus ∽. Then the form became that of an ellipse with a hollow ellipse at each of the two foci, all the time drifting slowly towards α Andromedæ. At 1h. 55m. the train was still faintly visible at δ Andromedæ, the whole time of visibility exceeding forty-five minutes.

"At about 4h. 30m., and at 4h. 31m. two meteors left trains in the vicinity of Sirius and δ, of Canis Major, each assuming the form of the Greek Ω, and continuing visible together for several minutes.

"As day began to dawn the meteors, which shot down towards and below Venus, were in many cases of a bright red or crimson colour.

"Many unconformable meteors were observed during the night, and the tracks of many of these corresponded to a radiant between the Pleiades and the Haiades.

"In several cases the remarkable phenomenon was noticed of a disappearance, and almost immediate reappearance, as of a light extinguished and rekindled.

"In general the finest meteors were seen in the north and north-west."

The state of the weather in England on the night of the 13–14th of November was not in general favourable to observations of the shower. Yet a clear condition of the sky beginning to prevail at Glasgow at 3h. 30m. A.M., and being finally established at 4h. 30m. A.M., a perfect view of the principal portion of the display was obtained by Prof. Grant. The meteors resembled those of the 14th of November, 1866, in three or four instances leaving streaks which remained visible for two or three minutes after the disappearance of the meteor. Their colour was white, in some instances with a slight tinge of red, and the colour of the streaks was less inclined to green than in the former shower. Three or four of the meteors far exceeded Jupiter in brightness, but not equalling the planet Venus, which shone at the same time with intense brilliancy in the east. Their rate of frequency appearing to increase, their number observed in successive minutes was recorded from 4h. 56m. A.M. until 6h. 5m. A.M., when 256 meteors had been counted by one observer. The number really visible during the interval of one hour and ten minutes was in all probability three times as great as this, or as many as seven or eight hundred. The time of greatest frequency was observed at 5h. 15m. A.M., the number afterwards diminishing considerably during the continuance of the observations. In the successive intervals of ten minutes,

Ending at ..	5h. 6m.	16m.	26m.	36m.	46m.	56m.	6h. 6m.
There were counted	50	54	36	39	26	24	27 = 256 meteors.

Shortly after six o'clock, while the shower was still active, although the period of its greatest intensity seemed to have already passed, the sky became cloudy, and no further observations could be made. (Monthly Notices of the Royal Astronomical Society for December 11th, 1868, vol. xxix. p. 60*.)

At the Royal Observatory, Greenwich, the sky was densely overcast, on the

* The same Number of the 'Monthly Notices' (p. 62) contains a memorandum on the shower by Prof. D. Kirkwood, of Bloomington, Indiana, in the United States. The number counted in 6h. 31m. was 3280; one observer counting 780 in 1h. 16m., ending at 6h. 11m. A.M. The maximum was at about 3h. 30m. A.M.

morning of the 14th of November, until 1h. 57m. A.M.; it was clear from this time until 2h. 50m. A.M., and during this interval forty-six fine meteors were observed, and their apparent paths described. The number of meteors at this time was very great, both large and small, and quite bewildering; several large meteors were present at the same time, and all could not be observed. The sky then became overcast until 3h. 53m. A.M. It was clear but hazy from 4h. to 4h. 23m., when clouds began to collect increasingly until 4h. 48m. A.M., after which time the sky was overcast throughout the night. Sixty-nine fine meteors were observed, some of which were exceedingly brilliant, leaving streaks varying in duration to more than one minute. When the sky was cloudy, lightning-like flashes were frequently observed until after six o'clock, evidently connected with large meteors, lighting up the whole sky as several of the meteors were observed to do when the sky was clear. A meteor which burst, and left a streak for eight seconds midway between γ Leonis and Mars, was without motion. The majority of bright meteors observed were conformable to the radiant in Leo, other radiant-points which were discernible being generally connected with the smaller meteors.

The 'Times,' Dec. 7th, 1868, contained a letter from Dr. J. M. Hamilton, describing the meteoric shower as it appeared in Shetland. The meteors were abundant from 3h. 30m. A.M. until sunrise, sometimes appearing two or three at once, many of them brighter than Venus, and a few so bright that one could have read ordinary print, for an instant, by their light. The streaks were bright white, or in some cases of a bluish or reddish tinge; those left by some of the brightest meteors remained visible for one to three minutes, and were even visible towards daybreak. The sky was generally clear, and when it was partly overcast the meteors shone between the interstices of the clouds. The point in Leo from which the meteors appeared to emanate remained stationary among the fixed stars from 3h. 30m. A.M. until nearly the time when the sun rose.

A letter from Mr. G. T. Kingstown, Director of the Toronto Magnetic Observatory, in the 'Times' of December 8th, states that the sky was clear, except between 5h. and 6h. A.M., on the morning of the 14th of November, and that 3000 meteors were counted before that hour, 99 per cent. of the meteors radiating from the constellation Leo. Some, which exceeded Sirius in brightness, exhibited a variety of colours. The luminous streaks often continued visible from two to four minutes. The following Table shows the number of meteors seen at different parts of the night, together with the state of the sky:—

Interval in Toronto time.	Number of meteors seen.	State of the sky.
From 10h 45m P.M. to 12h P.M.	173	Very clear.
„ 12 0 „ 1 A.M.	329	Ditto.
„ 1 0 A.M. „ 2	583	Ditto.
„ 2 0 „ 3	489	Occasional very light haze.
„ 3 0 „ 4	375	Ditto.
„ 4 0 „ 5	572	Haze increasing.
„ 5 0 „ 6	365	Clouds 0·4; very hazy.
	2886	

At Rome, on the night of the 13–14th of November, 1868, the meteors began to appear about midnight, with diffuse light in the N.N.E. and N.E., several meteors being seen near the Lion's "Sickle" at 12h. 9m. From 12h. 30m. until 1h. 20m. an interval of cessation occurred, in which very few meteors appeared; but at 1h. 10m. a splendid fireball made its appearance in the Lynx (see Catalogue). From 1h. 30m. to 2h. 30m. a shower of meteors appeared in all parts of the sky, radiating from a point at the centre of the stars $\gamma, \epsilon, \mu, \zeta, \eta$ Leonis. *In the N.E. and N.N.E.* directions only, ninety meteors were counted in two hours. The maximum, which was also noted at the same time by Prof. Pinelli at Civita Vecchia, took place at 4h. 50m. A.M., on the 14th. The total number of meteors visible between midnight and 6h. A.M., in all parts of the sky, was probably not less than 3000. (Annuaire de l'Observatoire Royal de Bruxelles for 1868–69, p. 166; letter of Madame Scarpellini to M. Quetelet.)

The numbers of shooting-stars seen by three observers at the Observatory of the Capitol at Rome, on the night of the 13–14th of November, 1868, is thus stated by Father Secchi in a letter to Abbé Moigno, printed in 'Les Mondes' for November 26th, 1868:—

In the successive quarters of an hour ending as below, Rome time, November 14th A.M., there were seen,—

h	m	Meteors.	h	m	Meteors.
2	45	29	4	30	208
3	0	50		45	233
	15	48	5	0	264
	30	84		15	270
	45	140		30	339
4	0	148		45	250
	15	141			

Total, in three hours, 2204 meteors.

According to another letter in the 'Times,' the meteoric shower was also seen with great brilliancy at Naples. A brief extract from a letter received by Sir John Herschel states that at Florence the meteoric shower was also very splendid.

At Moncalieri, and at Bra, in Piedmont, the sky was cloudless for a few hours after midnight, and the beginning of the star-shower was observed. The hourly numbers of meteors seen at Moncalieri on the nights preceding the 13th of November were:—

On the night of the	9th.	10th.	11th.	12th.	
Horary number of meteors.	11	*8	23	24	*Sky very hazy.
	At Bra			21	
	At Alessandria			45	

As soon as the constellation Leo rose above the horizon at Moncalieri and at Bra, the meteoric shower appeared in groups of three, four, or even five meteors at once. The following Table shows the number of meteors counted at each place in the successive hours before midnight, and half-hours after midnight on the morning of the 14th of November. The sky became almost overcast at Bra at one o'clock, and completely so at Moncalieri at ten minutes after two o'clock A.M.

Intervals (P.M. & A.M.) ending at Nov. 13–14	h 7	h 8	h 9	h 10	h 11	h 12	h m 12 30	h 1	h m 1 30	h 2	h m 2 30
No. of Meteors seen: Moncalieri	7	14	18	24	26	25	40	46	70	94	42*
Bra ..	5	19	26	21	19	19	35	26	9*		

Total:—At Moncalieri, 406; at Bra, 179.

The meteors seen after midnight presented the same appearance as those of November 14th, 1866, leaving brilliant streaks which often remained visible for several seconds. Their brightness exceeded that of Jupiter or Venus, of a reddish hue. Their directions were all conformable to a radiant-point in Leo, situated exactly between γ and ζ of that constellation. The gradual increase of the horary numbers shows that the maximum was not attained, and that the meteoric shower probably commenced a few hours before midnight at Moncalieri. At the neighbouring station of Mondovi, where the sky was partially clear from 4h. until 4h. 15m. A.M., eighteen bright meteors were counted in the few clear spaces; and after this time, when the sky was completely overcast, two meteors and fifteen lightning-like flashes were seen through the clouds by Prof. Bruno, in the space of a quarter of an hour, between 5h. 30m. and 5h. 45m. A.M.

On the night of the 14th–15th, observations of meteors in Piedmont were prevented by bad weather at all the stations. (Letter from Father F. Denza to the Secretary of the Committee.)

At the Royal Observatory of Madrid the horary number of meteors did not surpass six or eight on the night of the 12th–13th, and before midnight on the night of the 13th. From that time until 2h. A.M. on the 14th 200 meteors were counted by two observers, among which six or seven bolides illuminated the country round the observatory with the brilliancy of moonlight. The radiant-point of all the meteors was in Leo. Between 2h. and 3h. A.M. the number of meteors seen by the two observers rose to 350 in one hour. A splendid fireball (see Catalogue) appeared at 2h. 33m. A.M. Between 3h. and 4h. A.M. the number of meteors seen remained about the same as in the previous hour, after which time they became more frequent; and between 5h. and 5h. 30m. A.M. twenty meteors could be counted in a minute. One meteor in every ten was then brighter than a first-magnitude star; their course was short, especially near the radiant-point, which was close to η Leonis. After 5h. 30m. A.M. the intensity of the shower began to decline, the approaching dawn at the same time obscuring some of the smallest meteors.

The majority of the nuclei were bluish, many white, a few bright red, and a very few bright emerald-green. The maximum probably occurred soon after daybreak, as thirteen bright meteors were counted between 6h. and 6h. 35m. A.M., when Mars, Sirius, and even Venus had disappeared, and the last meteor observed was recorded five minutes before the sun rose.

During the night of the 14th–15th, as on that of the 12–13th, the number of meteors was very small. A large fireball must, however, have appeared at 12h. 20m. A.M. (see Catalogue), as its bright persistent streak remained visible for several minutes.

The appearance of the maximum of the shower in 1868 was accordingly chiefly visible in America, and the first commencement of the shower was not discernible in Europe. Although less dense in its frequency, yet in the greater extent of its duration, and uniformity of its structure, the meteoric

* During these half-hours the sky was partly overcast.

cloud in 1868 considerably surpassed that traversed by the earth on the 13th–14th of November, 1866.

3. *Meteoric Shower of December 12th*, 1868.—The cloudy and unsettled state of the weather in England on the periodical night of the annual return of this meteor-shower prevented any continuous observations of shooting-stars. A considerable shower of meteors was, nevertheless, noted by Mr. Wood, at Birmingham, who reports as follows:—

"Some meteors were observed on the 10th, but the overcast state of the skies on the nights of the 11th, 12th, and 13th prevented observations requisite to fix the time and intensity of the maximum (except within wide limits). An hour's observation, however, on the morning of the 12th gave evidence of a good display, namely, twenty meteors per hour for one observer, of which 53 per cent. radiated very accurately from θ Geminorum, and the remaining 47 per cent. from the coexistent radiants, Ga, LG, R_3, RG. The shower presented the usual features,—meteors white, with an occasional bluish tint, brief in duration and trainless."

4. *Meteoric Showers of January 2nd, April 11th and April, 20th*, 1869.—At London and Manchester the sky on the night of the 2nd of January was densely overcast. On the night of the 3rd the sky was remarkably clear in the neighbourhood of London. Mr. Crumplen, and two other observers, watching there, independently, for several hours failed, however, to get a glimpse of any shooting-stars. If the shower took place on the previous night it must accordingly have been short-lived, and its limits must have been defined within very narrow bounds. Mr. Crumplen also watched for meteors on the night of the 24th of December, 1868, when the sky was partially clear, without success. The unfavourable character of the weather for observations of luminous meteors in England throughout the last winter and early part of the spring was equally attended by negative results on the 10–11th, and 20th of April, 1869.

At Moncalieri, in Piedmont, forty meteors were observed on the evening of the 11th of April, of which two were bolides (see Catalogue) whose apparent paths were accurately recorded. Two other bolides appeared on the same evening with such brilliancy that the attention of all the seven observers stationed on the terrace of the observatory, and looking towards different parts of the sky, was drawn towards them by their light. Father Denza is preparing for publication the observations of meteors made in Piedmont during the first four months of the present year, among which the number of bolides recorded has been unusually large.

On the morning of the 21st of April, 1869, between 2h. and 4h. A.M., eighty-four meteors were counted at Moncalieri, of the usual characteristic brightness, and radiating, with the general uniformity of the meteors of this shower, from a point in the neighbourhood of the constellation Lyra. (Bulletins of the Royal Academy of Belgium for June 1869, vol. xxvii. p. 632–4.)

In the Meteorological Bulletin of the Observatory of Urbino for April and May, 1869, Prof. A. Serpieri records the apparent paths of forty-one shooting-stars, observed during the evenings of those months; nine of which were observed in 1h. 10m. on the morning of the 21st of April. The last of these nine April meteors was of red colour, moved slowly, as if resisted in its flight, and left sparks of light upon its track. In a reply to Prof. Serpieri, who sent these observations to him at Milan, Prof. Schiaparelli writes:—"Seven of the nine meteor-tracks proceed from a radiant-point at about R.A.$=267°$, N. Decl.$=+35°$. The radiant-point of the Comet I., 1861, is at about R. A.$=270°{\cdot}4$, N. Decl.$=+33°{\cdot}5$.

"The positions of the radiant of this meteor-shower, as stated by other authors, are as follows:—

Greg................	R. A. 282°	N. Decl. +33°
A. Herschel..........	277·5	+34·5
Heis	277	+38
Galle and Karlinski....	278	+34·5

"Your observations, accordingly, are more nearly conformable to the radiant-point of the comet than those of all the other observers."

Eight meteors observed in one hour, on the evening of the 1st of May, diverged from a radiant-point which remained sensibly fixed at about R. A. 202°, N. Decl. 62°. The position of the radiant-point M 7, 8, near η Ursæ Majoris, as given by Mr. Greg in the last edition of the 'British Association Atlas' (see Report for 1868, p. 401), for the interval between April 25th and May 25th, is at R. A. 202°, N. Decl. 52°, about 10° from the position assigned to the vanishing-point of these meteors at Urbino.

5. *The August Meteor-shower in* 1869.—The following Table contains a summary of observations by Mr. Greg, at Manchester, on the periodic nights of the 9–11th of August. During the intervals of time recorded in the list, the sky was generally clear.

Date and interval of observations.	Average rate of frequency of the meteors seen by one observer.	Remarks and average radiant-point.
1869. h m h m	m m	
Aug. 9. 10 5 to 11 25 P.M....	1 in 5 or 6	Radiant about B Camelopardi.
11. 12 5 1 25 A.M....	1 2½	Mostly Perseids; radiant *k* Persei.
12. 10 15 11 45 A.M....	1 4	One half appeared in 20m., between 10h. 15m. and 10h. 35m. A.M.

Mr. Greg observed a fireball, three times as bright as Jupiter, on the evening of the 9th, at 10h. 23m. P.M. It was bluish white, and lasted one second, commencing at γ Pegasi, and proceeding 12° or 15° in a direct course from η Persei. The meteors on the night of the 10–11th were bluish white, of short course, and leaving momentary streaks in those of first and second magnitude, and dull yellowish-red in the smaller stars; they radiated from near η, *k* Persei, instead of from Cassiopeia as during the previous years, or from B Camelopardi as on the preceding night, and were about twice and a half as frequent as on the evening of the 9th, coming occasionally in groups of two or three in a minute, after a lull of five or six minutes without any appearance of a shooting-star. No large meteors were seen on the nights of the 10th and 11th.

At Broadstairs, in Kent, Mr. George Chapman noted the appearance of eight meteors, about the average brightness of second-magnitude stars, two of which left momentary trains, during the half-hour from 9h. to 9h. 30m. P.M. on the evening of the 10th, and two similar shooting-stars during the quarter of an hour ending at 10h. 15m. P.M. on the evening of the 12th of August. The duration and length of path of these meteors was about 10° in less than two seconds. Their colour was principally white, and the apparent paths of all were remarkable for the uniformity with which they radiated from a point about midway between γ Persei and the bright stars of Cassiopeia. On the night of the 11th the sky was overcast.

The particulars of the observations of the meteoric shower at Birmingham are summed up by Mr. W. H. Wood in the following remarks:—

Date and interval of observation.			Numbers of meteors seen.	Condition of the sky.
1869.				
Aug.	8.	At night	......	Quite overcast.
,,	9.	10^h 30^m P.M. to 11^h 30^m P.M.	16	Quite clear.
,,	10.	At night	1	Overcast (occasional clear spaces).
,,	11.	10^h to 11^h P.M.	4	Clear.
,,	11.	11^h to 12^h P.M.	12	Clear.
,,	12.	At night	......	Overcast.

Active radiant points observed.	Number of meteors observed, per cent., from each radiant.	Magnitudes as per stars.	Number of meteors per cent.
η Persei	30	Equal to or brighter than	
γ Persei	16	1st-magnitude star	30
ϵ Cassiopeiæ	16	2nd-magnitude star	25
T, $T_{2, 3, 4}$ (in Pegasus)	10	3rd ditto, and under	45
$N_{8, 1}$, R_1 (χ, κ, a Persei), and other radiant-points	28		100
	100		

"Colours of the meteors bluish white, yellowish white, pale green. The present display exhibits a decline below the average of the past ten years in hourly numbers and apparent magnitudes, which differ strikingly from the corresponding data of the August meteor-shower in 1868 (see the Report for that year, p. 381). The proportion of small meteors will be found to have increased twofold, and of the more conspicuous ones to have diminished in the ratio of about 3 : 5. A curious feature is presented by the fact that the percentage number of meteors diverging from η Persei in the present year is the same as that of the meteors radiating from the same centre in the year 1868, and that the percentage numbers of meteors from γ Persei and ϵ Cassiopeiæ are, as in that year, equal to each other, and only less by four than in the year 1868. The frequency of meteors from the radiant-points in Pegasus is this year a little in excess. The data furnished by this year's observations regarding the other coexisting radiant-points are insufficient for comparison with those of former years. There were no sporadic meteors."

Up till the 8th of August the number of meteors observed during the month, in Piedmont, exceeded 1500, of which Mr. Denza will publish a description and chart in the 'Bulletino' of the Observatory of Moncalieri. At Moncalieri itself the following numbers of meteors were observed on the nights of August

1st.	2nd.	3rd.	4th.	5th.	6th.	7th.
15*	72	87	69	overcast	39†	17*

The sequel of the remaining observations of the August period at Moncalieri, and at other places in Italy, will be published in the Monthly Bulletin of that Observatory. Many of the meteors radiated from Cygnus, and from Cassiopeia. (Letter of F. Denza to Mr. R. P. Greg.)

* Overcast. † Partly overcast.

A letter from M. Amadée Guillemin to the Secretary of the Committee, describes the state of the sky, at Paris, on the night of the 10th of August as overcast, and, accordingly, unfavourable for observations of the August meteoric shower.

General Radiant-points of Shooting-stars.—Copious lists of shooting-stars observed in Piedmont and Italy during the last two years have been communicated by their authors to the Committee, whose object it has been to reduce them, for comparison with the results obtained from the British Association Catalogue, whenever a constant divergence appeared to present itself among the meteors, to specific radiant-points. In this inquiry their labours have met with encouraging success by the complete verification of a considerable number of the known radiant-points, and by the means of rectifying the positions and durations of others, less certainly established by the paucity of previous data, afforded by the additional observations.

Mr. R. P. Greg having lately projected on the Celestial Maps, in use by the Committee of the British Association, about 150 meteor-tracks, from observations made last year under the care of Signor Denza, Director of the Observatory at Moncalieri in Piedmont, and since published in the Meteorological Bulletin of that Institution, has been enabled to redetect and verify the radiants AG_1, $M_{1,2}$, M_3, MG, $A_{1,2}$; and more slightly the radiants $A_{3,4}$, SG_1, $S_{2,3}$, NG, $M_{4,5}$. The observations in question were made on the evenings of the 7th–19th January; and 30th January to 6th February, 1868. Two new radiants were also fairly obtained, not before noticed by Greg and Herschel,—one for the evenings between the 29th of January and (?) 6th of February, near Quadrans, R. A.=223°, N. Decl. 54°; and the other near μ Eridani, R. A. =73°, S. Decl. 2°, for the evenings of the 9th–19th January, and at r Orionis, R. A.=68°, N. Decl. 6°, for 30th January to 5th (? 11th) of February.

The former of these, at Quadrans, is evidently identical with Heis, K_2, at R. A. 227°, N. Decl. 60°, for 15th–31st January, but must certainly not be identical with the special shower, $K_{1,3}$, of Greg and Herschel for January 2nd, which, there is good reason to believe, is a shower of only twenty-four hours' duration.

Mr. Greg also finds in Signor Zezioli's observations, made at Bergamo, April 25th–May 3rd, 1868, abundant confirmation of the radiants W, WG, Q_1, DG_2; also of N_8, OZ, and OZ_1.

Prof. Serpieri, in the 'Bulletino Meteorologico' of Urbino for August 1868, gives a radiant for eight shooting-stars on the 11th of July, 1868, the position R. A. 200°, N. P. D. 35°, which almost exactly agrees with the radiant MG_5 for July 1st–11th, as determined last year by Mr. Greg (Report for 1868, p. 403) from Signor Zezioli's observations, made at the same time at Bergamo, the position determined being at R. A. 210°, N. P. D. 35°, as given in the 2nd edition of the 'Celestial Atlas,' published last year by the British Association.

Considerations of the space usually allotted in these Reports to observations of luminous meteors (which in the present year is amply occupied), and a sense of the scientific importance of the papers communicated, during the past year, by their authors to the Committee, will only permit a list of their titles and of the principal contents of their pages to be here appended. The annually decreasing splendour of the November meteor-shower, and the absence of its attendant observations, will, in a future year, enable the recent contributions of special importance to meteoric literature to be carefully reviewed.

1. "Le Stelle Cadenti del Periodo di Agosto osservate in Piemonte ed in

altre contrade d'Italia nel 1868" (Fourth Memoir on Shooting-stars observed in Piedmont and Italy, by Francesco Denza, Director of the Observatory of the Royal University of Moncalieri, near Turin).—Several extracts and references to the memoirs have been made in former Reports, and principally to the present memoir in this Report (Appendix III.) on the August meteoric shower in 1868.

2. "Le Meteore Cosmiche," Milano, E. Treves & Co., Biblioteca utile, 1869, by the same author, is a brief but lucid lecture, delivered to a popular audience at the Museum of Natural History and Philosophy in Florence, on the subject of the recent discoveries in cometic and meteoric astronomy.—The author, in common with Schiaparelli, regards comets, aërolites, and shooting-stars as bodies of a common origin in the nebulous matter of the universe, differing only from each other in the degree of concentration wrought in them by the effects of universal gravitation and of time. The gaseous and self-luminous character of the nucleus of Tempel's comet, observed by Huggins, which is not referred to by Father Denza, differing so essentially from that of aërolites, does not receive any very obvious or satisfactory explanation on this hypothesis.

3. "Etudes géométriques sur les Etoiles filantes," par G. M. Goulier (in 8vo, pp. 154, with plates: Metz, F. Blanc, 1868).—The principal object of the work is an instructive manual intended to direct the observations of shooting-stars projected by the recently instituted Meteor-Committee of the Imperial Academy of Metz. The phenomena of visibility, rate of apparition, apparent position, and hourly variation of the radiant-point, and the calculations of the real heights, velocities, and dates of the periodical returns of shower-meteors are discussed, with mathematical formulæ intended to adapt the careful observations of luminous meteors conveniently and with increased accuracy to the development of the new cosmical theory of shooting-stars. The same clear arrangement and demonstrations of all the fundamental propositions of Professors Newton and Schiaparelli on the apparitions of shower-meteors and their orbits are given in subsequent chapters of the work. The sixth and last chapter contains a review of the conjectures to which the cosmical theory of luminous meteors has given rise, and suggests some brief considerations on the possible identity of shooting-stars and aërolites.

4. "Zur Theorie der Sternschnuppen," von A. Erman (extracted from Erman's 'Archives,' vol. xxv. part 3: Berlin, 1867).—A detailed account of the attempts is given, which were made before the time of Schiaparelli, to determine the form and dimensions of the August and November meteor-orbits,—first, on the method employed by Erman, and adopted by other observers of determining by direct observations the real velocities of the meteors, relative to the earth; and, secondly, in the manner adopted by Professor Newton, of determining the periodic time of revolution by examining the dates of ancient star-shower records. The description of the first of these two methods, adopted by astronomers from the time of Benzenberg and Brandes, occupies the principal and most extensive portion of the narrative. The third, and last method, which led Schiaparelli to discover the quasi-cometary character of the meteor-orbits by calculating the velocities of shooting-stars from the laws of their annual and diurnal variations of frequency, receives full exposition in the last few pages of the pamphlet.

5. "Expériences synthétiques relatives aux Météorites. Rapprochements auxquelles ces expériences conduisent," par M. A. Daubrée (in 8vo, pp. 68: Dunod, Paris, 1868).—The experiments of fusion and crystallization of meteorites and terrestrial rocks, and on the imitation of aërolites by the

reduction and oxidation of various minerals (see Report for 1868, p. 415), led M. Daubrée to the conclusion that the latter process of *imperfect* scorification, like that which the materials of the earth's crust appear to have *completely* undergone by oxidation, represents the original process of formation of meteorites. In the rare aluminiferous meteorites of Juvenas, Jonzac, Stannern, and Petersburgh (U. S.), the crystallization, like that of granite on the earth, can only have taken place in the presence of water; since their felspathic ingredients are converted into glass or vitreous slags by fusion. Some new points of interest on the classification of meteorites *, and on the recent acquisitions in the Paris Museum of Geology of aërolitic specimens, are added by M. Daubrée to the former chapters of his original researches, which are otherwise reproduced in the present pamphlet without change. Among the recent specimens acquired at Paris, not less than 950 perfect aërolites of the stonefall of Pultusk (1868, January 30th), varying from the size of a hazel-nut to that of a hen's egg, have lately been deposited by M. Daubrée in the Geological Museum.

6. In 'Cosmos' for January 18th, 1868, M. Stanislas Meunier communicates a new chemical test for distinguishing the protosulphuret of iron (Fe S) from the ordinary terrestrial magnetic sulphuret or pyrrhotine ($Fe_7 S_8$). The former, even when slightly supersulphuretted, precipitates metallic copper from its solutions; but when the proportion of sulphur approaches to that contained in pyrrhotine, and in the case of the mineral pyrrhotine itself, no such precipitate is produced. The fact that the magnetic sulphuret of iron (troilite) found in meteorites remains inactive, or "passive," when placed in a solution of sulphate of copper, leads M. Meunier to conclude that its chemical formula and mineralogical characters approach more nearly to those of pyrrhotine ($Fe_7 S_8$) than to those (with which it is usually compared) of the protosulphuret of iron, Fe S. A paper by the same author, in the 'Cosmos' for March 21st, 1868, describes at length the process employed in the laboratory of the Paris Museum of Geology for analyzing meteoric irons.

7. "Licht, Wärme, und Schall bei Meteoritenfällen," von W. v. Haidinger (extracted from the Vienna Academy Sitzungsbericht, vol. lviii. part 2, for October 8th, 1868).—An English version of the paper appears in the Philosophical Magazine for April, 1869.

Some remarks by M. Daubrée and M. Meunier in the foregoing papers appearing to admit of theoretical exceptions, the opportunity of reviewing the facts recently observed regarding the falls of the meteorites in different parts of the globe, and the conclusions to which they lead in confirmation of M. Haidinger's views of their interpretation, is made the occasion of a clear exposition by the eminent mineralogist of Vienna of the progress of aërolitic science during the long time in which it has engaged his attention, and especially of the rapid strides which, owing to the able geological and astronomical inquiries which have recently been devoted to the subject, it has principally been enabled to make during the last few years.

8. "Recherches sur la composition et la structure des Météorites," par M. Stanislas Meunier (in 4to, pp. 73; Gauthier Villars, Paris, 1869.—A thesis presented to the Faculty of Sciences of Paris for the award to the author of the degree of Doctor in Physical Science).—The results of special methods of analysis employed in foreign, and original researches on the composition of a large number of meteoric irons are recapitulated by M. Meunier at the end of the memoir, in the following general conclusions:—

* 'Comptes Rendus' for March 25 and April 2, 1867, and subsequent Numbers.

1°. Meteoric irons consist of a small number, only, of different minerals combined together in variable proportions.

2°. These minerals, which may be called *proximate ingredients of meteoric irons*, possess physical and chemical characters which enable them to be separated from each other in a state of purity.

3°. The majority possess a definite composition, capable of being expressed in simple chemical formulæ.

4°. They are not mixed together at random in the masses which they compose, but their positions relatively to each other obey certain fixed laws.

5°. Lastly, proximate chemical analysis of meteoric irons affords the only effectual means of obtaining a satisfactory classification of these bodies.

9. Observations on the recent November meteoric showers.

"Shooting-stars on the morning of November 14th, 1867," by H. A. Newton (American Journal of Science for January 1868, vol. xlv. p. 78), contains a discussion of the principal observations of frequency of the meteors, and a curve showing the time of maximum of the star-shower, as observed in the United States, together with some remarks on its geographical extent of visibility, on the probable width of the stream, and its possible connexion with the comet observed in China on the 25th of October, A.D. 1366.

"On the 'Shooting-stars' [of November 1867] as observed at Shanghai," by B. V. Marsh (Proceedings of the American Philosophical Society, vol. x. p. 384).—The following notes of a meteor-shower which occurred in China on the 15th of November, 1867, were received by Mr. Marsh from Mr. B. R. Lewis, U. S. Deputy Consul-General at Shanghai.

Log of U. S. steamer 'Ashuelot,' Capt. Febiger, at Shanghai:—"Nov. 15th, 1867, 4^h to 8^h A.M. Large number of shooting-stars to the N. and E. falling to the N.; visible until broad daylight. Clear and cold; light N.W. winds."

Log of U. S. steamer 'Monocacy,' Capt. Carter, at Shanghai:—"November 15th, 1867, from midnight to 4^h A.M. At 2^h A.M. observed a number of meteors falling from the westward towards the east. This shower of meteors continued till 4^h A.M., decreasing in number from 3^h, seven or eight being the largest number visible at one time.

"From 4^h to 8^h A.M. Between 4^h and 5^h observed several meteors falling to the eastward."

Extract from the 'Shanghai News Letter' of January 16th, 1868 [*].—"From Mr. O. B. Bradford of the U. S. Consular Service we obtain the following glowing account of the meteoric shower of 1867, as witnessed by him not far from the great wall of China. It was on the morning of the 15th of November, while on his way back from the Nankow Pass, and when about fifty miles N.N.W. of Pekin, that Mr. Bradford observed these grand phenomena of the heavens. The grand spectacle was displayed in an arc of not less than 120° in the north-east part of the sky, which at times seemed to be rent in twain, from about 25° of the zenith, by solid masses of luminous bodies, of various magnitudes and surprising brilliancy, darting across his vision. Several hundreds [!!] of these meteors would be visible at the same time, all emitting the most intense light, and the nebulæ of the largest lasting sometimes three minutes. One of the largest shone with brightness above that of the moon as it issued from about 15° of the north star and passed to the horizon, giving off as it fell coruscations of various bright colours, and,

[* The paragraph is considerably curtailed from the figurative language and descriptions of the original article.]

when disappearing, a nebula, which resembled a waterspout in high latitudes. It was not until $6^h 30^m$ A.M. that approaching dawn and sunrise put an end to the display."

In reference to these accounts, it is stated by Mr. Marsh that the observations of 1866 afforded no ground for expecting this Asiatic display of 1867, since the star-shower appeared and disappeared in the United States of America within two hours of its appointed time, or at about $4^h 30^m$ A.M., New York time, on the 14th of November. Since the latter hour would, from the difference of longitude ($12^h 40^m$ *east* of New York), *and from the commencement of the day earlier* (by that space of time) in China than in America, correspond to about $5^h 10^m$ P.M. on the afternoon of the 14th of November at Shanghai, it follows that the Chinese shower of November 15th, 1867, was observed *ten or twelve hours later*, in absolute time, than the time of the great appearance of the November meteors in the United States. On the other hand, it has since been pointed out by Mr. Marsh, in a more recent communication to the Committee, that the maximum of the great November star-shower of 1865 was visible in America, and in Europe, on the morning *of the 13th of November, about twelve hours earlier* than corresponded to the time of the principal apparition of the shower in the years 1866 and 1867. The central and densest portion of the meteor-stream through which the earth passed in the latter years appears accordingly to be flanked on either side by lateral and somewhat less dense but wider meteoric currents at a distance from the orbit of the main stream, which the earth crossed in about twelve hours on the mornings of the 13th of November, 1865, and 15th of November, 1867. The Asiatic shower of the latter date accords *almost exactly* in its epoch with the unexpected reappearance last year in Europe and America of the great display of meteors on the morning of the 14th of November 1868.

The following extract of a letter from Mr. Marsh to the Secretary of the Committee, dated Philadelphia, January 15th, 1869, contains an ingenious and clear statement of the above interesting result derived from the recent observations :—

"The Chinese maximum was at about $3^h 30^m$ P.M. November 14th, Philadelphia time, so that we should have been in the centre of that group, or stream, *this year* at $9^h 30^m$ P.M. November 13th. The shower which we actually encountered was in full progress here by $11^h 30^m$ P.M., and from the European observations it is proved to have begun two hours earlier. Whereas the *American shower* of 1867 should have begun at 9^h A.M, November 13th, and ended at about noon on that day, our shower of this year seems much more directly to represent *the Chinese* than the American shower of 1867.

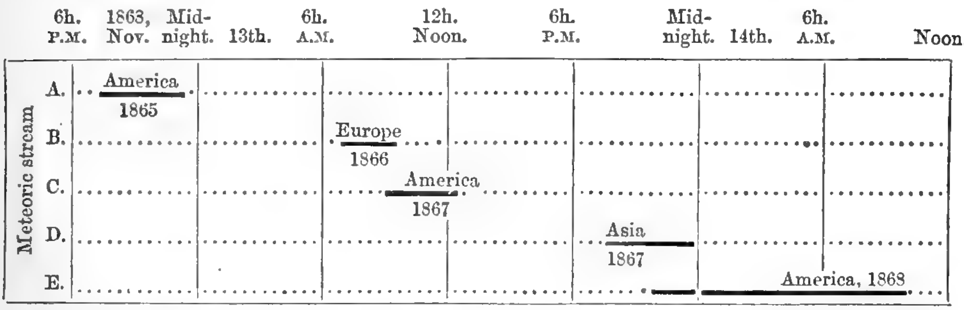
"We had, on the 13th of November, 1865 (maximum at about 3^h A.M.), quite a fine display, much exceeding (I judge from your Reports) yours of the same year, so that the principal displays of the present series were as follows :—

	"Place, year, and local time of maximum.		Philadelphia time of do.
"Shower A.	Philadelphia, 1865, Nov. 13, 3^h 0^m A.M.	...	1865, Nov. 13, 3^h 0^m A.M.
,, B.	London, 1866, ,, 14, 1 15 ,,	...	1866, ,, 13, 3 0 P.M.
,, C.	Philadelphia, 1867, ,, 14, 4 30 ,,	...	1867, ,, 14, 4 30 A.M.
,, D.	Shanghai, 1867, ,, 15, 4 30 ,,	...	1867, ,, 14, 3 30 P.M.
,, E.	Philadelphia, 1868, ,, 14, 3 0 ,,	...	1868, ,, 14, 3 0 A.M.

"Philadelphia should have crossed those several streams, *this year*, as follows :—

	"Meteoric stream, and its duration.	Time of maximum.
A.	1868, Nov. 12, 7^h 0^m P.M. to 9^h 0^m P.M.	1868, Nov. 12, 9^h 0^m P.M.
B.	„ „ 13, 7 0 A.M. to 9 0 A.M.	„ „ 13, 8 0 A.M.
C.	„ „ 13, 9 0 A.M. to 12 0 (noon)	„ „ 13, 10 30 A.M.
D.	„ „ 13, 7 30 P.M. to 11 30 P.M.	„ „ 13, 9 30 P.M.
E.	„ „ 13, 10 0 P.M. to 8 0 A.M. (Nov. 14)	„ „ 14, 3 0 A.M."[*]

The accompanying diagram, subjoined to the last Table by Mr. Marsh, most clearly illustrates its meaning, and the relation which the several November meteor-streams recently observed bear to each other when reduced to a common epoch :—



"November Meteors of 1868, observed at the U. S. Naval Observatory Washington" (Report of Professor J. R. Eastman, with a chart of the meteor-tracks).—For the purpose of determining with accuracy the position of the radiant-point, and to afford means for calculating the real altitudes and velocities of the November meteors, gnomonic charts of the heavens, having the constellation Leo in the centre of the map, were last year distributed by the Meteor-committee of the Newhaven Academy. The tracks of 90 meteors were recorded on such a chart, which accompanies the Washington Report; and by its means the position of the radiant-point was fixed at a well-defined point in R. A. 148° 30′, N. Decl. 22° 30′. The points of beginning and end of these apparent tracks are given, in a table, by their right ascensions and declinations. The maximum frequency occurred at about 5^h 0^m, when they fell at the rate of about 2500 per hour, and by 6^h A.M. 5078 meteors had been counted. The display continued until after daybreak, and was the grandest ever witnessed at the Washington Observatory. The majority of the meteors, although obscured by the full moonlight, surpassed in brightness those of the previous year. The trains of two large fireballs, after passing through colours of red, green, and blue, at last formed light fleecy clouds, and remained visible, respectively, for ten, and thirty minutes.

"Meteors of November 14th, 1868," by H. A. Newton (American Journal of Science and Arts, vol. xlvii. p. 399, with two plates).—Especial provisions were made by the Newhaven Luminous-Meteor Committee, in November last, to obtain carefully recorded observations of the apparent paths of meteors, at the return of the expected star-shower. Among the shooting-stars whose positions were thus mapped, or sufficiently described, accounts are given in the memoir of ten large meteors; and of this number, five were observed at distant places, so that the real altitudes of the meteors, or of their luminous streaks, could be determined. The largest fireball was observed at 1^h 12^m A.M., N. Y. T., the streak of which remained visible for forty minutes over the south-eastern part of Pennsylvania, between Newhaven and Washington, at both of which places its apparent place was noted. Par-

[* Time of the shower as actually seen in 1868.]

ticulars of this brilliant fireball and of the remaining large meteors, whose real altitudes were ascertained, are described in Appendix I. of this Report.

10. "Das November-phänomen der Sternschnuppen in seinen einzelnen Erscheinungen von den ältesten Zeiten bis 1866," von G. von Boguslawski, in Stettin (no date or reference).—The catalogue is completed until the 12th–14th of November, 1849, and its continuation is reserved for a future publication.

11. "On Shower Meteors," by Dr. Edmund Weiss (Astronomische Nachrichten, No. 1710).—On the supposition that comets must, in general, be accompanied by meteoric clouds, Dr. Weiss has computed the following data regarding the comets whose orbits nearly intersect the orbit of the earth, either at their ascending (☊) or descending nodes (☋). The following Table gives the longitude and date of passage of the earth through the comet's node, the difference (at that point) of the sun's distance from the earth (R), and from the comet's orbit (r), the apparent position of the radiant-point of the cometary particles, and (the tabular logarithm of) their velocity, relative to the earth.

The distance ($R-r$) of the earth (at node) from the comet's orbit in the direction of the sun is expressed in terms of the earth's distance from the sun as unity.

No.	Comet.	Longitude.	Date.	$R-r$.	Radiant-point. R. A.	Radiant-point. N. Decl.	Log. of geocentric velocity.
					°	°	
1.	1792 II. ☋	284·1	Jan. 5.	−0·066	193·8	+24·6	0·3447
2.	1840 I. ☋	300·1	20.	+0·036	128·4	−28·6	0·1112
3.	1718 ☋	309·8	29.	−0·042	208·4	−31·2	0·3714
4.	1857 I. ☋	313·1	Feb. 2.	−0·028	261·3	+23·2	0·2352
5.	1092 ☋	316·1	5.	−0·012	103·2	−34·4	9·8977
6.	1854 IV. ☋	324·4	13.	+0·015	304·0	+37·3	0·0132
7.	1858 IV. ☋	324·9	13.	+0·045	271·8	+11·8	0·2661
8.	1862 IV. ☋	355·6	Mar. 16.	+0·013	249·4	+ 1·0	0·3467
9.	1683 ☊	355·6	16.	−0·052	206·9	−48·4	0·2574
10.	1763 ☋	357·6	18.	−0·026	312·4	+21·6	0·1884
11.	1861 I. ☋	29·8	Apr. 20.	+0·002	270·4	+33·5	0·2001
12.	1790 III. ☋	34·0	24.	−0·063	319·1	+19·0	0·3020
13.	1863 II. ☊	71·1	June 2.	−0·054	0·5	−44·7	0·3015
14.	1684 ☊	90·6	22.	−0·010	62·7	−47·1	0·1323
15.	1850 I. ☋	92·9	24.	−0·065	312·4	+60·6	0·1405
16.	1864 II. ☋	95·0	27.	+0·047	12·0	+ 6·3	0·3742
17.	1737 II. ☋	125·5	July 29.	+0·025	175·2	+70·9	9·9872
18.	1852 II. ☊	137·5	Aug. 10.	−0·013	40·7	−13·4	0·3336
19.	1862 II. ☊	146·4	19.	−0·027	47·5	+13·0	0·3750
20.	1854 III. ☊	167·6	Sept. 10.	−0·018	53·0	−15·8	0·2819
21.	1790 I. ☋	173·7	16.	−0·053	108·1	+37·7	0·3519
22.	1763 ☊	177·6	20.	+0·029	44·5	−24·1	0·1856
23.	1864 IV. ☋	203·0	Oct. 16.	−0·044	209·6	+42·7	0·0778
24.	1779 ☊	206·0	19.	+0·022	39·3	−29·7	9·9863
25.	1849 I. ☋	215·2	29.	−0·027	185·0	+61·1	0·2236
26.	Biela ☋	245·8	Nov. 28.	+0·011	23·4	+43·0	9·7282
27.	1819 IV. ☊	257·6	Dec. 9.	+0·086	346·2	−44·5	9·5504
28.	1680 ☋	274·5	26.	+0·050	132·0	+21·4	0·2347

The comet No. 21 agrees too closely in all its particulars with the course of the meteors of the 20th of April, from an observed radiant-point about in R. A. 278°·7, N. Decl. 35°, to leave any doubt of its connexion with the star-shower of that date. Dr. Oppolzer, who observed the comet, remarks that the visible connexion between its tail and nucleus was so slight as to appear as if it would shortly be dissolved; and the possibility that the comet is gradually becoming broken up into portions is not an improbable assumption to account for the extremely irregular returns of this great meteoric shower. The occurrence of a meteoric shower with a radiant-point in Cerberus (R. A. 273°·0, N. Decl. 25°·5), observed by Professor Herschel on the morning of the 13th of April, 1864, agrees well with the elements of the same comet as computed by Oppolzer.

	Orbits of the Meteoric Streams of April 13th and	April 20th.	Orbit of Comet I., 1861. Oppolzer.
☊	23°	30°	29°·8
π	235°	229°	243°·2
i	95°	83°	79°·8
log q	9·9706	9·9907	9·96412
ϵ	1·0	1·0	0·98346

Again, reducing the nodal passages of Biela's comet at former returns to the fixed equinox for 1850·0, they are found to be, with the corresponding positions of the radiant-point:—

Year.	Long. of ☋	Nodal passage of the Earth.	Position of the Radiant. R. A.	N. Decl.
1772	258°·4	Dec. 10	18°·7	58°·1
1826	251°·8	„ 4	22°·8	47°·7
1852	245°·8	Nov. 28	23°·4	43°·0

The meteors observed on the 6th–8th of December by Brandes in 1798, by Flangergues and Herrick in 1838, and by Heis in 1847, are stated by the latter observer (Die Periodischen Sternschnuppen: Cöln, 1849) to have radiated from a point in Cassiopeia at about R. A. 25°, N. Decl. +40°. In his latest list of radiant-points the radiant A_{19} for the first half of December is placed at R. A. 21°, N. Decl. + 54°, while in Greg's list of radiant-points (see Report for 1868, p. 403) the elongated radiant $A_{14}, {}_{16}$, producing meteors in November and for some weeks earlier, is situated between α and δ Cassiopeiæ from R. A. 10° to 25°, and N. Decl. 54° to 60°. The radiant is supposed to be continuous with A_{16} (Nov. 23–Dec. 18), near B Camelopardi, whose position is about at R. A. 45°, N. Decl. 60°. Observations on shooting-stars on the nights of the last week of November and first week of December accordingly deserve particular attention, with a view to determining the exact position of their point of radiation.

The following are some other comets of the list, all the particulars of whose nodal passages and radiant-point appear to agree approximately with those of meteoric showers included in Greg's catalogue of radiant-points for the northern, and Heis and Neumayer's catalogue for the southern hemisphere. The particulars of the meteor-showers apparently indicated are placed for comparison, in the Table, adjoining those computed from the cometary orbits to which they appear to correspond:—

In the Northern Hemisphere.

No.	Comet.	Date.	Radiant. R. A.	Radiant. N. Decl	Greg's letter.	Radiant. R. A.	Radiant. N. Decl.	Epoch.	Place by Stars.
1	1792 II. ☋	Jan. 5 ...	193°·8	+24°·6	MG_1	187°–172°	+40° to +30°	Jan. 1–25	Canes Venatici
(?) 6	1854 IV. ☋	Feb. 13	304·0	+37·3	WZ	305	+37	Mar. 15–Ap. 20	γ Cygni.
8	1862 IV. ☋	March 16	249·4	+ 1·0	SZ	247	− 3	Mar. 3–25	δ, ε Ophiuchi.
15	1850 I. ☋	June 24	312·4	+60·6	B_1	325	+60	June 11–July 11	α Cephei.
17	1737 II. ☋	July 29	175·2	+70·9	V	172	+60	July 29–Sept. 6	α, δ Ursæ Majoris.

In the Southern Hemisphere.

No.	Comet.	Date.	Radiant. R. A.	Radiant. N. Decl	Greg's letter.	Radiant. R. A.	Radiant. N. Decl.	Epoch.	No. of meteors mapped.
2	1840 I. ☊	Jan. 20	128·4	−28·6	Γ_2	105	−27	January	30
5	1092 ☊	Feb. 5 ...	103·2	−34·4	Γ_3	105	−45	February.........	15
9	1683 ☊	March 16	206·9	−48·4	H_1	192	−38	March	15
24	1779 ☊	Oct. 19...	39·2	−29·7	X_1	10	−35	October	12

Meteoric Observations, continued from previous Report.

Observer—W. H. Wood. Place of observation—Birmingham

March 1869.

Date	Hour, G.M.T.	Mag. as per stars.	Colour.	Duration.	Apparent Path. From — To	Accordant Radiant.	Remarks.
				secs.			
18	P.M. $10^h\ 8^m$	>1	Yellow	2·5	$\frac{\pi\ o}{2}$ Leonis to θ Hydræ, +5°	M G(2) or Q H(1)	Tail. See remarks f previous mont below.
				April.			
10	h m 9 37	>1	White, Yellow	2·5	α= δ= 107° +36° to γ Geminorum	M4,5	Irregular flight a decreasing speed
10	10 26	4	Blue	0·5	μ to α Persei	A3,4 or S(1)......	One meteor per ho
11	A.M. 12 34	1	Pale blue	1·0	κ Ursæ Majoris, towards μ Lyncis, path 25°+	Q H2 or G D2	Intercepted view.
20	P.M. 10 21	1	White	1·0	$\frac{\text{Polaris, Capella}}{2}$ to Capella	N(3)	19th overcast.
20	10 38	Sirius	White	0·75	Capella towards γ Geminorum.	N(5)	Imperfect view.
20	11 3	2	Blue	1·0	θ to ξ Herculis	N8 or D G2 ...	Slow.
20	11 6	♃	Yellow, then red	1·5	α= δ= α= δ= 298° +26° to 306° +28° ...	S G(1)	Tail; slow. Met pear-shaped; bu with a flash.
20	11 33	2	Blue	1·0	α= δ= α= δ= 237 0 to 245 0 ...	S4	19th overcast.
20	11 38	2	Blue	0·5	$\frac{\beta\ \alpha}{2}$ Ophiuchi to θ Serpentis	S5, 6	See remarks below
20	11 52	>1	White	0·3	284° +56° to γ Cephei	Q H2	Four meteors per 7 in 1¾ h.; 21st, 11 11.30 P.M. no mtr

July.

Hour, G.M.T.	Mag. as per stars.	Colour.	Duration.	Apparent Path. From To	Accordant Radiant.	Remarks.
h m			secs.			
11 15	1	Blue	0·5	α Sagittæ to A_2 Herculis ...	H..................	Sky hazy, moon 3rd qr. One meteor in half an hour.
11 35	3	Pale blue	0·5	λ Pegasi to π_2 Cygni	T(1) or H	29th overcast.
11 37	>1	Intense blue.	0·2	κ Pegasi, path 1° towards Delphinus.	R2	An elongated steel-blue flash.
11 44	3	Red.	0·75	γ Delphini to $\frac{\gamma \text{ Delphini}, \epsilon \text{ Cygni}}{2}$	H..................	Overcast till 11.30, then 3 mtrs. in 20 ms. Night of 31st overcast.

REMARKS.

January 1st and 2nd, overcast at night; 3rd, 9–10 P.M., cloudy, with rain; lightning in N.N.W. horizon at $10^h\ 5^m$, sky clear after 10 P.M.; no meteors in three-quarters of an hour.

April 15th, 10^h–11^h P.M. and after, fine display of Aurora Borealis; streamers, pink, green, and crimson colours, reached and radiated from the zenith, seen simultaneously in the U. S., America.

The Meteoric Shower of April 20.

There was a pronounced display of Meteors on this date at the rate of four meteors per hour for one observer, showing no tendency to maximum further than an absence on the succeeding night. The night was clear and moonlight after 10^h, moon 1st qr. There was no prominent radiant, but a feeble emission from seven or eight radiants common to the month, and mentioned in the list of meteors.

July 15th and 16th, from $10^h\ 30^m$ till $11^h\ 30^m$ P.M., sky cloudy at times, remaining clear about zenith; no meteors seen. 17th and 18th, overcast at $10^h\ 30^m$ P.M. 19th, sky clear, moonlight $10^h\ 30^m$–11^h; no meteors.

Notices of Meteors from Newspapers, 1869.

An aërolitic fall in Sweden, mid-day, January 1st.

Large meteor (?) seen at Weston-super-Mare, Jan. 3rd.—"A meteor of unusually bright appearance between the hours of 9 and 10 shot from the heavens and disappeared beneath the waves. So vivid and instantaneous was the appearance and disappearance of the meteor that, although seen by a number of persons, there were many speculations as to its real nature. Many, by whom the reflection alone was seen, were of opinion that it was a vivid flash of lightning, whilst others thought it a rocket of unusual magnitude."—*Bristol Daily Post.*

Jan. 13, 1.20 A.M.—A bright meteor observed at Brighton in W. of N.; two detonations in three minutes; meteor calculated, according to sound, to have burst thirty miles from observer.—Writer in 'Standard,' Jan. 14.

The same seen at Hampton, rising in N. Colour, indigo.—Writer in 'Standard.'

April 3rd, between 4^h and 5^h A.M., a large meteor seen in Scotland. (See enclosed paragraph from 'Lloyd's News,' and various other papers.)

May 31, 11.5 P.M., a large meteor seen at Norfolk, also at London. (See 'The Times' of June 2nd and 3rd, also the 'Standard' of June 3rd, and other papers.)

Meteor seen at New York.

May 20th, at night a meteor equal to the full moon was seen at New York. It changed colour from red to green and burst into fragments. It cast deep shadows, and had a long tail. Appeared 10° N.N.W. of α Aquilæ; path 30° N. westerly.—From American papers.—*Morning Star*, June 3rd.

Report on the best means of providing for a uniformity of Weights and Measures, with reference to the Interests of Science. By a Committee, consisting of Sir JOHN BOWRING, *F.R.S.*, The Right Hon. C. B. ADDERLEY, *M.P.*, SAMUEL BROWN, *F.S.S.*, Dr. FARR, *F.R.S.*, FRANK P. FELLOWS, Professor FRANKLAND, *F.R.S.*, Professor HENNESSY, *F.R.S.*, JAMES HEYWOOD, *F.R.S.*, Sir ROBERT KANE, *F.R.S.*, Professor LEONE LEVI, Professor W. A. MILLER, *F.R.S.*, Professor RANKINE, *LL.D.*, *F.R.S.*, C. W. SIEMENS, *F.R.S.*, Colonel SYKES, *F.R.S.*, *M.P.*, Professor A. W. WILLIAMSON, *F.R.S.*, JAMES YATES, *F.R.S.*, Dr. GEORGE GLOVER, Sir JOSEPH WHITWORTH, *Bart.*, *F.R.S.*, J. R. NAPIER, H. DIRCKS, J. V. N. BAZALGETTE, W. SMITH, Sir W. FAIRBAIRN, *Bart.*, *F.R.S.*, *and* JOHN ROBINSON :—Professor LEONE LEVI, *Secretary*.

YOUR Committee have much pleasure in reporting that during the year considerable progress has been made towards the assimilation of weights and measures in all countries. As briefly stated last year, the North-German Confederation, by a law dated 13 June 1868, adopted the metre as the basis of measures and weights, and they resolved to take as the primary standard measure of length the platinum bar in the possession of the Prussian Government, which in the year 1863 was found by a Commission appointed by the French and Prussian Governments to be equal to 1·00000301 metre at the temperature of melting ice by comparison with the metre deposited at the Archives in Paris. Whilst adopting the metric nomenclature, the North-German Confederation added corresponding idiomatic names wherever possible, as, for instance, the Metre is also called the "Stab" or "Ell," the Centimetre the new "Zoll" or "Inch," the Millimetre the "Strick" or "Line," the Dekametre the "Kette" or Chain, the Litre the "Kanne" or Pot, the Hetolitre the "Zass" or Cask, the half Kilogram the "Pfund" or Pound, and the 50 Kilograms or 100 pounds the "Zentner" or Hundredweight. In the United States the use of metric weights and measures has been rendered legal, and they are employed in all post-offices exchanging mails with foreign countries. In the Postal Convention with this country, signed at London on the 18th June 1867, the authorized weight of a single letter was stated to be half an ounce in the United Kingdom, or fifteen grammes by the metrical scale in the United States. It were much to be desired that the Post-Office of this country would second the enlightened opinion of the Americans and adopt fifteen grams as the minimum weight of letters sent to foreign countries. But still greater progress has been made in the introduction of the Metric System into India. The question of revising the Indian system of weights and measures had engaged the attention of the Government of India at various periods since 1837, and, in consequence of representations from the Madras Government and the Chambers of Commerce, the Government of India passed a resolution in 1864 authorizing the appointment of local Committees in each Presidency to deliberate and report on the whole matter, with instructions to submit their views to the Central Committee at Calcutta for their consideration. In course of time, when these answers were received, it was found that in Madras and Bombay, the North-west Provinces and the Punjaub, the Committees were in favour of a uniform system, based on the Imperial, their recommendation being that the unit of weight should consist of a Seer fixed at two lbs. avoirdupois, that the Imperial quart should be the unit of capacity, and the Yard and Acre the units of linear and superficial measure. The Bengal Committee, however, thinking that the days of the Imperial System were numbered, and that when all the rest of the world had adopted, or is about to adopt, the French Metric System it would be a retrograde step to adopt the English weights and measures, proposed the gradual but complete adoption of the French Metric System, and their recommendation received the support of the Bengal Government.

On the 1st October, 1867, Colonel Strachey, the President of the Central Committee, with the view of bringing forward an expression of public opinion, published a memorandum in which he supported the proposal of the Bengal Committee. In his opinion, the assimilation of the English weights to those of France was a mere question of time, and the existing English system could not last, and he therefore advocated the adoption of the French kilogram as the basis of the new system of weights in India. But Colonel Strachey's memorandum did not meet with the assent of a majority of the Committee, and he retired from it almost at the beginning of its labours, whereupon the Committee, with a new President, completed their labours, and concluded by recommending a new system based on Imperial units with decimal multiples and binary divisions. Thus the question stood when a Deputation from your Committee and the Council of the International Decimal Association waited on Sir Stafford Northcote, the then Secretary of State for India, for the purpose of urging the importance of introducing the Metric System in India; and it is gratifying to your Committee to state that, in a despatch dated 1st Feb. 1868, in conveying to the Government of India a full report of the representation of the Deputation, Sir Stafford Northcote wisely urged that whilst it would be better for the Committee to endeavour to establish a system more nearly approaching the best theoretical system than to adopt the English, the Government should be cautious not unduly to sacrifice practical convenience to theoretical symmetry. Soon after this a change of opinion appears to have taken place in the Indian Government. A decisive minute was made by the Commander-in-Chief, Sir W. R. Mansfield, dated 5th September 1868, in favour of the Metric System. The same was confirmed by the Governor-General, Sir John Lawrence; and after the subject had been fully discussed in Council, the whole matter was summed up in a despatch to the Secretary of State for India, recommending that the new unit of weight should be a Seer equal to the Kilogram, or 2·205 lbs. avoirdupois, and that a system of decimal multiples and subdivisions of the unit of weight should be accepted as a fundamental part of the new scale to be recognized by law. The Government of India further urged that the best preparation for the general adoption of the new metric weights would be their introduction and authoritative use in the first instance by all the Departments of the Government, by all Municipal bodies, and on the Railways. On the receipt of this despatch with the accompanying documents, the Duke of Argyll, the new Secretary of State for India, remitted the whole question to the Board of Trade, and asked them whether any measure is under consideration for a change in the weights of this country. At that time, the subject being under the consideration of the Standard Commission, the answer was delayed; but as it became known that the Commissioners were favourable to the introduction of the Metric System, and that a decided opinion existed in this country in favour of advancing still further in the policy of the Permissive Act of 1864, the Duke of Argyll sent a despatch to the Indian Government approving of the introduction of the kilogram as the unit of weight throughout British India; and thus nearly 15,000,000 more of people will in a short time join the large family having one common system of weights, the adoption of the metric unit of length being certain to follow at no distant date. From India, with reference to the many colonies and dependencies of the empire, your Committee waited upon the Secretary of State for the Colonies, urging the advantage of at least a permissive law to use the Metric System in all the Colonies, and also the need of having the system taught in all their schools; and, with the consent and cooperation of the Secretary of State, your Committee, in conjunction with the Council of the International Association, sent a letter to all the Governors of the Colonies to the same effect. Judging from the great success achieved in India, we trust it will not be long before a decided uniformity of weights and measures shall be realized in Canada and Australia, the Cape and the West Indies, Malta and Gibraltar, in short in every colony of the empire.

In their last Report your Committee alluded to the unsatisfactory condition of the law in this country, which, whilst making it permissive to make contracts on the terms of the Metric System, made no provision for the stamping of metric weights and measures in general use. This anomaly having been brought by your Committee to the notice of Her Majesty's Government, the subject was remitted by the Board of Trade to the Standard Commission for their consideration, and your Committee are pleased to state that the second report of that Commission, just published, recommends the removal of every difficulty and the full and legal introduction of the Metric System. The resolution of that Commission on the subject is as follows:—

"Considering the information which has been laid before the Commission, of the great increase during late years of international communication equally in relation to trade and commerce, of the general adoption of the Metric System of Weights and Measures in many countries both in Europe and other parts of the world, and more recently in the North-German Confederation and in the United States of America, of the progress of public opinion in this country in favour of the Metric System as a uniform international system of weights and measures, and of the increasing use of the Metric System in scientific researches and in the practice of accurate chemistry and engineering construction, we are of opinion that the time has now arrived when the law should provide and facilities be afforded by the Government for the introduction and use of Metric Weights and Measures in the United Kingdom, and that for this object Metric Standards, accurately verified in relation to the primary Metric Standards of Paris and deposited in the Standard Department of the Board of Trade, should be legalized, and that verified copies of the official Metric Standard should be provided by the local authorities for inspection of such districts as may require them." The Commissioners were not favourable to the compulsory measure on the subject; but they recommended that customs duties should be allowed to be levied by Metric Weights and Measures as well as by Imperial weight and measure; that the use of the Metric System concurrently with the Imperial System should be adopted by other public departments, especially the Post-Office, and in the publication of the principal results of the statistics of the Board of Trade, as well as for the admeasurement and registration of the tonnage of shipping; and that Mural Standards of the Metric System as well as of the Imperial System be exhibited in public places. Your Committee regret the recommendation of the Commissioners to maintain for an indefinite time two legal systems in general use, it being subject to trouble and confusion. Nor do they agree with the reason assigned for any hesitation in this matter. It is asserted that there is no immediate cause for a change for the purpose of internal trade. But what say the Chambers of Agriculture and the Chambers of Commerce on the subject? The Barnstaple Farmers' Club recently petitioned Government in the following terms:—

"That your Petitioners, in common with the rest of the community, and more especially of the farmers, suffer much needless disadvantage, and are burdened with much unnecessary labour, by the great variety and complicated character of the legal, and still more of the customary, Weights and Measures in use in the United Kingdom, which add much to the number and difficulty of the calculations required in business transactions, and deprive your Petitioners of a great part of the benefit to be derived from the publication of the prices current at the different markets in different parts of the country.

"That while under different heads, such as Long Measures, Land Measures, Liquid Measures, Dry Measures, and Weights of different kinds, for different sorts respectively of lengths, of surfaces, of work, and of articles, dry and liquid, there are at least ten distinct sets of well ascertained, though utterly unsystematic, Weights and Measures recognized by law, besides an unknown multitude of customary Weights and Measures in use, in different localities in the United Kingdom, your Petitioners hear with envy of the superior facilities enjoyed by their rivals abroad in those foreign countries where a uniform Decimal System, comprising five series only, all equally easy to be learnt and all founded on the same scientific basis, has been established by law for the measurement respectively of length, of surface, of capacity, of solid bulk and of weight—a system which, owing to its obvious convenience, has either already become, or is rapidly becoming, general in practice wherever legally established.

"That this System (known as the 'Metric,' because wholly based on the Metre) was unanimously recommended in 1862, after a full inquiry, by a Committee of the House of Commons, comprising distinguished men of all political parties; and has already been adopted in its entirety by countries with a population of nearly 150,000,000, and a trade with the United Kingdom of nearly £180,000,000 sterling, and adopted in part by countries with a population of nearly 70,000,000, and a trade with the United Kingdom of £50,000,000, each class of countries comprehending some of the most highly civilized nations in the world, and each, as might be expected, continually receiving additions, notwithstanding the refusal hitherto of this country and the United States to do more than render the use of Metric Weights and Measures permissive, and that of Russia to recognize it at all.

"The existing confusion in Weights and Measures in this country and its Indian and Colonial Empire, equally complained of by the opponents and supporters of the Metric System, renders the present time, in the opinion of your Petitioners, particularly favourable for its legal adoption in its entirety; since a change to this, the simplest, most convenient, and most widely used System ever yet known, would cause hardly more trouble or inconvenience than would the rigid general enforcement of our cumbrous and utterly irrational Imperial set of Weights and Measures.

"Your Petitioners therefore humbly pray your Honourable House to take measures for rendering the use of the Metric System not only legal but compulsory, at the earliest practicable period, throughout the United Kingdom and as many as possible of its dependencies."

The Scottish Chamber of Agriculture have deliberated on the subject of the grievance of having so many weights and measures in use. Grain is somewhere sold by the quarter or bushel, and elsewhere it is weighed and sold by the cental or other weight. The practice differs in every county, nay in every market, in the United Kingdom. The Royal Commissioners further urge, as a reason against the immediate complete introduction of the Metric System, that there are nearly thirty millions of ordinary weights and measures of the existing Imperial System now in common use. But how many of these are altogether unreliable? And is the temporary inconvenience of having to substitute new weights and measures to be considered a sufficient reason for delaying a reform of such importance to the trade and interests of the empire? The example of France and all countries where the Metric System has been introduced points out that it is necessary, in order to facilitate the change, to indicate a time when the introduction of the change must be effective, and your Committee hope that when Her Majesty's Government bring forward a Bill on the subject, the Legislature will see the necessity of providing that after a definite time the concurrent use of the Imperial and Metric Systems shall cease, and the Metric be finally adopted as the new Imperial System of weights and measures in the United Kingdom.

Your Committee have already observed that the Royal Commissioners recommended that the Metric Standards should be accurately verified in relation to the primary Metric Standards at Paris. These standards are a platinum metre and kilogram, deposited at the Palais des Archives in 1793. But it is not by these that new standards are now made. A copy of these standards was made at the same time to save the original standards, and for the purpose of verifying the Metric Standards of foreign countries where the Metric System is adopted; and this copy was first deposited at the Observatoire, and afterwards, in 1848, transferred to the Conservatoire des Arts et Métiers. The practice, therefore, is to verify any new standard by that copy, which, notwithstanding the lapse of time, differs very little from the standard of the Archives. It is objected, however, to such a practice, first, that it is inconvenient in all cases to resort to Paris for such verification; second, that if each country prepares its own standards and in its own way these will be found to differ from one another, and there may be not one but many metres; and, third, that the standards themselves are not complete. Upon this subject your Committee have recently received a Report of a Committee of the Physico-Mathematical Department of the Academy of Sciences of St. Petersburg, recommending that the different States should be invited to nominate an International Commission for the purpose of preparing prototype standards of the metre, and so create a unit of measure truly universal and effectively international. Your Committee are glad to hear that M. de Jacobi, to whose able pen we owe the valuable Report issued by the Committee of Weights and Measures for the International Conference in 1867, will be present at this Meeting to advocate this suggestion. The mode of obtaining a correct standard is a question of administration which may be safely left to the Warden of the Standards; yet your Committee are of opinion that the Commission thus suggested may prove most beneficial, especially in endeavouring to correct any small scientific defects in the system itself, and in the weights and measures separately in connexion with it. Your Committee are happy in reporting that the Mural Standard, made under their direction, of the Metre is highly appreciated, and during the year copies of the same have been forwarded for public exhibition at Norwich and Exeter, and to the Harvard University in the United States. Your Committee are desirous of making further grants of such Mural Standards, but the funds at their disposal do not allow them to use these efficient means for diffusing the knowledge of the Metric System. Your Committee have much pleasure in reporting that considerable stimulus has been given to the study of the Metric System by the prizes offered to the students passing the examination of the Society of Arts and the British and Foreign School Society on the subject; and that the prize of £10 offered for the best school-book on the Metric System was gained by W. C. Vaughan for an excellent treatise on the subject, which your Committee trust will soon be published and become extensively useful.

Upon the subject of International Coinage no step has been taken since the report of the Royal Commissioners.

The Chancellor of the Exchequer, however, has recently enunciated his views in favour of imposing a seigniorage of about one per cent., and of taking it from the coin with the view that the sovereign may become identical with the 25-franc piece. In his opinion, whilst the sovereign would still remain as a current coin in this country of exactly the same value as now, it would have the additional advantage that it would be identical in value with the 25-franc piece. The subject has been frequently before your Committee, but they conceive that a general understanding on this and many other points of extreme difficulty and magnitude should be arrived at by those conversant with the practical administration of the mints in different countries before the subject is deliberately submitted for the approval of the country; and your Committee content themselves in echoing the recommendation of the Royal Commissioners on International Coinage, that another International Conference may speedily be held for that purpose. The question is well worthy of the attention of the British Association, and your Committee recommend that the Council of the British Association should make a representation to that effect to Her Majesty's Government. In conclusion, your Committee are persuaded that their efforts have not been in vain in stimulating the early realization of one uniform system of weights, measures, and coins in all countries, an object of the highest importance in the interest of science, education, commerce, and peace; but their task being far from complete, and with a view to labour still further towards that end, they recommend the reappointment of the Committee, with a grant of at least £50 for the purpose.

Report on the Treatment and Utilization of Sewage. Drawn up by Dr. Benjamin H. Paul, *at the request of the Committee, consisting of* *J. Bailey Denton, *M. Inst. C.E., F.G.S.,* Dr. J. H. Gilbert, *F.R.S.,* *Richard B. Grantham, *M. Inst. C.E., F.G.S., Chairman,* W. D. Harding, *J. Thornhill Harrison, *M. Inst. C.E.,* *Dr. Benjamin H. Paul, *Ph.D., F.C.S.,* Dr. R. Angus Smith, *F.R.S., and* Professor J. A. Wanklyn.

Probably one of the most important results of modern scientific inquiry is the general recognition of the fact that attention to the hygienic requirements

* These Members only have attended the Meetings of the Committee.

of towns and populous places has a great influence on the preservation of health and life. Hygienic measures calculated to prevent disease have therefore come to be regarded even of more importance than the knowledge gained by two thousand years' experience in the art of medicine.

Pure air and water are two of the most essential requirements of all populous places. The removal of water from the surface and from the subsoil by some kind of drainage has also been found essential to the healthiness of a place; but the thing most of all important in its influence on the sanitary condition of towns &c., and as affecting the purity of the air and water, is undoubtedly the mode in which the excretal refuse of their population is dealt with.

Even in the most primitive states of society it has always been found necessary to dispose of excreta and other refuse materials from dwellings in such a manner as to prevent them from becoming a nuisance; and the most simple mode of effecting that object was probably the plan prescribed by Moses to the Jews *.

The fact that animal excreta are useful as manure has also led, in many cases, to the adoption of some plan of dealing with them for that purpose, by which their accumulation in the vicinity of dwellings would be prevented to a great extent; and in that way no great difficulty would be experienced in thinly populated places in devising simple measures sufficient to meet all requirements. Under such circumstances the mode of effecting the object in view would be a matter to be determined and carried out by the individual residents of a place. But wherever the population became concentrated in villages or towns, difficulties arose as to the disposal of excreta or their immediate removal and use as manure, in consequence of which it became a practice almost universal to allow them to collect, together with other refuse, in pits dug in the ground near each house or group of houses, and then at intervals to remove the accumulated contents of these pits for use as manure. As the magnitude of towns increased, the difficulty of thus dealing with excretal refuse became greater, and the offensive consequences of its accumulation near dwellings more sensible. Hence this subject became more and more a matter to be dealt with by the local authorities, at first by regulation of the practices adopted by the inhabitants of a place, and eventually it became a duty to be provided for and performed by the authorities themselves in such a way as to ensure the common convenience and well-being of the population.

However, the full importance of this subject in other respects was far from being appreciated until within the last thirty or forty years. It is only within this recent period that there has been anything like an adequate recognition of the fact that the sanitary state of dwellings and towns, the health and mortality of their population, the condition of rivers, and other matters of importance are, as a general rule, largely influenced by the practices adopted in regard to excretal refuse. Within that period inquiry and experience have shown that excretal refuse, besides being offensive and, in some cases, a great nuisance when accumulated in a state of putrefaction or decay near dwellings, may be, and often is, a source of vast injury to the public health. Opinions may vary as to the precise mode in which that influence is exercised—whether by the evolution of deleterious gases, by the pollution of water, by the development of those minute organisms which are now very generally considered to be the media of infection, or in all of these ways conjointly; but there is no longer any doubt or difference of opinion as to

* Deuteronomy, ch. xxiii. ver. 12 *et seq.*

the general truth that, in regard to the mode of dealing with excretal refuse, the sanitary point of view is far more important than any other. If, then, the weightiest question to be solved by a municipal body be, how best to preserve the health and life of the population committed to its charge, it is evident that one of the first duties of such a body is that of providing for the disposal of excretal refuse in a suitable manner. The recognition of this sanitary axiom has been so imperatively enforced during the present century by the frequent prevalence of epidemic diseases, such as cholera and fever, that it may perhaps now be regarded as unquestionable, except where ignorance overcomes intelligence, and where mistaken notions of economy prevail.

Under this aspect the subject has lately attracted very general attention, not only in this country but also in most civilized countries abroad. It will therefore be desirable to recite briefly the circumstances under which excretal refuse may become a source of injury to health, and to trace the course events have taken in regard to this subject since public attention was first directed to the sanitary condition of towns, and since measures have been adopted with a view to its amelioration.

Besides the inconvenience and offensive character of the system of collecting excretal refuse in pits or vaults near dwellings, the evils consequent on that plan arose chiefly from the impregnation of the surrounding soil with decomposing material, and sometimes also from the pollution of water used for domestic purposes. The pits or reservoirs were in some cases provided with overflow channels or with drains, by which the liquid contents were discharged into a neighbouring watercourse or into a sewer; but in many cases that was unnecessary, where the soil was of a sufficiently porous nature to admit of the continuous free escape of liquid from the pits. By this natural drainage, according to the nature of the soil, the liquid portions of the excreta would permeate the soil and gain access to the wells, which were, as a very general custom, placed close to the pits where excreta were collected. Moreover this foul drainage would be augmented in many cases by the access of surface-water to the pits, especially during wet weather.

These evils were often much aggravated by the absence of any systematic drainage or sewerage of towns sufficient for the removal of subsoil water, which became stagnant and putrefied beneath the dwellings. Even where underground sewers existed they appear to have been intended only for the removal of surface-water; the connexion of house-drains with these sewers was prohibited, and it was penal to discharge or throw any excretal or other offensive refuse into rivers.

At that time the water-closets (introduced by Bramah in 1793) were very rarely in use; they had been adopted only in the better class of houses in towns, and then they were used in conjunction with underground vaults for receiving the material discharged from them. Their subsequent more general adoption, and the concurrent acquisition of a better and more copious water-supply, were no doubt largely conducive to domestic comfort and convenience; but, in regard to the condition of towns, these changes were attended with a decided aggravation of the evils arising from the use of vaults or pits as receptacles of excreta; for the drainage or overflow from these pits became continuous on account of the use of water in the closets, and it was no longer dependent on the occasional access of rain. Under these circumstances the pits or vaults became cesspools *, constantly charged with liquid, and in most cases they had no outlet into the sewers. Even so late as 1844 the Health

* This term appears to be of recent origin, as it is not to be found in old dictionaries.

of Towns' Commissioners state, in their first Report, that "in some of the larger and most crowded towns all entrance into the sewers by house-drains or drains from water-closets or cesspools is prohibited under a penalty;" while in other places, including part of the metropolis, the entrance of house-drains was deemed "the concession of a privilege subjected to regulations and separate proceedings with attendant expenses," tending either to restrict the use of sewers for the purpose of removing excretal refuse and the drainage from pits containing it, or to confine the advantages of this plan to the wealthy.

The removal of the domestic nuisance and inconvenience attending the use of privies and pits for collecting the refuse, by the introduction of water-closets, gave rise in this way to the creation of a *town nuisance*; the old town sewers or drains proved inadequate to the duty thrown upon them; for in some instances an improved water-supply was taken into a town without any means being provided for taking it out again: the pent-up overflow from cesspools, connected with water-closets, saturated the subsoil, the water of wells became permanently polluted, fœtid water rose in the cellars of houses, rendering the air impure by its exhalations, sickness followed, and eventually there arose a loud outcry against the cesspool system as an intolerable nuisance, affecting not merely individual houses but the town generally.

The plan proposed as a remedy for this evil was the general adoption of water-closets, combined with a system of thorough town sewerage, the connexion of house-drains with the sewers being made compulsory on the owners of houses under certain conditions. By this means the necessity for allowing excretal refuse to accumulate at all near dwellings or within towns was to be done away with; this refuse was to be at once removed from dwellings into the sewers by a copious use of water, and swept rapidly through them out of the town with the waste water from houses and the surface-drainage.

By this plan the whole of the water entering a town is eventually polluted either by use or by admixture, and then constitutes what is now commonly termed town-sewage, the expeditious removal of which from the vicinity of towns is indispensable for the health of the neighbourhood.

This system, known as the water-carriage system, has been largely adopted in this country, and, as a consequence, both the drainage of towns and the removal of the excretal refuse have been in many cases effected by the same means. The utilization of this town-sewage as manure, by irrigating land, was contemplated at the outset, but it was not enforced, and it has been carried out only in a few cases, the sewage as a rule being discharged from the sewers into any adjoining river or into the sea, this being permitted so long as it does not create a nuisance. Individuals or towns injured by the discharge of sewage in this way were left to obtain what redress they could by legal means. The adoption of this system is well known to have given rise to much litigation, and many towns where it has been adopted have been placed in a very difficult position in consequence of injunctions by the Court of Chancery prohibiting the discharge of their sewage into watercourses.

Moreover the adoption of the water-closet and sewerage system of dealing with excretal refuse has been followed by a greatly augmented pollution of rivers, which is now acknowledged to have become an evil of *national* importance, and is still a subject of official inquiry. At this point, when the measures adopted for removing successively the domestic nuisance and the town nuisance, arising from the disposal of excretal refuse, have given rise to a national nuisance, it has become a very serious matter to determine what is to be done with the sewage of towns. The importance of this question is shown by the fact that, besides engaging the attention of the late General Board of Health, besides being frequently discussed in Parliament and by the various local authorities throughout the kingdom, it has within the last thirteen years given rise to the appointment of three Royal Commissions charged with the duties of investigating the subject and of suggesting remedial measures, viz.:—

I. The Sewage Commission, dated 5th January 1857, "to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses," from which three reports have issued, bearing date March 1858, August 1861, and March 1865. The conclusions the Commissioners arrived at were to the effect that the direct application of sewage to land favourably situated, if judiciously carried out and confined to a suitable area exclusively grass, is profitable to persons so employing it; that where the conditions are unfavourable, a small payment on the part of the local authorities will restore the balance; that this method of sewage application, conducted with moderate care, is not productive of nuisance or injury to health.

That methods of precipitation are satisfactory merely as a means of mitigating a nuisance.

That the only radical way of restoring the rivers to their original purity is to prevent the discharge of foul matters into them, and especially the discharge of sewage and other refuse of large towns.

That the right way to dispose of town sewage is to apply it continuously to land, and that it is only by such application that the pollution of rivers can be avoided.

That the magnitude of a town presents no real difficulty to the effectual treatment of its sewage, provided it be considered as a collection of smaller towns.

II. The Rivers' Commission, dated 18th May 1865, "to inquire how far the present use of rivers for carrying off the sewage of towns, populous places, &c. can be prevented without risk to the public health, and how far such sewage &c. can be utilized," from which three reports have already issued, bearing date March 1866, May 1867, and August 1867, and further reports are expected.

And III. The Royal Sanitary Commission, dated November 1868, "to inquire into and report on the operations of the sanitary laws for towns, villages, and rural districts in Great Britain and Ireland, so far as these laws apply to sewerage, drainage, water-supply, removal of refuse, prevention of overcrowding, and other conditions conducive to the public health." This latter Commission is now engaged in its first proceedings, which are limited to the consolidation and improvement of existing laws, and the establishment of a better recognized central control. It is expected that a preliminary report from this Commission will shortly appear.

The object of your Committee has been understood by its Members as that of supplementing the above-mentioned public inquiries, with special information, as to the local circumstances and practical experience of various towns throughout the kingdom, and with other positive data relating to the subject, such as the Royal Sewage Commission have pointed out as requisite to be ascertained.

Your Committee, in entering on its duties, came to the conclusion that since town sewage, as it is now most commonly known in this country, is a source of nuisance, inconvenience, and injury to health, chiefly by reason of its containing the excretal refuse of the population, it was desirable the term sewage should not be restricted to the liquid discharged from sewers in places where there is a thorough system of sewerage combined with water-closets and a copious supply of water, or, in other words, where the water-carriage system of disposing of excretal refuse has been adopted, but that it should, for the purposes of this inquiry, be understood as comprising excretal refuse in any state. This extended application of the term sewage seemed to be the more desirable, since there are many towns and places that are at present debarred from adopting any measures for dealing with their excretal refuse by doubts entertained as to the sanitary efficacy of such a system as that just mentioned, and by a knowledge of the difficulties attending the disposal of the sewage produced under that system. In order to ensure an explicit understanding on this point in all correspondence and communications, the following resolution was passed at a meeting of your Committee on the 5th of January, 1869, viz.:—

"That the Committee do interpret the word 'sewage' in the instructions of the Association as meaning any refuse, from human habitations, that may affect the public health;" and this interpretation of the term was specified in all applications for information.

Bearing in mind the circumstance, already referred to in the introductory remarks, that formerly town-sewers were essentially drains, the objects of which were simply and exclusively the removal of surface- and slop-water by the most direct course to the nearest stream, as well as the fact that such sewers, originally intended only for drainage, have in various ways come to be confounded with and used as sewers for removing excretal refuse as well as the surface and subsoil water, it was, for these reasons, considered to be especially important to make a marked distinction between drainage and sewerage, and, with that object, to designate the removal of surface and subsoil water from land by permeable channels "drainage by drains," and the removal of excretal or other refuse from dwellings, factories, streets, &c., by water through impervious conduits, "sewerage by sewers." According to this distinction, a drain should be understood as a permeable channel adapted throughout its entire length to remove water from the soil surrounding it; while a sewer should be understood as a channel sufficiently impermeable to be adapted for conveying away house refuse without allowing either the refuse to escape through its sides or water to penetrate from without.

One of the first steps taken by the Committee was to apply to Her Majesty's Secretary of State for the Home Department for his assistance in obtaining information from foreign countries respecting the practices prevailing abroad for disposing of the refuse of towns, villages, public institutions, factories, dwellings, &c., and having reference to the sanitary condition of the districts in which they are situated, the state of rivers, or the support and increase of the produce of the soil; to this application Mr. Secretary Bruce has given effect by transmitting from time to time very valuable information, received from the following countries.

Received from the Home Office.

15th March, 1869. From Hamburg.—1. Statement as to the sewerage in Hamburg. 2. Plan of sewers in Hamburg forwarded by Mr. Ward to Lord Clarendon.

16th March, 1869. From Saxe Coburg Gotha.—Statement as to removal and disposal of refuse from dwellings in Gotha, in a despatch from Mr. C. T. Barnard to Lord Clarendon.

25th March, 1869. From Holland.—1. Statement addressed by M. Boest van Limburg to Vice-Admiral Harris. 2. Statement of the Minister of the Interior at the Hague.

30th March, 1869. From Bavaria.—1. Despatch from Prince Hohenlohe to Sir Henry Howard. 2. Die Kultur-Gesetze Bayerns unter der Regierung Maximilian II. (The agricultural laws of Bavaria under the government of Maximilian the Second.) 3. Die bayerische Gesetzgebung und Verwaltung im Bereiche der Landwirthschaft. (Legislation and administration relating to agriculture in Bavaria.)

14th April, 1869. From Baden.—1. Despatch from Mr. E. W. Cope to Mr. G. I. R. Gordon, describing the modes of emptying cesspools in Carlsruhe and Freiburg, and disposing of the refuse. 2. Statement addressed by Baron Freidorf to Mr. E. W. Cope as to the treatment of house-refuse in the Grand Duchy. 3. Vertrag über die Vornahme und Besorgung der geruchlosen Entleerung der Abtrittsgruben, Abfuhr des Strassenkehrichts und der Haushaltungsabfälle, sowie der Reinigung der unterirdischen Kanäle in Karlsruhe, nebst einem Anhange enthaltend die hierher bezüglichen ortspolizeilichen Vorschriften. (Contract relating to the inodorous emptying of cesspits, removal of rubbish from the streets and dwellings, as well as the cleansing of the underground sewers in Carlsruhe, together with an Appendix containing the local regulations relating thereto.)

26th April, 1869. From Saxony.—1. Statement respecting the treatment of town-refuse addressed by M. de Bosse to Mr. Hume Burnley, with extracts from the official regulations on this subject.

26th April, 1869. From Prussia.—1. Despatch from Baron Thiele to Lord Aug. Loftus, stating that the practice in use for transporting and disposing of the refuse of towns and villages in Prussia are at present very different, and in general unsatisfactory, and that very great difference of opinion prevails as to the necessary regulations to be made. 2. Gutachtliche Ausserungen des Landes-Melioration Bau-Inspectors Röder und des Professors der Agricultur-Chemie Dr. Eichhorn über die Verwerthung der Dungstoffe der Stadt Berlin für die Bodenkultur mit Bezugnahme auf das Project des geheimen Baurathes Wiebe "Ueber die Reinigung und Entwässerung der Stadt Berlin." (Report of Herr Röder, Inspector of Building and Improvements, and Dr. Eichhorn, Professor of Agricultural Chemistry, on the utilization of excreta from Berlin for agriculture with reference to the plan proposed by Herr Wiebe "On the Cleansing and Drainage of Berlin.") 3. Proposition des Landes-Oeconomie Rathes Weyhe betreffend die projectirte Kanalirung Berlins und die Anwendung eines zweckmässigen Systems zur Entfernung und Nutzbarmachung der Dungstoffe der Stadt im Interesse der Bodenkultur, u. s. w. (Memorandum by Hr. Weyhe in reference to the proposed sewerage of Berlin, and to the application of an efficient system of removing excreta from the town, and utilizing them for the advantage of agriculture, &c.) 4. Die Abfuhr und Verwerthung der Dungstoffe in verschiedenen deutschen und ausserdeutschen Städten, und darauf bezügliche Vorschläge für Berlin. Bericht der von Seiner Excellenz dem Minister für die landwirthschaftlichen Angelegenheiten Herrn von Selchow ernannten Kommission C. von Salviati, O. Röder, und Dr. Eichhorn. (Report of the Commission appointed by the Minister of Agriculture to inquire into the removal and utilization of excreta in various German and other towns, and to consider the plans proposed with those objects for Berlin.) 5. Ueber die Kanalisation von Berlin. Gutachten der Königl. wissenschaftlichen Deputation für das Medicinalwesen nebst einem Nachtrage mit zusatzlichen Bemerkungen von Rud. Virchow. (Report of the Royal Medical Commission on the Sewage of Berlin, with Appendix and remarks by Rud. Virchow.)

18th May, 1869. From Switzerland.—1. Report from the Department of the Interior at Berne to the Federal Council, forwarded by Mr. Bonar to Lord Clarendon, and containing information collected from the municipal bodies of various Swiss towns. 2. Ueber Anlage städtischer Abzugs-Kanäle und Behandlung der Abfallstoffe aus Städten. Von A. Bürkli. (The construction of town-sewers, and treatment of the refuse of towns.) 3. Ueber die Kloaken-Verhältnisse der Stadt Berne von Dr. Adolf Vogt. (The sewerage of Berne.) 4. Die Wasserverhältnisse Berns in Beziehung zu den Infections Krankheiten von Dr. A. Ziegler. (The connexion between water-supply and infectious diseases in Berne.) 5. Instruction sur l'Assainissement des habitations et des rues. (Directions for improving the sanitary condition of dwellings and streets.) Drawn up by the Special Sanitary Commission appointed by the Municipality of Lausanne in 1867, and approved by the Municipal Board of Health.

20th May, 1869. From Austria and Hungary.—1. Despatch from the Minister of Foreign Affairs at Vienna to Lord Blomfield, describing the methods in use in both portions of the empire.

20th May, 1869. From Belgium.—1. Report from M. Vanderstichelen to Mr. Savile Lumley on the regulations for disposing of refuse in towns and villages in Belgium. 2. Police des Etablissemens dangereux insalubres ou incommodes. (Regulations concerning works that are dangerous, unhealthy, or a nuisance.) 3. Mémoire sur la révision de la Législation des cours d'eau non-navigables ni flottables, &c. (Memoir on the revision of laws relating to watercourses that are not navigable.) A prize essay by M. Jules Sauveur.

20th May, 1869. From Sweden.—1. Despatch from Count Wachtmeister to Mr. Jermingham. 2. Report presented to the Grand Governor in Stockholm by the Board charged with the removal of refuse from the town. 3. Statement of expenditure and receipts of the Board during 1868. 4. Öfver-Ståthallare-Embetets Kungörelse angående särskelda ordningsföreskrifter för Stockholm utöfver hoad Kongl. Majts. Nådiga Ordningstadga för Rikets Städer innahåller, 11 Jan. 1869. (Regulation issued by the Grand Governor respecting removal of refuse.) 5. Project for removing refuse by railway as suggested to the Town Council of Stockholm by M. A Hanongren.

20th May, 1869. From Denmark.—1. Despatch from Sir C. L. Wyke to the Earl of Clarendon, stating that no precise data can be obtained.

20th May, 1869. From Turkey.—1. Extract from Mr. Elliot's despatch, stating that in Turkey matters are conducted in the most primitive manner.

20th May, 1869. From Greece.—1. Despatch from the Minister of Foreign Affairs at Athens to the Hon. E. M. Erskine, stating that the refuse of dwellings is generally carried out of the towns in carts at the expense of the municipal authorities, and that its application in agriculture is very limited.

20th May, 1869. From Russia.—Statement of the regulations as to removal of town refuse and its application in agriculture, for preventing pollution of water and other matters relating to public health.

20th May, 1869. From the United States of America.—1. Despatch from Mr. Thornton to the Earl of Clarendon, containing information furnished by H. M. Consuls at some of the principal cities in the United States. 2. Annual Report from the Superintendent of Health in Boston to the

City Council for the year 1868. 3. Copies of ordinances issued by the Health Office and Mayor of the City of Boston in reference to house-offal, ashes, &c. The construction of vaults and privies. Sanitary visitation. 4. Description of a plan for the Drainage of Washington proposed by Mr. P. H. Donegan. 5. Letter addressed from the Mayor's office of the City of Salem to Mr. Consul Lousada, stating that a system of sewerage is being constructed in that city by which the whole of the town-refuse will be carried into the two rivers between which it stands, instead of being collected, as heretofore, in vaults or cesspits, and carted away at intervals to serve as manure. 6. Municipal Register containing the ordinances, regulations, &c. of the City of Salem for 1867.

20th May, 1869. From Würtemberg.—1. Despatch from Mr. Gordon to the Earl of Clarendon. 2. Strassen-Polizei-Vorschriften für die Stadt Stuttgart. (Police regulations for the streets of Stuttgard.) 3. Report on the disposal of refuse in towns and dwellings, addressed to the Minister of the Interior by the Central Board of Agriculture in Stuttgard.

It appears from these documents that in most cases (both in town and country places) the use of privies is very general, water-closets being rare even in large towns, and that the usual method of dealing with human excreta is to allow them to collect in pits (Abtrittsgruben, fosses), which are sometimes drained, either naturally by the permeable character of the soil, or artificially, so that most or all of the liquid portion of the contents of the pits flows away or infiltrates the surrounding soil. Frequently privies are built over rivers, with the object of getting rid of the excreta at once; and at some places methods still more objectionable are adopted, many houses are without either water-closets or privies, the common custom being to use nightstools, which are emptied into pits near the house; thus, for instance, in Berlin, with a population under 600,000, there are said to be no less than 50,000 nightstools in daily use.

Only in some few foreign towns is there any system of sewerage for the removal of excreta by means of water; this is the case in Hamburg, Paris, Brussels, Hanover, Washington, Philadelphia, San Francisco, and some other American towns to a greater or less extent. In some other towns modified arrangements of the privy and pit system have been to some extent adopted. These consist in substituting for the ordinary pit either a fixed or a portable reservoir for receiving the excreta. These reservoirs are sometimes constructed with a drain by which the overflow or the liquid contents escape, and sometimes they are both water- and air-tight, the discharge of the liquid contents into the sewers being prohibited. In some cases such reservoirs are constructed so as to receive only the excreta, and sometimes so as to separate the solid and liquid excreta; but they are also used in combination with water-closets, and sometimes they receive rain-water from the house-roofs &c. as well.

The contents of the fixed reservoirs are removed periodically in several different ways, and according to divers local regulations. Sometimes the contents are simply dipped out, and sometimes they are removed either by pumping into closed tank-carts with lift-pumps, or by means of a vacuum previously produced in the tank-cart. In some few cases the time that may elapse between the removal of the contents of these reservoirs is fixed by the local authorities. The portable reservoirs are from time to time removed and replaced by empty reservoirs, then carried outside the town, and their contents used as manure in some way. Both the fixed and portable reservoirs are frequently ventilated by means of shafts rising above the house-tops. Fixed reservoirs are used in Carlsruhe, Ostend, Antwerp, Strasburg, Berlin, Dresden.

Portable reservoirs are used in Gratz, Dresden, Leipzig, Strasburg, Berlin, Paris. Generally the contents of pits and of fixed or portable reservoirs are used as manure. In some cases each householder pays for the removal of excretal refuse, in others the contents of pits and reservoirs are sold. At some places the town authorities pay for the removal of the refuse and street-sweepings. Thus in Carlsruhe, a town with about 25,000 inhabitants and 1400 houses, about £500 a year is paid to the contractor for this service, and the contractor sells the manure.

Sometimes a town derives some return from the excretal and other refuse removed and used as manure. In the town of Groningen the yearly profit amounts to about £1600, in Antwerp it is £2700, at Ostend £700. In Strasburg the cost of removal is only just covered by the sale of the manure. The sale of the refuse from the barracks at Carlsruhe, where 2800 men were quartered, has realized a profit of £300 a year, and the attendant expenses amounted to about £40 a year.

According to experience in the neighbourhood of Berne, Basle, Munich, Zurich, Ghent, and other towns where excretal refuse is removed and used as manure, there is always a profit realized after payment of the cost of removal and transport; and it appears to be considered probable that the expense attending this system would be reduced by the adoption of portable reservoirs. In some other towns the cost of removal and transport exceeds the return; thus, in Stockholm, with a population of about 150,000, the expenditure amounts to £35,000 a year, and the income derived from the sale of the refuse as manure is £33,000 a year.

In Hamburg there is an extensive system of sewerage, and in a large part of the town the excreta are removed by water-carriage through sewers. In Brussels, Paris, Lausanne, and Lugano the water-carriage system is also more or less adopted in some form adapted to local conditions. However, in the two latter towns water-closets are but rarely used, and in Basle likewise the privies are situated so as to discharge into the Rhine, or into one of its tributaries. In the case of Hamburg the water of the Elbe is stated to be much polluted by the discharge of sewage, but without any apparent serious influence on health. However, statistics furnished by the Secretary to the Hamburg Board of Health show that the rate of mortality has kept pace with the increase of population. In 1840, before the construction of the sewerage, the population was 137,000, with a mortality of 28 per thousand. In 1848 the population was 148,000, with a mortality of 22 per thousand; in 1859 the population was 174,000, with a mortality of 26 per thousand; and in 1866 the population was 195,000, with a mortality of 28 per thousand.

The general purport of the communications received from foreign countries is to show that the question as to the means by which excretal refuse may be disposed of and removed from dwellings, villages, and towns, so as to prevent nuisance or evil consequences as regards the sanitary condition of the locality, is, at least, quite as much an open and disputed question as it is in this country. In these documents there is abundant evidence that, wherever the subject has been considered, there is a strong, though vague sense of the injury to health resulting from the accumulation of excretal materials in pits &c. within populous districts, by the impregnation of the soil, by the pollution of rivers and well-water with drainage from such accumulations, or from the discharge of excretal materials into watercourses directly or indirectly; and it appears to be generally admitted that these are serious evils that require to be remedied.

Besides these views as to the sanitary aspect of the subject, there is still more decisive evidence of the conviction that a vast quantity of material is now wasted which might be of great service in agriculture for sustaining and augmenting the fertility of cultivated land. There is, however, no instance in which decisive conclusions have been arrived at as to the best mode of dealing with town-refuse so as to secure a satisfactory state of public health, and at the same time admit of the agricultural value of that refuse being realized without concurrent disadvantages. It does not appear that any particular improved system of dealing with house-refuse has been generally adopted as a substitute for the old practice of collecting such refuse in pits with periodical removal of the contents; neither is there any case where an attempted improvement has been long enough practised to furnish satisfactory evidence as to the efficacy of the means adopted, and their influence on public health. In both these respects it may safely be said that foreign towns are, as a rule, far behind some towns in this country.

The method of removing excretal refuse by pumping it into carts and carrying it out of the town to the neighbouring land, has in some instances been continued with satisfaction, while in other instances it has been abandoned after trial.

The plans of collecting and removing excretal refuse in portable closed reservoirs has been largely adopted in France, Saxony, Switzerland, and other countries; but in no case is any specific information given as to the extent to which the liquid portion escapes, spontaneously or by drainage, to pollute the adjoining soil and watercourses, or how far the portion of the refuse that remains represents the original value of the excreta for agriculture. In some towns it is evident that only the solid excreta are used as manure; thus in Zurich there is a system of sewerage which carries off both the rain-water and liquid drainage from gutters, houses, and reservoirs for collecting excreta. Probably in most cases, where cesspools or fixed and portable reservoirs are in use, the greater part of the liquid excreta drains away.

In some towns, as in Berlin for instance, the use of water as a means of transporting the refuse has been proposed, and it is still under consideration. Some of the scientific authorities deputed to inquire into the subject have, however, recommended that any general system of sewerage, based on that principle, should not be adopted, because of the increased difficulty it gives rise to in the realization of the value of the excreta as manure, and because of the anticipated prejudicial influences on the air of the district if the sewage were applied to land, and upon the water of rivers if the liquid refuse were mixed with it.

There does not appear to be, in any country, general or systematic legislation in reference to sanitary matters. Almost everywhere the regulations with that object are in the hands of the police or other local authorities; and though the provisions relating to removal of refuse, cleaning of streets, &c. are often very minute and stringent, they are seldom or ever of such a nature as to deal effectually with those tendencies to unhealthiness which result from accumulation of excretal and other refuse material, especially in large towns or densely populated districts.

As to the precise conditions that affect the public health, the connexion between the sanitary state of towns and the drainage, water-supply, mode of disposing of excretal refuse, &c., there appears to be, even more than in this country, an absence of definite knowledge or of demonstrative evidence in favour of any particular view, though at the same time there is everywhere in civilized countries an earnest consideration of these subjects in all their bearings—sanitary, municipal, and agricultural.

While this information was being collected from foreign countries, the Committee prepared a series of questions with the object of eliciting information as to the several cities, towns, and rural districts throughout the United Kingdom, so far as the means at its disposal would permit. These questions were sent to 340 local sanitary and sewer authorities, representing a population of about 10 millions. Up to the present time replies have been received from 107 places having an aggregate population of more than 4 millions.

Number and Population of Towns &c.

	Applied to.	Answered.
Towns with upwards of 100,000	16	8
„ „ between 100,000 and 50,000	23	13
„ „ „ 50,000 and 20,000	59	22
„ „ „ 20,000 and 10,000	69	23
„ „ „ 10,000	134	33
Rural districts	39	8
	340	107

Total Area, Number of Houses, and Rateable Value.—Of the 107 places from which replies have been received, the total area of 78 of them is stated to be 413,218 acres. The areas of the remaining 29 places have not been specified.

In 93 of these places the total number of houses is stated to be 727,816, and their aggregate rateable value £14,849,556.

In fourteen instances no particulars were stated as to these points.

Water-supply.—It appears that the sources of water-supply in these places are as follow:—

	Number of towns.	Aggregate population.
Surface-wells	24	354,890
Springs	8	63,680
Springs and gathering-grounds	16	1,210,906
Gathering-grounds and wells	3	606,552
Gathering-grounds and rivers	2	59,000
Rivers and streams	26	843,140
Lakes	1	19,000
Artesian wells	12	263,500
Artesian wells, rivers, and surface-wells	2	446,000
No information given	13	393,746

Of these places, 80 are provided with waterworks,

27 are without waterworks, or give no definite information.

The quantity of water supplied per head of the population is stated to be as under:—

	Number of towns.	Aggregate population.
From 50 to 30 gallons	7	596,800
„ 30 „ 20 „	25	1,477,007
„ 20 „ 15 „	13	455,500
„ 15 „ 10 „	15	370,500
Under 10	3	42,500
Not stated	43	1,444,000

The largest amount of water supplied is in the case of Lynn, where it is stated to be 56 gallons per head daily, and the smallest amount is said to be supplied in the case of Stroud, where it is only 4 gallons per head.

Disposal of Excretal Refuse.—Of the 107 places there are 42 where the old system of using privies with pits for collecting the refuse is general, and 25 where it is partially adhered to. In 42 places water-closets are general, and in 25 places they have been adopted partially to a greater or less extent.

Sewerage.—Out of the 107 places there are only 11 where no system of sewerage exists; in the remainder the sewerage of the towns is either general or partial, but in some instances very defective.

	Number of towns.	Number of Houses.		Population.	
		Total.	Sewered.	Total.	Discharging into sewers.
Completely sewered	48	375,002	375,002	2,230,578	2,230,578
Partially sewered..	48	337,299	152,785	1,973,753	1,039,731
Not sewered......	11	24,800	......	145,000	
	107				

Of the places which are completely sewered there are,—

29 where water-closets are general.
12 „ privies „ „
7 „ both are used.

Of the places which are only partially sewered there are,—

12 where water-closets are general.
22 „ privies „ „
14 „ both are used.

Of the places which are not sewered there are,—

1 where water-closets are general.
6 „ privies „ „
3 „ both are used.

Disposal of Liquid Sewage and Contents of Pits &c.—At 71 places out of the 107 the liquid sewage, consisting either of the discharge from water-closets, or of the drainage and overflow from pits and cesspools, is discharged into the adjoining stream or river, and in two instances it is discharged into pools of water. At a few of those places the sewage is first submitted to some kind of treatment, chiefly with the object of preventing or mitigating nuisance. At Bury St. Edmunds the liquid sewage is partly got rid of by means of dead wells.

In 38 places the contents of pits and cesspools are carted away.

At 15 places the liquid sewage is applied to land, either wholly or partially, and at 2 of those places it is previously subjected to treatment.

The number of towns where these different plans are adopted is shown by the following Table:—

				Sewage discharged into rivers &c.	Sêwage used for irrigation.	Contents of pits carted away.
Towns completely sewered......	48	Water-closets general	29	26	3	
		Privies............	12			15
		Both used	7	2	5	
Towns partially sewered	48	Water-closets general	12	9	3	
		Privies............	22	17	2	18
		Both used	14	12		
Towns not sewered ..	11	Water-closets used ..	1			
		Privies............	6	4		5
		Both..............	4	1		
Total number	107					

It will be evident that, according to local conditions, there will be great differences in the nature of the liquid sewage of different places, and that even the contents of pits, cesspools, &c. will vary, according as the soil is readily or slightly permeable. The amount of the water-supply and the admission or exclusion of surface-water from the sewers will also be of influence in this way.

Total Quantity and Amount of Liquid Sewage.—Among the 96 places where there is a system of sewerage, either general or partial, combined with water-closets and a copious supply of water, the minimum daily quantity of liquid sewage discharged varies from 20,000 gallons as at Alton, to 17 million gallons as at Birmingham, and 130 million gallons as at Liverpool.

The storm-discharge at places where the surface-water is admitted to the sewers varies from one and a half to twenty times as much as the discharge during dry weather, and at places where the surface-water is wholly or partially excluded it varies from one and one-tenth to seven times as much as the dry-weather discharge.

The average amount of liquid sewage per head of the population in places where the surface-water is admitted to the sewers varies from 10 to upwards of 100 gallons, and at places where the surface-water is excluded it varies from 6 to 100.

Treatment of Liquid Sewage.—At 15 of the places which are sewered wholly or partially, the liquid sewage is subjected to treatment either by allowing it to remain for a time in settling-tanks, from which the deposit is occasionally removed, as at Burton-on-Trent, Birmingham, Epsom, Fareham, and Andover, or by filtering, as at Uxbridge and Ealing.

In eight instances deodorizing materials are added to the sewage. Lime and carbolic acid are used at Carlisle and Harrow, lime alone is used at Leicester, lime and chloride of lime at Luton, perchloride of iron at Cheltenham, perchloride of iron and lime at Northampton, ferruginous clay treated with sulphuric acid at Stroud, and at Leamington the lime treatment has lately been superseded by the method proposed by Messrs. Sillar and Wigner. By this treatment the sewage is clarified, and a deposit is separated which is sold as manure.

In regard to the effects thus produced, it is stated that at Leicester the sewage runs off as pure as ordinary rain-water ; at Ealing it is said to be free from smell, colourless, and harmless to vegetable or animal life ; at Stroud and Luton the effect is stated to be satisfactory. At Harrow the nuisance is said to be somewhat mitigated, and at Abergavenny the stench is said to be abated by the treatment of the sewage. At Bury St. Edmunds upward filtration through charcoal and gypsum has been abandoned as too costly and in favour of irrigation. At Banbury treatment of the sewage has failed, and irrigation is now resorted to. At Hereford, where it was proposed to be adopted in the Parliamentary plans, it has not been tried, on the score of expense. At Tonbridge it is about to be tried ; and at Hastings and Cambridge experiments are being made.

The cost of treatment amounts to £1200 a year at Leicester for a population of 89,000 discharging into the sewers. At Ealing, with a population of 7500, the annual cost is £300, and the cost of the plant for the purpose was £3000. At Luton, with a population of 18,000, the annual cost is £500; at Cheltenham, with a population of 36,000, it is £350; at Uxbridge, with 7000 population, it is £200; and at Alton, with 3300 population, it is £46.

The solid deposit obtained by treating liquid sewage is sold at prices varying from 6*d.* to 2*s.* 6*d.* per ton. At Leicester as much as 5000 tons is produced. At Luton the deposit is mixed with night-soil, at Banbury with street-sweepings, and at Stroud it is made the basis of a manure that is said to be sold at £7 10*s.* per ton.

Application of Liquid Sewage for Irrigation.—In only 15 places out of the 96 where the water-carriage system of removing excretal refuse is adopted, either generally or partially, is the sewage applied for irrigating land. Of these places 8 are completely sewered; in 11 of them water-closets are general, and in 2 they are partial. The remaining 7 towns are only partially sewered, and in 3 of these water-closets are general, while privies are general in the other 4 towns.

The areas of land to which the sewage of these places is applied are shown by the following Table:—

		Towns.	Population discharging into sewers.	Area of irrigated land.	Area required for irrigation	Character.	Additional land.
				Acres.	Acres.		
Water-closets general.	Completely sewered.	Edinburgh	190,000	336	....	Various.	
		Carlisle	31,000	110	110	Pasture.	Some in hands of lessee.
		Rugby	8,700	65	50	Gravel&clay.	
		Chelmsford	8,500	50	50	....	150 acres, too high to reach.
		Epsom...............	4,000	30	100	....	90 ,,
		Harrow	3,500	15	....	Clay.	None.
		Banbury	10,800	120	134	Stiff.	14 ,,
		Newmarket	3,500				
	Partially sewered.	Bedford	16,504	55	....	Gravel subsoil.	
		Braintree............	5,000	....	....	Pasture.	
		Malvern	5,000	40 to 50	....	....	100 ,,
Privies general.		Tenterden	4,000				
		Birmingham	360,000	135	....	Clay and gravel.	
		Chorley	13,300	41	....	Clay subsoil.	46 ,,
		Bury St. Edmund's	14,000	....	15	Light.	

The following towns are about to apply their sewage for irrigation, or they contemplate doing so:—

	Towns.	Population discharging into rivers.	Area of land to be irrigated.	Character.	Additional land.
			Acres.		
W.C. general.	Tunbridge Wells ...	12,800	123	....	170 acres.
	Surbiton	7,100			
	Kingston-on-Thames	12,000			
	Nottingham...........	86,000			
	Inverness..............	18,000 ?	....	Light loam.	
	Perth	16,000	....	Sandy.	
	Aberdeen	60,000			
	Norwich	57,000	700	Light.	500 ,,
	Skipton	5,500			
	Reigate	9,000			
	Aylesbury				
	Evesham				

At Tonbridge it is stated that the application of the sewage for irrigating land would be almost impossible, and the local authorities believe all trials that have been made to apply sewage in this way are failures and a source of dissatisfaction on account of nuisance and expense. Lincoln is also said not to admit of this application of sewage. At Cambridge the subject is under consideration.

Comparing the extent of land irrigated and the population discharging into the sewers at the places above named, it appears that in the case of Birmingham there is only ·4 of an acre per 1000 of population; at Edinburgh there is 1·7 acre per 1000; at Carlisle, Bedford, and Chorley there is from 3 to 3·5 acres; at Harrow, Reigate, and Chelmsford there is from 5 to 6·6 acres; at Epsom, Rugby, and Malvern from 7·5 to 10 acres; at Tunbridge Wells, Banbury, and Norwich from 10 to 12 acres per 1000.

There does not appear to be any provision in most cases for additional land for irrigation except at Carlisle and Norwich. At Chelmsford there is some, but it is too high to be reached; and at Tunbridge Wells the purchase of additional land is contemplated.

At Carlisle, Reigate, Epsom, Inverness, and Tenterden the land selected for irrigation is situated within the district, under control of the local sewer authorities, at a distance of from one-fifth of a mile to half a mile from the centre of the town, and within a quarter of a mile of the outskirts. At Edinburgh, Bedford, Rugby, Chelmsford, Harrow, Skipton, Norwich, Perth, and Bury St. Edmunds, it is outside the district, at a distance of from half a mile (Perth) to 3 miles (Norwich) from the centre of the town, and from half a mile (Bury St. Edmunds, Harrow, Chelmsford, Bedford) to $1\frac{1}{4}$ mile (Norwich) beyond the outskirts; at Birmingham, Chorley, Braintree, Banbury, and Malvern the land is partly within and partly outside the district under the sewer authorities.

The distance of the irrigated land from the lowest sewer-outlet of the town varies from 100 yards to upwards of a mile. In some cases it has been purchased, as at Harrow, Reigate, and Tunbridge Wells; but in most cases it has been leased. Sometimes it is occupied by the sewer authorities, sometimes let to a farmer, as shown in the accompanying Table, which shows also the cost of delivery to the land by gravitation or pumping, and other details.

At most places the application of the sewage to land has been found to exercise a most beneficial influence on the condition of the streams and rivers receiving the drainage of the district. At Epsom there was some damage done to the Hog's Mill River, but no complaint is now made. Even where only the solid portion of the sewage is separated by filtration or precipitation, the state of rivers receiving the discharge is to some extent improved. At Northampton an application for an injunction has been made by a miller resident on the stream.

Generally speaking no objections appear to have been made to the application of sewage for irrigation; and where such objections have been urged, on the ground that the application was offensive and injurious, they do not appear to have been supported by medical authority, and in several instances they have ceased.

As regards the sanitary condition of these districts, it appears that in most cases the application of sewage for irrigation has not been attended with any apparent change; but there is said to be a marked improvement at Braintree.

It is to be understood that, in all cases, the data given in this Report and relating to this country, have been obtained from the local sewer authorities, in reply to letters of inquiry sent by the Committee, and that since there has

Situation of irrigated land relatively to the district under control of the sewer authorities.	Name of town.	Distance of irrigated land			Irrigated land has been		Occupation of the irrigated land		Sewage applied to land	
		from the town		from the lowest sewer outlet.	Leased.	Bought.	by the sewer authorities.	let to farmers.	by gravitation.	pumped.
		centre.	outskirts.							
		mile	mile	mile						
	Edinburgh	....	....	....	......	......	....	*	*	....
	Bedford	1	$\frac{1}{2}$	$\frac{1}{4}$	*	......	*	....	....	*
	Rugby	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	*	......	*	....	*	....
	Chelmsford	1	$\frac{1}{2}$	$\frac{3}{4}$	......	......	....	*	....	*
Without...........	Harrow	$1\frac{1}{2}$	$\frac{1}{2}$	....	......	*	*	....	*	....
	Skipton	....	....	....	......	......	....	*	*	....
	Norwich	3	$1\frac{1}{4}$	$1\frac{1}{4}$	*	......	not decided		....	*
	Perth	$\frac{1}{2}$	500 yds.	150 yds.	......	......	....	....	....	*
	Bury St. Edmunds	1	$\frac{1}{2}$	100	*	......	....	*	*	*
	Birmingham	$2\frac{1}{2}$	$\frac{1}{2}$	....	*	......	*	....	*	*
	Chorley	1	$\frac{3}{4}$	600	*	......	*	....	*	....
Partly within......	Braintree............	$\frac{1}{2}$	....	$\frac{1}{8}$	......	......	....	*	....	....
	Banbury	....	....	$\frac{1}{2}$	*	......	*	....	*	*
	Malvern	1	$\frac{1}{4}$	$\frac{1}{4}$	......	......	....	....	*	....
	Carlisle	$\frac{1}{2}$	....	....	*	......	....	*	....	*
	Reigate	....	....	....	......	*	....	....	....	....
Within	Epsom...............	$\frac{1}{2}$	$\frac{1}{4}$	....	*	......	....	....	*	*
	Inverness...........	1	....	$\frac{1}{2}$	......	......	partly		....	....
	Tenterden	....	....	....	......	......	....	*	*	....

not yet been any opportunity for examining in detail the circumstances of any particular locality, it would be premature at present to venture on any conclusions as to the numerous questions arising in reference to the treatment and utilization of sewage, or even to trust implicitly to the figures &c. given. Even on the assumption that the information furnished to the Committee does fairly represent the whole of the circumstances to be considered, that information presents so much variation and even discrepancy in several important details, that it seems indispensable there should be, in many instances, a minute investigation upon the spot, which the Committee has not yet had the power to make.

Although the Committee regards the present Report as dealing only partially with the subject of sewage, and as being in fact only a preliminary step towards the work required to be done, it is considered that there are two points (viz. the cost of various methods of dealing with excretal refuse, and their influence on the sanitary condition of towns) which must be referred to here, so far as the data obtained will permit.

The removal of the contents of pits and cesspools by cartage appears to be in some few instances conducted with some profit; more frequently, however, the cost is at least equal to the return obtained, and very often it is a source of loss. In regard to this point there is a marked difference between the results obtained in this country and those obtained on the Continent, where the removal of the contents of the pits is frequently profitable, either to individuals or to towns. The treatment of liquid sewage does not appear to have been advantageous in any instance, except in lessening the nuisance that would otherwise be caused by the discharge of sewage into rivers, and in most instances it has been a source of loss to the towns where it is practised.

The cost of the application of sewage for irrigating land appears to be dependent on a number of local conditions, and consequently to vary considerably. It would seem, from the data obtained, that in many instances the outlay requisite for this purpose would exceed what a farmer could be expected to incur, and that, in such cases at least, it would be proper to regard this outlay as coming under two distinct heads, viz. that which a town may reasonably be expected to bear for the mere object of getting rid of its refuse, and that which landowners or farmers may be able to incur for the improvement of their land. It is probable that, when viewed in this light, the application of liquid sewage to land would become a source of revenue to towns only under specially favourable circumstances; and that, in opposition to the opinions which have been somewhat hastily formed in certain cases, it will more frequently entail some amount of expenditure on the towns themselves. At the same time the benefit to land, and the improvement in the condition of rivers to be realized by the mode of dealing with liquid sewage, can scarcely be matter of doubt or uncertainty any longer.

In regard to the sanitary aspect of the subject, it may be regarded as beyond question that the practice of allowing excretal refuse to accumulate and remain neglected for a long time near dwellings, in pits, middens, cesspools, or otherwise, is almost invariably accompanied by prejudicial effects on the sanitary condition of the places where it is adopted, either by the impregnation of the soil with decaying material, by the pollution of water, or by noxious exhalations.

But even in some places where the water-supply has been improved, where a system of sewerage has been adopted, and other measures have been taken with the object of getting rid of excretal refuse, the fact that the rate of mortality has not been sensibly, if at all diminished, appears to point to some circumstance, as yet insufficiently guarded against, which still exercises a prejudicial influence. The imperfect or defective nature of the sewerage may, by allowing infiltration of sewage into the soil and its passage to the foundations of houses, in some cases be the cause to which this result is referable. But one part of the sewerage system which most urgently demands attention at the present time is the ventilation. Gases of a poisonous or deleterious nature are freely given off from liquid sewage in its passage along the sewers, or from deposits collecting in them and in the house-drains. These gases naturally ascend the sewers, and find egress, either into the streets of a town or into the dwellings, by means of the house-drains and otherwise. The means adopted for getting rid of these gases, without injury to the sanitary state of a town or of the houses in it, are rarely of such a kind as to be effective; and the returns already obtained in reference to this matter sufficiently show that attention has not been directed to it in a degree commensurate with its importance.

On these grounds the Committee considers that it would be in the highest degree desirable to institute an inquiry into the nature of the gaseous emanations from sewers in various places, that being one of the points now most important in connexion with the system of disposing of excretal refuse which is rapidly being adopted throughout this country. In reference to the application of liquid sewage to land, it is also considered that, in addition to various other points relating to the application and purification of sewage-water by irrigation, it would be very serviceable to make some inquiry into the nature of the sewage discharged in various places, so as to ascertain the differences that exist in liquid sewage so far as its value as manure is concerned, and at the same time to endeavour to obtain more definite information as to the cost of removing night-soil, and as to its agricultural value as established by practice.

Supplement to the Second Report of the Committee on the Condensation and Analysis of Tables of Steamship Performance.

The Committee have to report that the sum of £30 granted to them has been wholly expended in the payment of Mr. Quant, their calculator, as authorized in the resolution by which they were appointed. The calculator's time was employed partly in revising the printed Tables, which appeared in the volume of Reports for 1868, and partly in making an additional analyzed Table. The last-mentioned Table in MS. was delivered to the Secretary of the British Association early in the present year, and is annexed hereto. The Committee beg leave to represent that it is desirable that they should be reappointed, for the purpose of superintending the printing of that Table; but that no further grant of money will be required. They have again to express their satisfaction with the manner in which Mr. Quant performed his duties.

Revised Analysis, according to the method of Mr. Scott Russell.

In the Table of analyzation according to Mr. Scott Russell's method, as originally computed, the length of forebody was assumed at ·55 of the length of the ship, which in practice is generally the place of the midship section. This length of bow belongs to the displacement of the ship, but not to the speed. Therefore in calculating the resistance there are introduced a coefficient of diminished resistance belonging to one bow and a speed belonging to another bow, or, in other words, two ships have been used.

In the following Table this has been rectified by taking a length of bow belonging to the speed and also to the displacement. For example, the speed of a ship is 11·22 knots, or 18·96 feet per second; to this belongs a bow of 70 feet, and an afterbody of 47 feet; the ship is 336 feet long, hence there remains for middlebody 219 feet. Now the question arises, what is the corresponding area of midship section? because if the area of midship section as given in the Tables were used, it would result in too large a displacement with the above dimensions of fore, after, and middlebody. For this purpose we have as follows:—

$$\text{Area of midship section} \times (\cdot 5l + \cdot 5l' + l'' + \cdot 19635\,\text{B}) = \text{D} \times 35.$$

Substituting $l=70$, $l'=47$, $l''=219$, $\text{B}=40{\cdot}92$, and $\text{D}=3979$, the result is an area of midship section$=487{\cdot}7$ square feet. By the Tables it is given as 653; and the calculated section is therefore 165·6 □′ too small, or the vessel under the above dimensions sits lighter on the water. It is the lighter midship section which has been used in the following Table. To find the corresponding draught, taking the sides of the ship at the midship section as nearly vertical, the difference is divided by the beam of the ship and the quotient subtracted from the given draught. This results in a lighter draught of 14·3 feet instead of 18·35 as given by the Table—a difference of 4·04 feet. The difference is not always so large; in some vessels it does not amount to a foot.

Twice this difference in draught has been deducted from the actual girth of the midship section in order to find a girth suited for calculating the wetted surface; in the example this gives $\text{G}=54{\cdot}72$ instead of 62·8.

The coefficient of diminished resistance has been taken to belong to the bow as assumed above, and has been calculated by taking the square of the sine of the angle formed by half the beam and the length.

The skin has been calculated by the following formula,

$$(\cdot 58\text{G} + \cdot 84d)(l + l') + l''\text{G} = \text{skin or wetted surface},$$

in which formula the lighter girth at the midship section and the lighter draught must be substituted.

The calculations of resistance due to ship's way, skin, &c. have been made in the manner explained in the second Report. It may happen that the length of bow belonging to speed is greater than the ship itself as given in the Tables, as in the case of the 'Midge' and 'Penelope.' In such cases an afterbody is added to the forebody belonging to that speed, and with the two lengths and the given displacement the area of midship section, draught, and girth have been calculated.

It will be seen that in the following revised Table most of the negative quantities which appeared in the former Table have disappeared. The quantities in the following Table belong to ships of the same displacement, same speed, same length, same beam, and same indicated horse-power with the actual ships; whilst those in the former Table belong to ships of the same displacement, same length, same breadth, same draught, and same indicated power, but not the same speed, although that speed was introduced in the calculations resulting for the most part in the negative quantities as found for slip or engines.

Revised Table of Analysis, accordi[n]

	Atrato (paddle).	Tasmanian (screw).	Valparaiso (paddle).	Leonidas (screw).	Pera (screw).	Ceylon (screw).
Speed of ship, in knots per hour	11·22	14·25	11·53	11·7	12·556	13·34
Speed of ship, in feet per second...........	18·96	24·08	19·48	19·77	21·22	22·54
Length of bow belonging to speed, in feet	70·	116·	76·	76·	89·5	101·16
Length of stern, in feet...	47·	78·	51·	51·	59·6	67·44
Length of middlebody, in feet..................	219·	138·	105·	76·	151·	131·40
Total length of ship as calculated, in feet ...	336·	332·	232·	203·	300·1	300·
Total length of ship as actual, in feet	336·	332·	232·	203·	300·	300·
Breadth of ship, in feet...	40·92	39·	29·	29·12	42·08	41·
Area of midship section, as belonging to calculated ship	487·7	500·	246·	195·	414·	460·
Area of midship section, actual	653·	577·	308·	207·	592·	582·
Displacement, in cubic ft.	139265·	118125·	42700·	28350·	104020·	102900·
Draught of water belonging to calculated ship D	14·31	17·08	9·53	7·34	14·74	14·57
Draught of water, actual	18·35	19·08	11·67	7·75	18·25	18·25
Slip, in feet per second...	5·19	4·92	9·22	3·7	1·53	1·98
Coefficient of diminished resistance ...	·0786	·0274	·0351	·0353	·0524	·039
Indicated horse-power...	2207·98	2800·	800·	340·	1414·	2040·
Girth, corresponding to lighter draft D....	54·72	57·72	36·54	33·53	51·	57·
Skin or wet surface, in square feet............	17102·	17240·	6772·	5799·	13957·	15124·
Resistance due to ship's way, in pounds	13783·	7952·	3277·	2692·	10476·	9209·
Resistance due to skin, in pounds	21530·	35008·	9002·	7938·	22003·	26914·
Total resistance, in lbs...	35313·	42960·	12279·	10630·	32479·	36123·
Horse-power required for ship's way	299·	348·	116·	96·7	404·	377·
Horse-power required for skin	742·	1532·	318·8	285·	850·	1103·
Horse-power required for slip	333·	384·	206·	71·	90·	130·
Horse-power required for engines and propeller..................	833·	536·	160·	......	70·	430·
Percentage of total horse-power required for ship's way........	13·	12·4	14·5	21·	28·	18·
Percentage of total horse-power required for skin	·33	54·7	39·8	80·	60·	54·
Percentage of total horse-power required for slip	15·	13·7	25·7	19·	6·5	6·
Percentage of total horse-power required for engines and propeller	37·	19·	20·	......	5·	21·

to Mr. Scott Russell's Method.

San Carlos (screw).	Guayaquil (screw).	Delta (paddle).	Lancefield (screw).	Undine (screw).	Penelope (screw).	Midge (screw).	Leinster (paddle).
11·75	12·	14·67	9·6	9·26	10·85	10·53	16·28
19·85	20·28	24·79	16·22	15·64	18·33	17·79	27·51
77·	82·	122·	53·	47·5	67·	63·5	148·
55·	55·	81·	35·	34·	44·	42·	99·
60·	58·	105·	56·67	43·5	………	………	80·
192·	195·	308·	144·67	125·	111·	105·5	327·
192·	195·	308·	145·	125·	74·33	58·75	327·
30·	30·	35·25	23·	25·	12·75	12·67	35·
185·76	222·	377·	119·28	115·42	28·	24·	302·
260·	260·	400·	157·	154·3	32·	40·	330·
24500·	29400·	80500·	12565·	10290·	1627·	1575·	63525·
8·45	10·	14·17	7·	7·69 without keel.	3·77	2·84	12·57
11·83	11·71	15·	8·	7·66 without keel.	4·08	4·	13·37
9·19	9·52	4·	6·18	3·29	7·17	6·21	5·71
·0365	·0334	·0204	·0471	·0648	·0089	·0099	·0137
500·	600·	1624·	200·	157·09	93·	·100	4160·
35·	38·26	50·34	30·	32·84 without keel.	15·48	13·6	42·9
5715·	6409·	13626·	3748·	4106·79 with keel.	1346·43	1083·8	12185·
2672·	2956·	4732·	1408·	1830·	84·34	75·6	3142·
7890·	9228·	29324·	3468·	3521·	1585·	1201·	32290·
10562·	12184·	34056·	4876·	5351·	1669·34	1276·6	35432·
96·5	109·	213·	41·5	52·	2·81	2·45	157·
284·7	340·	1321·	102·2	100·	52·82	38·8	1615·
………	11·	247·	54·	32·	21·7	14·4	368·
119·	140·	………	2·7	………	15·67	46·65	2020·
19·	18·	12·	20·	28·	3·	2·5	3·8
56·	56·	74·	51·	54·	56·	38·	38·
………	2·	14·	27·	17·	23·	14·5	8·8
23·	23·	………	1·3	…	17·	45·5	50·

Report on Recent Progress in Elliptic and Hyperelliptic Functions. *By* W. H. L. Russell, *F.R.S.*

I shall never forget the evening when I first became acquainted with Mr. Ellis's report on the present state of Analysis published by this Association. I felt like a traveller who, on entering an unknown country through dark and narrow paths, suddenly arrives at an eminence from which he sees the whole region spread out like a map before him, and perceives at a glance the roads leading to the principal cities, and the most desirable mansions. I followed this guidance in my reading, and, as I proceeded, became anxious to attempt for others what Mr. Ellis had effected for me, and in consequence to undertake the present Report.

I shall keep steadily in view three main objects. In the first place, I shall endeavour to prove theorems enunciated by their authors without demonstration. Secondly, to explain passages which may present difficulties, and to give such directions as may enable the reader to arrive with the least difficulty at the most important parts of the different memoirs which will come under review. And, thirdly, to give such a connected view of the whole, as will enable anyone entering on the study of our present subject to know beforehand the nature of the results which have been obtained.

Elliptic functions will first be considered; and I shall divide the subject into four parts.

(1) I shall consider recent researches in this branch which do not involve the idea of periodicity.

(2) Recent investigations relative to function Θ, and its allied series.

(3) Modular equations, and some other researches of a similar description.

(4) Some of the most important geometrical and physical applications of elliptic functions.

Part I.

Section 1.—It will be proper to commence by giving a list of the principal algebraical integrals which can be reduced to elliptic functions. They are taken from Schellbach's 'Lehre von den Elliptischen Integralen,' and from a paper by Röthig in the fifty-sixth volume of Crelle's Journal. Along with the integrals I shall indicate the transformations necessary for their reduction.

$$\int\frac{dx\mathrm{R}(x)}{\sqrt{a_0+a_1x+a_2x^2+a_3x^3+a_2x^4+a_1x^5+a_0x^6}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let $z=x+\frac{1}{x}$. I know not if it has ever been remarked that the same substitution will enable us to integrate $\int\frac{dx\mathrm{R}(x)}{\sqrt{a+bx+cx^2+bx^3+ax^4}}$ in logarithms or circular arcs.

Hence we can reduce to elliptic functions

$$\int\frac{dx\mathrm{R}(x^2)}{\sqrt{a_0+a_1x^2+a_2x^4+a_1x^6+a_0x^8}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

by putting $x^2=z$, to which can be reduced

$$\int \frac{dx\mathrm{R}(x)}{\sqrt{a_0+a_1x^2+a_2x^4+a_1x^6+a_0x^8}}, \qquad (3)$$

since $\mathrm{R}x=\mathrm{R}_1x^2+x\mathrm{R}_2x^2$.

We can also reduce

$$\int \frac{dx}{\sqrt{a+bx^4+cx^8}} \qquad (4)$$

by putting $cx^8=az^8$.

So also

$$\int \frac{dx\,\mathrm{R}(x^2)}{\sqrt{a+bx^2+ex^4+cx^6}} \qquad (5$$

by putting $x^2=z$, to which can be reduced

$$\int \frac{dx\,\mathrm{R}(x)}{\sqrt{a+bx^2+ex^3+cx^6}}, \qquad (6)$$

since $\mathrm{R}(x)=\mathrm{R}_1x^2+x\mathrm{R}_2x^2$.

We are also able to express

$$\int^3 \frac{dx\,\mathrm{R}(x)}{\sqrt[3]{ax+bx^2+cx^3}} \qquad (7)$$

by elliptic functions, if we put $xz=\sqrt[3]{ax+bx+cx^3}$, to which can be reduced

$$\int \frac{dx\,\mathrm{R}(x)}{\sqrt[3]{a+bx+cx^2+ex^3}} \qquad (8)$$

by putting $x=y+p$, where $a+bp+cp^2+ep^3=0$.

Again, we can reduce

$$\int \frac{dx\,\mathrm{R}(x^2)}{\sqrt[4]{a+bx^2+cx^4}} \qquad (9)$$

to elliptic functions, if we make $x^4z^4=a+bx^2+cx^4$; and also

$$\int \frac{dx\,x\mathrm{R}(x^2)}{\sqrt[4]{a+bx+cx^2}} \qquad (10)$$

if we make $z=\sqrt[4]{a+bx+cx^2}$.

Moreover

$$\int \frac{dx\,\mathrm{R}(x)}{\sqrt[4]{a+bx^2+cx^4}} \qquad (11)$$

can be reduced to the two last cases, since

$$\mathrm{R}(x)=\mathrm{R}_1x^2+x\mathrm{R}_2x^2.$$

Lastly, the more general integral

$$\int \frac{dx\,.\,\mathrm{R}(x)}{\sqrt[4]{a+bx+cx^2+ex^3+hx^4}} \qquad (12)$$

can be reduced to (11) by putting $x=\dfrac{\alpha+\beta z}{\gamma+z}$, and proceeding as in elliptic functions.

Section 2.—In the eighth volume of the 'Cambridge and Dublin Mathematical Journal' there is a paper by Mr. F. Newman "On the Third Elliptic Integral." The principal object of this paper is to apply Lagrange's transformation to this integral so as to obtain available results. The interest and difficulty attaching to this are great, and I think it well, therefore, to present Mr. Newman's leading theorem to the reader in a form which he will find it easy to follow.

Let

$$\Delta_1=\sqrt{1-c_1^2\sin^2\theta_1},\quad \Delta=\sqrt{1-c^2\sin^2\theta},$$

$$\Pi(c,n,\theta)=\int\frac{d\theta}{(1+n\sin^2\theta)\Delta},$$

$$P(c,n,\theta)=\Pi(c,n,\theta)-\frac{F(c,\theta)}{F(c)}\Pi(c,n).$$

Then, following the usual scale of Lagrange, if

$$\sin\theta_1=(1+c')\frac{\sin\theta\cos\theta}{\Delta},\quad c'=\sqrt{1-c^2},\quad c_1=\frac{1-c'}{1+c'},$$

we have

$$\int\frac{d\theta_1}{(1+n_1\sin^2\theta_1)\Delta_1}=(1+c')\int\frac{\Delta d\theta}{\Delta^2+n_1(1+c')^2\sin^2\theta\cos^2\theta}\quad . \quad . \quad . \quad (1)$$

Let us assume

$$\Delta^2+n_1(1+c')\sin^2\theta\cos^2\theta=(1+n\sin^2\theta)(1-m\sin^2\theta),$$

where m and $-n$ are two new parameters. Then

$$nm=n_1(1+c')^2,\quad (1+n)(1-m)=c'^2,\quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\left.\begin{aligned}\sqrt{\left\{(1+n_1)\left(1+\frac{c_1^2}{n_1}\right)\right\}}&=\frac{n+m}{(1+c')\sqrt{nm}};\\ \sqrt{\left\{(1+n)\left(1+\frac{c^2}{n}\right)\right\}}&=\frac{(1+n)\sqrt{nm}}{n};\end{aligned}\right\}\quad . \quad . \quad . \quad (3)$$

whence, since remembering the second of equations (2),

$$\frac{\Delta}{(1+n\sin^2\theta)(1-m\sin^2\theta)}=$$

$$\frac{mn}{m+n}\left\{\frac{1+n}{n}\cdot\frac{1}{(1+n\sin^2\theta)\Delta}+\frac{1-m}{m}\cdot\frac{1}{(1-m\sin^2\theta)\Delta}\right\}.$$

Therefore from (1),

$$\Pi(c_1,n_1,\theta_1)=(1+c')\frac{mn}{m+n}\left\{\frac{1+n}{n}\Pi(c,n,\theta)+\frac{1-m}{m}\Pi(c,-m,\theta)\right\},$$

putting $\theta=\frac{\pi}{2}$, and therefore $\theta_1=\pi$,

$$2\Pi(c_1,n_1)=(1+c')\frac{mn}{m+n}\left\{\frac{1+n}{n}\Pi(c,n)+\frac{1-m}{m}\Pi(c,-m)\right\}.$$

Multiply this by $\frac{1}{2}\frac{F(c_1,\theta_1)}{Fc_1}=\frac{F(c,\theta)}{F(c)}$, and subtract from the last equation, and we have by definition

$$P(c_1, n_1, \theta_1)=(1+c')\frac{mn}{m+n}\left\{\frac{1+n}{n}P(c,n,\theta)+\frac{1-m}{m}P(c, -m, \theta\right\} \quad . \quad (4)$$

But (Hymers's 'Integral Calculus,' p. 284)

$$\frac{1+n}{n}\Pi(c, n, \theta)-\frac{1-m}{m}\Pi(c,-m, \theta)=\frac{c^2}{m}F(c, \theta)$$
$$+\frac{1}{\sqrt{mn}}\tan^{-1}\left\{\frac{\sqrt{mn}\sin\theta\cos\theta}{\Delta}\right\}.$$

From this we obtain

$$\frac{1+n}{n}P(c,n,\theta)-\frac{1-m}{m}P(c,-m,\theta)=\frac{1}{\sqrt{mn}}\tan^{-1}(\sqrt{n_1}\sin\theta_1); \quad . \quad (5)$$

therefore we have from (4) and (5), remembering (2),

$$\sqrt{\left\{(1+n)\left(1+\frac{c^2}{n}\right)\right\}}\,P(c,n,\theta)=\tfrac{1}{2}\sqrt{\left\{(1+n_1)\left(1+\frac{c^2}{n_1^2}\right)\right\}}\,P(c_1, n_1, \theta_1)$$
$$+\tfrac{1}{2}\tan^{-1}(\sqrt{n_1}\sin\theta_1);$$

whence it is easy to see that if θ_2 and n_2 &c. are formed from θ_1 and n_1 as θ_1 and n_1 were formed from θ and n, we have

$$\sqrt{\left\{(1+n)\left(1+\frac{c^2}{n}\right)\right\}}\,P(cn\theta)=\tfrac{1}{2}\tan^{-1}(\sqrt{n_1}\sin\theta_1)$$
$$+\tfrac{1}{4}\tan^{-1}(\sqrt{n_2}\sin\theta_2)+\tfrac{1}{8}\tan^{-1}(\sqrt{n_3}\sin\theta_3)+\dots$$

This very beautiful theorem applies to the third elliptic integral with circular parameters; but it is obvious that it may be easily extended to logarithmic parameters, as has been done by Mr. Newman. In a subsequent part of his paper, Mr. Newman points out the connexion between his own researches and some of Jacobi's discoveries.

Section 3.—In the 36th volume of Crelle's Journal there is a Memoir by the late Professor Plana, of Turin, on the reduction of $\int\frac{Tdx}{\sqrt{X}}$, to elliptic functions, where

$$T=G+G'x+G''x^2+\frac{H+H'\sqrt{-1}}{1+(K+K'\sqrt{-1})x}+\frac{H-H'\sqrt{-1}}{1-(K-K'\sqrt{-1})x}$$

and $$X=x^4+\lambda x^3+Ax^2+Bx+C.$$

It would be impossible to give an analysis of this memoir without reproducing it, which is the less necessary as so much has been written on this subject. I shall therefore confine myself to directing the reader's attention to a particular portion of it.

At the beginning of the ninth section there is a method for reducing the sums of two elliptic functions of the form

$$g\int\frac{dy}{(1-fy^2)\sqrt{Y}},\quad g'\int\frac{dy}{(1-f'y^2)\sqrt{Y}},$$

where $f=g+h\sqrt{-1}$, $f'=g-h\sqrt{-1}$,

$$Y=(M+Ny^2)(P+Qy^2)$$

to the sum of two of the form

$$\int\frac{dy}{(1+n'y^2)\sqrt{Y}},\quad \int\frac{dy}{(1+n''y^2)\sqrt{Y}},$$

where n' and n'' are real. The method is founded on substituting

$$p=\frac{y(1+\zeta y^2)}{\sqrt{Y}} \text{ in } \int\frac{dp}{1+\epsilon p^2},$$

and then finding two suitable values for ζ. The section to which I refer is almost detached from the rest of the memoir, and may be read without difficulty. There is another paper by Richelot on this subject in the 34th volume of Crelle's Journal.

Section 4.—Of late the theory of continued fractions has received a very wide extension. A very beautiful example of this will be found in the 56th volume of Crelle's Journal, in which Laplace's coefficients are applied to the expansion of functions in continued fractions. It is not, therefore, surprising that the expansion of elliptic functions in this manner should have been the subject of several successful efforts. In the 39th volume of Crelle's Journal there is a paper on this subject by Professor Malmsten. The known equations

$$k\frac{dE'}{dk}=E'-F',\quad kk'^2\frac{dF'}{dk}=E'-k'^2F' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

easily lead to the differential equation

$$(y^2-2k'^2y+k'^2)dk+kk'^2dy=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\text{where } y=\frac{E'k}{F'k}.$$

If we put

$$k=\left\{mx+\frac{1+c}{2}\right\}^{\frac{1}{2}} \quad y=\tfrac{1}{2}(1-c-2mx)+\frac{1-(c+2mx)^2}{2m}u \quad . \quad . \quad . \quad (3)$$

this last equation may be written

$$\left(m^2x^2+mcx+\tfrac{1}{4}(c^2-1)\right)\left(\frac{du}{dx}+u^2\right)+mu(2mx+c)+\tfrac{1}{4}m^2=0 \quad . \quad . \quad (4)$$

But from (3),

$$\frac{E'k}{F'k}=k'^2+2k^2k'^2\cdot\frac{u}{m}*.$$

Therefore by the second of equations (1),

$$2k^2k'^2\frac{u}{m}=\frac{kk'^2\frac{dF'}{dk}}{F'}$$

or

$$u=\frac{m}{2k}\cdot\frac{\frac{dF'}{dk}}{F'}=\frac{dk}{dx}\cdot\frac{\frac{dF'}{dk}}{F'}=\frac{\frac{dF'}{dx}}{F'}.$$

* I have been the fuller here because several steps are omitted by Malmsten.

Hence if $z=\mathrm{F}'\left(mx+\frac{1+c}{2}\right)^{\frac{1}{2}}$, $u=\frac{z'}{z}$, the equation (4) becomes

$$\left(m^2x^2+mcx+\frac{c^2-1}{4}\right)z''+m(2mx+c)z'+\frac{m^2}{4}z=0.$$

Therefore, differentiating $(n-1)$ times, we have

$$\left(mx^2+mcx+\frac{c^2-1}{4}\right)z^{(n+1)}+mn(2mx+c)z^{(n)}+\frac{(2n-1)^2m^2}{4}z^{(n-1)}=0\,;$$

from this we have

$$\frac{z^{(n)}}{z^{(n-1)}}=\frac{-\frac{(2n-1)^2m}{4(2mx+c)}}{n+\frac{m^2x^2+cmx+\frac{c^2-1}{4}}{2m^2x+mc}\cdot\frac{z^{(n+1)}}{z^{(n)}}},$$

an expression which of course leads to the development of (u) in a continued fraction.

From this Malmsten obtains several results. A very elegant consequence of this investigation is the following theorem:—

Let

$$k=\sqrt{\left\{\frac{\sqrt{1+x^2}-1}{2\sqrt{1+x^2}}\right\}}\,;$$

then

$$(1-2k^2)\left\{\frac{\mathrm{E}'k}{\mathrm{F}'k}-\frac{1-k^2}{1-2k^2}\right\}$$

$$=\frac{x}{2+}\;\frac{3.3.x^2}{4+}\;\frac{5.5.x^2}{6+}\;\frac{7.7.x^2}{8+}\;\frac{9.9.x^2}{10+},$$

which, with several others, will be found fully demonstrated in the paper.

Part II.

Section 1.—In entering on investigations relative to function θ, it is proper to observe that two distinct notations are used to express the same four series. It is now usual to write

$$\begin{aligned}
\theta\,x&=1-2q\cos 2x+2q^4\cos 4x-2q^9\cos 6x+\dots\\
\theta_1x&=\quad 2q^{\frac{1}{4}}\sin x-2q^{\frac{9}{4}}\sin 3x+2q^{\frac{25}{4}}\sin 5x\dots\\
\theta_2x&=\quad 2q^{\frac{1}{4}}\cos x+2q^{\frac{9}{4}}\cos 3x+2q^{\frac{25}{4}}\cos 5x\\
\theta_3x&=1+2q\cos 2x+2q^4\cos 4x+2q^9\cos 6x+\dots
\end{aligned}$$

These four series are written in 'Fundamenta Nova'

$$\Theta\frac{2\mathrm{K}x}{\pi},\ \mathrm{H}\frac{2\mathrm{K}x}{\pi},\ \mathrm{H}\frac{2\mathrm{K}}{\pi}\left(x+\frac{\pi}{2}\right),\ \Theta\frac{2\mathrm{K}}{\pi}\left(x+\frac{\pi}{2}\right).$$

The former notation is obviously more convenient; and as uniformity is most desirable, I shall usually adhere to it. It will, however, be occasionally necessary to make use of the second, as it is employed in Crelle's Journal in many papers which I shall have to bring before the reader.

Section 2.—It will be proper, on every account, to commence this division with an account of Jacobi's later researches relative to function Θ. Three of these are contained in the 36th volume of Crelle's Journal, and I shall consider them in succession. The first of these is entitled "Uber die unmittelbare Verification einer Fundamental-Formel der Theorie der elliptischen Functionen."

It is proved in the 'Fundamenta Nova' that if

$$S=1-q(z+z^{-1})+q^4(z^2+z^{-2})-q^9(z^3+z^{-3})+\ldots$$

$$\Pi=(1-q^2)(1-q^2)\ldots(1-qz)(1-q^3z)\ldots(1-qz^{-1})(1-qz^{-3})\ldots$$

S and Π are equal, and we must therefore have

$$\frac{dS}{dq}=S\frac{d\log\Pi}{dq},\quad \frac{dS}{dz}=S\frac{d\log\Pi}{dz}.$$

It appears, without much difficulty, that if (m) represent every whole number from 1 to ∞, $\psi(m)$ the sum of the factors of (m), p all odd numbers from 1 to infinity, i all whole numbers from $-\infty$ to $+\infty$, these equations lead to the following:

$$-i^2=2\Sigma\psi(m)q^{2m}+\Sigma\Sigma(-1)^m pq^{m(m+p-2i)}+\Sigma\Sigma(-1)^m pq^{m(m+p+2i)}$$

$$-i=\Sigma\Sigma(-1)^m q^{(m+p-2i)}-\Sigma\Sigma(-1)^m q^{m(m+p+2i)},$$

where $\Sigma\Sigma$ refer to m and p as above explained. The object of the paper is to prove these formulæ, and I make the two following observations to facilitate its study.

The first observation, in which Σ refers to p, is intended to illustrate page 77.

$$\Sigma_1^\infty(-1)^m pq^{m(m+p-2i)}+\Sigma_1^\infty(-1)^m pq^{m(m+p+2i)}$$

$$=\Sigma_1^{4i-1}(-1)^m pq^{m(m+p-2i)}+\Sigma_{4i+1}^\infty(-1)^m pq^{m(m+p-2i)}+\Sigma_1^\infty(-1)^m pq^{m(m+p+2i)}$$

$$=\Sigma_{-(2i-1)}^{2i-1}(-1)^m(2i+\pi)q^{m(m+\pi)}+\Sigma_1^\infty(-1)^m(4i+p)pq^{m(m+p+2i)}$$

$$+\Sigma_1^\infty(-1)^m pq^{m(m+p+2i)}$$

$$=\Sigma_{-(2i-1)}^{2i-1}(-1)^m(2i+\pi)q^{m(m+\pi)}+\Sigma_1^\infty(-1)^m(4i+2p)pq^{m(m+p+2i)}.$$

The second refers to page 78; there we have the following equation—

$$\Sigma\Sigma(-1)^{m+p}pq^{m(m+p)}=\Sigma\psi(m)q^{2m}.$$

It would be better to write this in the following way—

$$\Sigma\Sigma(-1)^{m+p}pq^{m(m+p)}=\Sigma\psi(r)q^{2r},$$

since $m(m+p)$ and $2r$ are intended to be equivalent.

Section 3.—Jacobi's second paper is entitled "Ueber die partielle Differential gleichung welcher die Zähler und Nenner der elliptischen Function Genugeleisten." Jacobi at the commencement of his paper gives the following formula without demonstration:—

$$\theta_3(x)=\sqrt{\frac{2K}{\pi}}\Delta\epsilon^{\int_0^u E(u)du-\frac{1}{2}\frac{E'u^2}{K}}.$$

To prove this, we remember the well-known expression

$$\theta(x)=\sqrt{\frac{2Kk'}{\pi}}\,\epsilon^{\int_0^\phi \frac{F'E\phi-E'F\phi}{F'\Delta\phi}d\phi};$$

$\theta_3(x)$ is derived from $\theta(x)$ by changing q into $-q$.

Now if we change q into $-q$,

$$\sqrt{\frac{2Kk'}{\pi}} \text{ becomes } \sqrt{\frac{2K}{\pi}},\ F'=K \text{ becomes } Kk',$$

$$E' \text{ becomes } \frac{E'}{k'}{}^*,\quad \Delta \text{ becomes } \frac{1}{\Delta},$$

$$E\phi=\int_0^\phi d\phi\sqrt{1-k^2\sin^2\phi} \text{ becomes } k'\int_0^\phi\frac{d\phi}{\Delta^3},$$

$$\text{and } \int_0^\phi\frac{d\phi}{\Delta^3}=\frac{1}{k'^2}E\phi-\frac{k^2}{k'^2}\,\frac{\sin\phi\cos\phi}{\Delta}\dagger,$$

and therefore $E\phi$ becomes

$$\frac{1}{k'}E\phi-\frac{k^2}{k'}\,\frac{\sin\phi\cos\phi}{\Delta}.$$

$$F\phi \text{ becomes } k'F\phi, \text{ and } \frac{d\phi}{\Delta} \text{ becomes } k'\frac{d\phi}{\Delta}.$$

Substituting all these in the expression for $\theta(x)$, we have

$$\theta_3(x)=\sqrt{\frac{2K}{\pi}}\,\epsilon^{\int_0^\phi\left\{\frac{1}{k'}E\phi-\frac{k^2}{k'}\frac{\sin\phi\cos\phi}{\Delta}-\frac{E'}{Kk'}F\phi\right\}\frac{k'd\phi}{\Delta}}$$

$$=\sqrt{\frac{2K}{\pi}}\,\epsilon^{\int_0^\phi\frac{E\phi d\phi}{\Delta}-\frac{1}{2}\frac{E'}{K}F(\phi)^2+\log_\epsilon\Delta}$$

$$=\sqrt{\frac{2K}{\pi}}\,\Delta\,\epsilon^{\int_0^\phi\frac{E\phi d\phi}{\Delta}-\frac{1}{2}\frac{E'}{K}E\phi^2},$$

which is, in fact, Jacobi's expression for $\theta_3(x)$. In the memoir now under consideration, Jacobi arrives by partial differentiation at the following theorem:

Let

$$Y=\int_0^t t^{\beta-1}(1-t)^{\gamma-\beta-1}(1-rt)^{-\alpha}dt,$$

$$y=\int_0^1 t^{\beta-1}(1-t)^{\gamma-\beta-1}(1-rt)^{-\alpha}dt,$$

$$\lambda=\int r^{-\gamma}(1-r)^{\gamma-\alpha-\beta-1}y^2dr,\qquad v=\frac{Y}{y},$$

* Fundamenta Nova, p. 111.

† Hymers's Integral Calculus, p. 220.

$$V=\tfrac{1}{2}r^{\gamma}(1-r)^{\alpha+\beta-\gamma+1}\left(Y\frac{dy}{dr}-y\frac{dY}{dr}\right)$$

$$=\tfrac{1}{2}\alpha t^{\beta}(1-t)^{\gamma-\beta}\int r^{\gamma-1}(1-r)^{\alpha+\beta-\gamma}(1-rt)^{-\alpha-1}y\,dr:$$

then V, considered as a function of v and λ, satisfies the partial differential equation

$$\frac{dV}{d\lambda}-2V\frac{dV}{dv}+r^{\gamma-1}(1-r)^{\alpha+\beta-\gamma}t^{2\beta-1}(1-t)^{2\gamma-2\beta-1}(1-rt)^{-2a+1}\frac{d^2V}{dv^2}=0.$$

Let $\gamma=1$, $\alpha=\beta=\frac{1}{2}$, and the differential equation becomes

$$\frac{dV}{d\lambda}-\frac{d\,.\,V^2}{dv}-\frac{d^2V}{dv^2}=0,$$

and Y becomes

$$\int_0^t\frac{dt}{\sqrt{r(1-t)(1-rt)}}=2\int_0^{\phi}\frac{d\phi}{\sqrt{1-r\sin^2\phi}},$$

where $t=\sin^2\phi$.

From this Jacobi shows that

$$\theta_3 x=\sqrt{\frac{2K}{\pi}}\,\Delta\epsilon^{\int_0^u Eudu-\frac{1}{2}\frac{E'.u^2}{K}}$$

satisfies the partial differential equation, originally seen to be true from the nature of the series

$$-4q\frac{d\theta_3(x)}{dq}=\frac{d^2\theta_3(x)}{dx^2}.$$

Section 4.—Jacobi's third paper is a very remarkable one, and there is a French translation in Liouville's Journal. It is entitled "Ueber die Differentialgleichung welcher die Reihen $1\pm2q+2q^4\pm\ldots2^4\sqrt{q}+2^4\sqrt{q^9}+\ldots$ Genuge leisten."

The main object of the paper is to show that

$$y=\sqrt{\frac{2K}{\pi}},\quad y=\sqrt{\frac{2Kk}{\pi}},\quad y=\sqrt{\frac{2Kk'}{\pi}},$$

each satisfy the following differential equation,

$$\{y^2d^3y-15y\,dy\,d^2y+30dy\}+32\{yd^2y-3dy^2\}^3=y^{10}\{yd^2y-3dy^2\}^2(d\log_\epsilon q)^2.$$

By differentiating the equation

$$K=\int_0^{\frac{\pi}{2}}\frac{d\theta}{\sqrt{1-k^2\sin^2\theta}}$$

with respect to k^2 it is proved without much difficulty that if $y=\sqrt{\frac{2K}{\pi}}$,

$$\frac{d\,.\,k^2k'^2\frac{d\,.\,y^2}{dk^2}}{dk^2}=\frac{y^2}{4}\quad\ldots\ldots\ldots\ldots\quad(1)$$

and from this that

$$\frac{d \,.\, \log_\epsilon \frac{k^2}{k'^2}}{d \log_\epsilon q} = y^4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Combining these equations together, we have

$$\frac{4}{y^6}\left(\frac{d}{d \log_\epsilon q}\right)^2 \frac{1}{y^2} = -k^2k'^2,$$

from whence we obtain

$$d\log_\epsilon \left\{ \frac{1}{y^6} \cdot \frac{d^2}{(d \log_\epsilon q)^2} \cdot \frac{1}{y^2} \right\} = \sqrt{\left\{ \frac{16}{y^6} \cdot \frac{d^2}{(d \log_\epsilon q)^2} \cdot \frac{1}{y^2} + 1 \right\}}\, y^4 d \log_\epsilon q^*,$$

which immediately leads to the required differential equation. A similar investigation applies to $y = \sqrt{\frac{2Kk}{\pi}}$, $y = \sqrt{\frac{2Kk'}{\pi}}$.

We may find a more general solution of Jacobi's differential equation thus It is easily proved that if k and k' are interchanged, equation (1) is unaltered, and therefore K′ is a particular solution of it. Therefore

$$Q = aK + b\sqrt{-1}K', \quad Q' = a'K + b'\sqrt{-1}K'$$

are also solutions of equation (1), and consequently

$$\frac{d}{d\,.\,k^2} k^2k'^2 \frac{d}{dk^2} \cdot \left\{ \frac{2Q}{\pi} \right\} = \tfrac{1}{4} \left\{ \frac{2Q}{\pi} \right\}.$$

Moreover, it is proved in the 'Fundamenta Nova,' p. 74, that

$$d \,.\, \frac{-\pi Q'}{Q} = \frac{(aa' + bb') d \log_\epsilon \frac{k^2}{k'^2}}{\left(\frac{2Q}{\pi}\right)^2}.$$

These equations exactly correspond with (1) and (2), and therefore

$$y = \sqrt{\frac{2Q}{\pi\sqrt{aa' + bb'}}}, \quad \log_\epsilon q = -\frac{\pi Q'}{Q}$$

satisfy Jacobi's differential equation.

Section 5.—In close connexion with this paper is another left by Jacobi among his manuscripts, "Darstellung der elliptischen Functionen durch Potenzreihen," published in the fifty-fourth volume of Crelle's Journal. Its object is to expand the four functions $\theta(x)$, $\theta_1(x)$, $\theta_2(x)$, $\theta_3(x)$ in terms of (x). I shall give the outlines of the investigation for $\theta_3(x)$.

* Because $\frac{d \log_\epsilon k^2k'^2}{d \log_\epsilon q} = \left\{ \frac{1}{k^2} - \frac{1}{k'^2} \right\} \frac{dk^2}{d \log_\epsilon q} = \sqrt{1 - 4k^2k'^2}\, \frac{d \log_\epsilon \frac{k^2}{k'^2}}{d \log_\epsilon q}$. I have followed a route somewhat differing from Jacobi's, and easier if we only wish for the differential equation for $\sqrt{\frac{2K}{\pi}}$. I should advise the reader to follow the method for $y = \sqrt{\frac{2K}{\pi}}$ indicated here, and then to read Jacobi entire.

It is easily seen that if

$$h=\log_\epsilon \sqrt[4]{q}, \quad A=\frac{2K}{\pi},$$

$$\frac{d^{2m}\theta_3(x)}{dx^{2m}}=(-1)^m\frac{d^m\sqrt{\frac{2K}{\pi}}}{dh^m}=(-1)^m\frac{d^m\sqrt{A}}{dh^m};$$

$$\therefore\ \theta_3(x)=\sqrt{A}-\frac{d\sqrt{A}}{dh}\cdot\frac{x^2}{1\,.\,2}+\frac{d^2\sqrt{A}}{dh^2}\cdot\frac{x^4}{1\,.\,2\,.\,3\,.\,4}+;\quad . \quad . \quad (1)$$

and therefore, putting $B=\frac{2k^2}{\pi}\int_0^{\frac{\pi}{2}}\frac{\cos^2\phi}{\sqrt{1-k^2\sin^2\phi}}$,

$$a=4(1-2k^2),\quad b=2k^2k'^2,$$

we obtain, by a process similar to that used in obtaining equations (1) and (2) of last article,

$$\frac{dA}{dh}=2A^2B,\quad \frac{dB}{dh}=bA^3,\quad \frac{da}{dh}=-16bA^2,\quad \frac{db}{dh}=abA^2\quad . \quad . \quad (2)$$

If H is a function of A, B, a, b, we obtain from these equations the following:—

$$\frac{dH}{dh}=2A^2B\frac{dH}{dA}+bA^3\frac{dH}{dB}+abA^2\frac{dH}{db}-16ba^2\frac{dH}{da}\quad . \quad . \quad . \quad . \quad (3)$$

Differentiating $\sqrt{A}$ a certain number of times in accordance with (3), we are led to suspect that

$$\left.\begin{aligned}\frac{d^m\sqrt{A}}{dh^m}&=n_1^{(m)}A^{\frac{2m+1}{2}}B^m+n_2^{(m)}r_2A^{\frac{2m+1}{2}+2}B^{m-2}\\&+n_3^{(m)}r_3A^{\frac{2m+1}{2}+3}B^{m-3}+\,.\,.+n_i^{(m)}r_iA^{\frac{2m+1}{2}+i}B^{m-i}+\ldots\\&+n_m^{(m)}r_mA^{\frac{2m+1}{2}+m},\end{aligned}\right\}\quad . \quad (4)$$

where $n_1^{(m)}$, $n_2^{(m)}$, &c. are certain integers, r_2, r_3, &c. certain functions of a and b independent of (m); so that the coefficient of $A^{\frac{2m+1}{2}+i+p}B^{m+p-i}$ in the expansion of $\frac{d^{m+p}\sqrt{A}}{dh^{m+p}}$ is $n^{(m+p)}r_i$. It will be observed that $r_1=0$.

Furthermore, we are led by induction to suspect that the numbers $n^{(m)}$ are such that

$$\theta_3(x)=\sqrt{A}\epsilon^{-\frac{1}{2}ABx^2}\left\{1+r_2\frac{A^4x^4}{1\,.\,2\,.\,3\,.\,4}-r_3\frac{A^6x^6}{1\,.\,2\,.\,3\,.\,4\,.\,5\,.\,6}+\ldots\right\}.\quad . \quad (5)$$

These assumptions may be thus verified:—

Equating coefficients in the two expressions for θ_3 &c. in (1) and (5), we have

$$\left.\begin{array}{l}\dfrac{d^m\sqrt{A}}{dh^m}=A^{\frac{2m+1}{2}}\{m_0B^m+m_2r_2B^{m-2}A^2+ \\ \quad m_3r_3B^{m-3}A^3+\ldots+m_mr_mA^m\},\end{array}\right\} \quad \ldots \quad (6)$$

where the coefficient

$$m_i=(2i+1)(2i+3)\ldots(2m-1)\,.\,\frac{m(m-1)\ldots(m-i+1)}{1\,.\,2\,.\,3\ldots i}; \quad . \quad . \quad (7)$$

we find from (6), in consequence of (3), that

$$\{(2m+2i+1)m_i-(m+1)_i\}r_i+(m-i+2)m_{i-2}br_{i-2}$$
$$+m_{i-1}ab\frac{dr_{i-1}}{db}-16m_{i-1}b\frac{dr_{i-1}}{da}=0,$$

which being transformed by means of (7), gives

$$r_i-(i-1)(2i-3)br_{i-2}=b\left\{a\frac{dr_{i-1}}{db}-16\frac{dr_{i-1}}{da}\right\},$$

which is independent of (m), as it should be, according to the assumption. Moreover the value of $\dfrac{d^{m+1}\sqrt{A}}{dh^{m+1}}$ found by equating coefficients in (1) and (5) is

$$\frac{d^{m+1}\sqrt{A}}{dh^{m+1}}=A^{\frac{2m+3}{2}}\{(m+1)_0B^{m+1}+(m+1)_2r_2B^{m-1}A^2+\ldots\};$$

and this can also be found by differentiating (6) with regard to h. The induction is completely proved. I think the reader will find no difficulty after these remarks in reading this paper,—one of the most beautiful productions of its illustrious author, the paper reviewed in last section having been previously studied.

Section 6.—In the thirty-seventh volume of Crelle's Journal there is a memoir of Jacobi of a very different nature to those we have been reviewing. Its title is "Ueber unendliche Reihen, deren exponenten zugleich in zwei verschiedenen quadratischen Formen enthalten sind." Many parts of this memoir relate to the theory of numbers, and contain no allusion whatever to the subject of this Report; nevertheless, as these investigations were suggested by a formula in the 'Fundamenta Nova,' it will be right to give some account of it here.

From the well-known formula in the 'Fundamenta Nova,'

$$(1-q^2)(1-q^4)(1-q^6)\ldots(1-qz)(1-q^3z)(1-q^5z)\ldots$$
$$(1-qz^{-1})(1-q^3z^{-1})(1-q^5z^{-1})\ldots=$$
$$1-q(z+z^{-1})+q^4(z^2+z^{-2})-q^9(z^3+z^{-3})+\ldots,$$

we deduce, by putting q^n for q and $\pm q^{\pm n}$ for z, the following expressions:—

$$\Pi\{(1-q^{2mi+m-n})(1-q^{2mi+m+n})(1-q^{2mi+2m})\}=\Sigma(-1)^iq^{mi^2+ni} \quad \ldots \quad (I.)$$

$$\Pi\{(1+q^{2mi+m-n})(1+q^{2mi+m+n})(1-q^{2mi+2m})\}=\Sigma q^{mi^2+ni}. \quad . \quad (II.)$$

It is easy to see that these equations will lead to a multitude of others of the form

$$\Pi(1-q^{\alpha_1 i+\beta})(1-q^{\alpha_2 i+\beta})(1-q^{\alpha_3 i+\beta})\ldots = \Sigma\Sigma(-1)^{i+k} q^{ai^2+bk^2+ci+ek},$$

where i in the products has the values 0, 2, 3, &c., and in the summations i and k have the values 0, ± 1, ± 2, ± 3, ...

Jacobi has given a Table of these equations. I select three of them for demonstration, which will give an idea of the whole sufficient for our present purpose.

(1) $\Pi\{(1-q)^{6i+2}(1-q^{3i+3})^2(1-q^{6i+4})\} = \Sigma(-1)^{i+k} q^{3i^2+3k^2+i},$

(2) $\Pi\{(1-q^{3i+1})(1-q^{3i+2})(1-q^{6i+3})^3(1-q^{6i+6})^2\}$

$= \Sigma(-1)^{i+k} q^{\frac{1}{2}(3i^2+6k^2+i)},$

(3) $\Pi\{(1-q^{4i+2})^3(1-q^{4i+4})^2\} = \Sigma(-1)^{i+k} q^{3i^2+2k^2+i}.$

By the formula (I.),

$$\Sigma(-1)^{i+k} q^{3i^2+3k^2+i} =$$

$$\Pi\{(1-q)^{6i+3}(1-q^{6i+3})(1-q^{6i+6})\Pi(1-q^{6i+2})(1-q^{6i+4})(1-q^{6i+6})\},$$

consequently formula (I.) reduces itself to

$$\Pi(1-q^{3i+3})^2 = \Pi(1-q^{6i+3})^2(1-q^{6i+6})^2,$$

or

$$\Pi(1-q^{3i+3}) = \Pi(1-q^{6i+3})(1-q^{6i+6}),$$

which is at once seen to be true.

To prove the second formula, we observe that

$$\Sigma(-1)^{i+k} q^{\frac{1}{2}(3i+6k^2+i)}$$

by formula (I.) is equivalent to

$$\Pi(1-q^{3i+1})(1-q^{3i+2})(1-q^{3i+3})\Pi(1-q^{6i+3})(1-q^{6i+3})(1-q^{6i+6});$$

and the equation reduces itself to

$$\Pi(1-q^{6i+3})(1-q^{6i+6}) = \Pi(1-q^{3i+3}),$$

the same as before.

We also have

$$\Sigma(-1)^{i+k} q^{\frac{1}{2}(3i^2+6k^2+i)} = \Pi(1-q^{2+i})(1-q^{6i+3})(1-q^{3i+3}),$$

a formula not noticed by Jacobi.

To prove formula (3), we have

$$\Sigma(-1)^{i+k} q^{3i^2+2k^2+i}$$

$$= \Pi(1-q^{6i+2})(1-q^{6i+4})(1-q^{6i+6})\Pi(1-q^{4i+2})(1-q^{4i+2})(1-q^{4i+4});$$

and the equation reduces itself to

$$\Pi(1-q^{6i+2})(1-q^{6i+4})(1-q^{6i+6}) = \Pi(1-q^{4i+2})(1-q^{4i+4}),$$

each member of which is immediately seen to be equivalent to $\Pi(1-q^{2i+2})$.

In this manner the following expressions for the modulus are deduced which will be found demonstrated on pages 76 and 77.

From

$$\sqrt{k'}=\frac{(1-q)(1-q^3)(1-q^5)\ldots}{(1+q)(1+q^3)(1+q^5)\ldots} \quad \sqrt[4]{k}=\sqrt[8]{q}\frac{(1+q^2)(1+q^4)(1+q^6)\ldots}{(1+q)(1+q^3)(1+q^5)\ldots},$$

$$\sqrt[4]{k'}=\frac{\Sigma(-1)^i q^{\frac{1}{2}(3i^2+i)}}{\Sigma(-1)^{\frac{i(i+1)}{2}}q^{\frac{1}{2}(3i^2+i)}}=\frac{\Sigma(-1)^i q^{2i^2+i}}{\Sigma q^{2i^2+i}}$$

$$=\frac{\Sigma(-1)^i q^{i^2}}{\Sigma(-1)^i q^{2i^2}}=\frac{\Sigma(-1)^i q^{2i^2}}{\Sigma q^{i^2}},$$

$$\sqrt[4]{k}=\frac{\sqrt{2}\sqrt[8]{q}\Sigma(-1)^i q^{6i^2+2i}}{\Sigma(-1)^{\frac{i(i+1)}{2}}q^{\frac{1}{2}(3i^2+i)}}=\frac{\sqrt{2}\sqrt[8]{q}\Sigma q^{4i^2+2i}}{\Sigma q^{2i^2+i}}$$

$$=\frac{\sqrt{2}\sqrt[8]{q}\Sigma(-1)^i q^{2i^2+i}}{\Sigma(-1)^i q^{2i^2}}=\frac{\sqrt{2}\sqrt[8]{q}\Sigma q^{2i^2+2}}{\Sigma q^{i^2}}.$$

Section 7.—Two papers by Heine next come under our notice. The first of these, "Untersuchungen über die Reihe

$$1+\frac{(1-q^\alpha)(1-q^\beta)}{(1-q)(1-q^\gamma)}x+\frac{(1-q^\alpha)(1-q^{\alpha+1})(1-q^\beta)(1-q^{\beta+1})}{(1-q)(1-q^\alpha)(1-q^\gamma)(1-q^{\gamma+1})}x^2+\ldots,\text{"}$$

is in the thirty-fourth volume of Crelle's Journal.

This series is denoted by Heine by the symbols $\phi(\alpha, \beta, \gamma)$ or $\phi(\alpha, \beta, \gamma, q, x)$, as may be most convenient. I shall consider those parts of the paper which relate to elliptic functions. Heine commences by showing that the elliptic functions

$$\frac{2k'\mathrm{K}}{\pi}\frac{\cos\mathrm{am}\frac{2\mathrm{K}x}{\pi}}{\cos\mathrm{coam}\frac{2\mathrm{K}x}{\pi}}, \quad \frac{2\mathrm{K}}{\pi}\frac{\sin\mathrm{am}\frac{2\mathrm{K}x}{\pi}}{\sin\mathrm{coam}\frac{2\mathrm{K}x}{\pi}},$$

$$\frac{2k^2\mathrm{K}}{\pi}\sin\mathrm{am}\frac{2\mathrm{K}x}{\pi}\sin\mathrm{coam}\frac{2\mathrm{K}x}{\pi},$$

$$\frac{2\mathrm{K}}{\pi\sin\mathrm{coam}\frac{2\mathrm{K}x}{\pi}}, \quad \frac{2k\mathrm{K}}{\pi}\sin\mathrm{coam}\frac{2\mathrm{K}x}{\pi}$$

can all be expressed by means of this series.

Thus we find $\frac{2k\mathrm{K}}{\pi}\sin\mathrm{coam}\frac{2\mathrm{K}x}{\pi}$ equivalent to

$$\frac{2\sqrt{q}}{1-q}\{\epsilon^{ix}\phi(1, \tfrac{1}{2}, \tfrac{3}{2}, q^2, -q\epsilon^{2ix})+\epsilon^{-ix}\phi(1, \tfrac{1}{2}, \tfrac{3}{2}, q^2, q\epsilon^{-2ix})\},$$

as is immediately seen by expanding the functions.

Following the methods employed by Gauss for the hypergeometrical series, Heine deduces a large number of equations, easy of proof, of which I write down the following:—

$$\left.\begin{aligned}&\phi(\alpha, \beta, \gamma, q, x)-\phi(\alpha, \beta, \gamma, q, qx)\\&\qquad=\frac{(1-q^\alpha)(1-q^\beta)}{1-q^\gamma}x\phi(\alpha+1, \beta+1, \gamma+1, q, x)\end{aligned}\right\}\quad . \quad . \quad (1)$$

$$\left.\begin{aligned}&(1-q^\gamma)(1-q^{\alpha+\beta-\gamma}x)\phi(\alpha+1, \beta, \gamma)+q^{\alpha+\beta-\gamma}x(1-q^{\gamma-\beta})\phi(\alpha+1, \beta, \gamma+1)\\&\qquad-(1-q^\gamma)\phi(\alpha, \beta, \gamma)=0\end{aligned}\right\}\ (2)$$

$$\phi(\alpha,\beta,\gamma-1)-\phi(\alpha,\beta,\gamma)$$
$$=q^{\gamma-1}x\frac{(1-q^{\alpha})(1-q^{\beta})}{(1-q^{\gamma-1})(1-q^{\gamma})}\phi(\alpha+1,\beta+1,\gamma+1) \quad . \quad . \quad . \quad . \quad (3)$$

$$\phi(\alpha,\beta+1,\gamma+1)-\phi(\alpha,\beta,\gamma)$$
$$=q^{\beta}x\frac{1-q^{\alpha}}{1-q^{\gamma}}\cdot\frac{1-q^{\gamma-\beta}}{1-q^{\gamma+1}}\phi(\alpha+1,\beta+1,\gamma+2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$\phi(\alpha,\beta+1,\gamma)-\phi(\alpha,\beta,\gamma)=q^{\beta}x\frac{1-q^{\alpha}}{1-q^{\gamma}}\phi(\alpha+1,\beta+1,\gamma+1) \quad . \quad . \quad (5)$$

$$\phi(\alpha+1,\beta,\gamma)-\phi(\alpha,\beta,\gamma)=q^{\alpha}x\frac{1-q^{\beta}}{1-q^{\gamma}}\phi(\alpha+1,\beta+1,\gamma+1) \quad . \quad . \quad (6)$$

$$\phi(\alpha+1,\beta,\gamma+1)$$
$$=q^{\alpha}x\frac{(1-q^{\beta})(1-q^{\gamma-\alpha})}{(1-q^{\gamma})(1-q^{\gamma+1})}\phi(\alpha+1,\beta+1,\gamma+2) \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\phi(\alpha-1,\beta+1,\gamma)-\phi(\alpha,\beta,\gamma)$$
$$=-q^{\alpha-1}x\frac{1-q^{\beta-\alpha+1}}{1-q^{\gamma}}\phi(\alpha,\beta+1,\gamma+1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$\phi(\alpha+1,\beta-1,\gamma)-\phi(\alpha,\beta,\gamma)$$
$$=q^{\alpha}x\frac{1-q^{\beta-\alpha-1}}{1-q^{\gamma}}\phi(\alpha+1,\beta,\gamma+1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

These formulæ are applied by Heine to the expression of the fundamental series in continued fractions. Thus from (4) we immediately obtain

$$\frac{\phi(\alpha,\beta+1,\gamma+1)}{\phi(\alpha,\beta,\gamma)}=\frac{1}{1-q^{\beta}x\frac{(1-q^{\alpha})(1-q^{\gamma-\beta})}{(1-q^{\gamma})(1-q^{\gamma+1})}\cdot\frac{\phi(\alpha+1,\beta+1,\gamma+2)}{\phi(\alpha,\beta+1,\gamma+1)}}.$$

Since

$$\frac{\phi(\alpha+1,\beta+1,\gamma+2)}{\phi(\alpha,\beta+1,\gamma+1)}=\frac{\phi(\beta+1,\alpha+1,\gamma+2)}{\phi(\beta+1,\alpha,\gamma+1)},$$

by the very nature of the series represented by the functions, we can repeat this process and expand $\frac{\phi(\alpha,\beta+1)(\gamma+1)}{\phi(\alpha,\beta,\gamma)}$ in a continued fraction. The result is

$$\frac{\phi(\alpha,\beta+1,\gamma+1)}{\phi(\alpha,\beta,\gamma)}=\frac{1}{1-}\,\frac{a_1x}{1-}\,\frac{a_2x}{1-}\,\frac{a_3x}{1-}\,\frac{a_4x}{1-},$$

where

$$a_1=q^{\beta}\frac{(1-q^{\alpha})(1-q^{\gamma-\beta})}{(1-q^{\gamma})(1-q^{\gamma+1})},\quad a_2=q^{\alpha}\frac{(1-q^{\beta+1})(1-q^{\gamma-\alpha+1})}{(1-q^{\gamma+1})(1-q^{\gamma+2})},$$

$$a_3=q^{\beta+1}\frac{(1-q^{\alpha+1})(1-q^{\gamma-\beta+1})}{(1-q^{\gamma+2})(1-q^{\gamma+3})},\quad a_4=q^{\alpha+1}\frac{(1-q^{\beta+2})(1-q^{\gamma-\alpha+2})}{(1-q^{\gamma+3})(1-q^{\gamma+4})}.$$

When $\beta=0$, $\phi(\alpha,\beta,\gamma)$ becomes unity, and we obtain a continued fraction for $\phi(1,\alpha,\gamma+1)$, which is immediately applicable to elliptic functions.

From the nature of the series we have at once

$$\phi(\alpha+1,\beta+1,\beta+1)=\phi(\alpha+1,\beta,\beta).$$

Consequently putting $\beta=\gamma=1$ in (1) and (6), we immediately obtain the following equation:—

$$\phi(\alpha, 1, 1, q, x)=\frac{1-q^{\alpha}x}{1-x}\phi(\alpha, 1, 1, q, qx);$$

$$\therefore \quad \phi(\alpha, 1, 1, q, x)=\frac{(1-q^{\alpha}x)\ldots(1-q^{\alpha+n-1})}{(1-x)\ldots(1-q^{n-1}x)}\phi(\alpha, 1, 1, q, q^{n}x);$$

and since q is supposed less than unity, the series $\phi(\alpha, 1, 1, q, q^{n}x)$ always approaches unity as (n) indefinitely increases, and consequently

$$\phi(\alpha, 1, 1, q, x)=\frac{(1-q^{\alpha}x)(1-q^{\alpha+1}x)(1-q^{\alpha+2}x)\ldots\ldots}{(1-x)(1-qx)(1-q^{2}x)\ldots\ldots} \quad . \quad . \quad (10)$$

Again, putting $x=q^{\gamma-\alpha-\beta}$ in series (2), we have

$$\phi(\alpha, \beta, \gamma, q, q^{\gamma-\alpha-\beta})=\frac{1-q^{\gamma-\beta}}{1-q^{\gamma}}\phi(\alpha+1, \beta, \gamma+1, q, q^{\gamma-\alpha-\beta});$$

and repeating this process,

$$\phi(\alpha, \beta, \gamma, q, q^{\gamma-\alpha-\beta})=\frac{(1-q^{\gamma-\beta})\ldots\ldots(1-q^{\gamma-\beta+n-1})}{(1-q^{\gamma})\ldots\ldots(1-q^{\gamma+n-1})}$$
$$\phi(\alpha+n, \beta, \gamma+n, q, q^{\gamma-\alpha-\beta}).$$

Now we have generally

$$\phi(\alpha+n, \beta, \gamma+n, q, x)$$
$$=1+\frac{(1-q^{\alpha+n})(1-q^{\beta})}{(1-q)(1-q^{\gamma+n})}x+\frac{(1-q^{\alpha+n})(1-q^{\alpha+n-1})(1-q^{\beta})(1-q^{\beta+1})}{(1-q)(1-q^{2})(1-q^{\gamma+n})(1-q^{\gamma+n-1})}x^{2}+\ldots.$$

As (n) increases without limit, this series approaches

$$1+\frac{1-q^{\beta}}{1-q}x+\frac{(1-q^{\beta})(1-q^{\beta+1})}{(1-q)(1-q^{2})}x^{2}+\ldots\ldots=\phi(\beta, 1, 1, q, x).$$

Hence when (n) is infinite, we have by (10)

$$\phi(\alpha+n, \beta, \gamma+n, q, q^{\gamma-\alpha-\beta})=\frac{(1-q^{\gamma-\alpha})(1-q^{\gamma-\alpha+1})\ldots\ldots}{(1-q^{\gamma-\alpha-\beta})(1-q^{\gamma-\alpha-\beta+1})\ldots\ldots},$$

and therefore

$$\phi(\alpha, \beta, \gamma, q, q^{\gamma-\alpha-\beta})$$
$$=\frac{(1-q^{\gamma-\alpha})(1-q^{\gamma-\alpha+1})\ldots\ldots}{(1-q^{\gamma})(1-q^{\gamma+1})\ldots\ldots}\,\frac{(1-q^{\gamma-\beta})(1-q^{\gamma-\beta+1})\ldots\ldots}{(1-q^{\gamma-\alpha-\beta})(1-q^{\gamma-\alpha-\beta+1})\ldots} \quad . \quad . \quad (11)$$

From these formulæ it will readily be perceived that the leading properties of functions θ can be deduced. For the details I refer to Heine's second paper, "Abriss einer Theorie der elliptischen Functionen," which will be found in the thirty-ninth volume of Crelle's Journal, and which, after the remarks here made, will offer no difficulty.

There are some consequences of formula (11) just proved which I shall insert in this place.

If we put

$$\omega(q, a)=\frac{(1-q)(1-q^{2})(1-q^{3})\ldots\ldots}{(1-q^{a+1})(1-q^{a+2})(1-q^{a+3})\ldots\ldots}$$

we shall obtain from (11)

$$\phi(\alpha,\beta,\gamma,q,q^{\gamma-\alpha-\beta})=\frac{\omega(q,\gamma-1)\omega(q,\gamma-\alpha-\beta-1)}{\omega(q,\gamma-\alpha-1)\omega(q,\gamma-\beta-1)}.$$

From this Heine deduces easily

$$\phi\left(\tfrac{1}{2}+\frac{xi}{\log_\epsilon q},\ \tfrac{1}{2}-\frac{xi}{\log_\epsilon q},2,q^2,q^2\right)=\frac{\omega(q^2,1)\omega(q^2,0)}{\omega\left(q^2,\tfrac{1}{2}-\frac{xi}{\log_\epsilon q}\right)\omega\left(q^2,\tfrac{1}{2}+\frac{xi}{\log_\epsilon q}\right)},$$

whence we have

$$\theta(x)=\theta'_1(0)^{*}\cdot\frac{1-2q\cos 2x+q^2}{2\sqrt[4]{q}}\cdot\frac{1}{1-q^2}$$

$$\left\{1+\frac{(1-2q\cos 2x+q^2)}{(1-q^2)(1-q^4)}q^2+\frac{(1-2q\cos 2x+q^2)(1-2q^3\cos 2x+q^6)}{(1-q^2)(1-q^4)(1-q^4)(1-q^6)}q^4+\ldots\right\},$$

and a similar formula for $\theta_1 x$.

Heine also gives some formulæ for the multiplication of elliptic functions, of which I shall give one here.

From the equation

$$\omega(q^n,a)\omega\left(q^n,a-\frac{1}{n}\right)\omega\left(q^n,a-\frac{2}{n}\right)\ldots\omega\left(q^n,a-\frac{n-1}{n}\right)=c\omega(q,na),$$

where

$$c=\frac{\{(1-q^n)(1-q^{2n})(1-q^{3n})\ldots\}^n}{(1-q)(1-q^2)(1-q^3)\ldots},$$

we have, where (n) is odd,

$$\prod_{m=0}^{m=n-1}\Theta\left\{q^n,\frac{2K_n}{\pi}(b-mi\log q)\right\}=\frac{(-1)^{\frac{1}{2}(n-1)}}{q^{\frac{1}{4}(n-1)^2}}h\Theta\left(q,\frac{2Kb}{\pi}\right),$$

and when (n) is even,

$$\prod_{m=0}^{m=n-1}\Theta\left\{q^n,\frac{2K_n}{\pi}(b-mi\log_\epsilon q)\right\}=-\frac{i(-1)^{\frac{1}{2}n}\epsilon^{ix}}{\sqrt[4]{q}\,q^{\left(\frac{n}{2}-1\right)^2}}h\mathrm{H}\left(q,\frac{2Kb}{\pi}\right),$$

where $\Theta\left(q^n,\frac{2K_n x}{\pi}\right)$ bears the same relation to q^n that $\Theta\left(\frac{2Kx}{\pi}\right)$ does to q, and

$$h=\frac{\{(1-q^{2n})(1-q^{4n})\ldots\}}{(1-q^2)(1-q^4)\ldots}.$$

Section 8.—The comparative simplicity of the functions θ naturally suggested to mathematicians the utility of adopting these series as ground-forms in the theory of elliptic transcendents. These functions have therefore been in these last times the subject of many investigations. Among the memoirs relating to these series, three may be particularly mentioned as having remarkably contributed to the advancement of our knowledge of their properties. These three papers are Jacobi's memoir "Sur la Rotation d'un Corps," in the thirty-ninth volume of Crelle's Journal, a paper by Krusemarck, "Zur Theorie der elliptischen Functionen," in the forty-sixth volume, and a paper by Richelot, "Ueber eine Merkwurdige Formel in der Theorie der elliptischen

* For the value of $\theta_1'(0)$ see a little further on.

Transcendenten," in the fiftieth volume of the same Journal. These methods have been admirably harmonized and developed by Schellbach in his 'Lehre von den elliptischen Integralen und den Thetafunctionen,' Berlin, 1864. I proceed to lay a summary of the results thus obtained before the reader, accompanied by such remarks as may obviate difficulties. I commence by writing in full the notation to be employed.

$$\theta(x)=1-2q\ \cos 2x+2q^4\cos 4x-2q^9\cos 6x+\ldots,$$
$$\theta_1(x)=\quad 2q^{\frac{1}{4}}\sin\ x-2q^{\frac{9}{4}}\sin 3x+2q^{\frac{25}{4}}\sin 5x-\ldots,$$
$$\theta_2(x)=\quad 2q^{\frac{1}{4}}\cos\ x+2q^{\frac{9}{4}}\cos 3x+2q^{\frac{25}{4}}\cos 5x+\ldots,$$
$$\theta_3(x)=1+2q\ \cos 2x+2q^4\cos 4x+2q^9\cos 6x+\ldots.$$

If $q=\epsilon^{-\nu}$, we shall sometimes use the following abbreviations for the four series, $\theta(x,\nu)$, $\theta_1(x,\nu)$, $\theta_2(x,\nu)$, $\theta_3(x,\nu)$. Let also

$$f(x)=\frac{\theta_1 x}{\theta x},\quad gx=\frac{\theta_2 x}{\theta x},\quad hx=\frac{\theta_3 x}{\theta x}.$$

Then

$$\sin\text{am}\frac{2\text{K}x}{\pi}=\frac{1}{\sqrt{k}}f(x),\quad \cos\text{am}\frac{2\text{K}x}{\pi}=\frac{\sqrt{k'}}{\sqrt{k}}gx,$$

$$\Delta\ \text{am}\ \frac{2\text{K}x}{\pi}=\sqrt{k'}hx.$$

The periods of these functions are given by Schellbach (section 22, p. 34). By direct multiplication we find that

$$\theta_3x\theta_3y=\theta_3(x+y,2\nu)\theta_3(x-y,2\nu)+\theta_2(x+y,2\nu)\theta_2(x-y,2\nu),$$
$$\theta\ x\theta\ y=\theta_3(x+y,2\nu)\theta_3(x-y,2\nu)-\theta_2(x+y,2\nu)\theta_2(x-y,2\nu),$$
$$\theta_1x\theta_1y=\theta_3(x+y,2\nu)\theta_2(x-y,2\nu)-\theta_2(x+y,2\nu)\theta_3(x-y,2\nu),$$
$$\theta_2x\theta_2y=\theta_2(x+y,2\nu)\theta_3(x-y,2\nu)+\theta_3(x+y,2\nu)\theta_2(x-y,2\nu).$$

I need hardly point out the close analogy between these and the ordinary trigonometrical formulæ.

From these formulæ are easily deduced the following:—

$$\theta\ \{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta\ \{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_3x\theta_3y-\theta_2x\theta_2y \quad\ldots\quad (1)$$
$$\theta_1\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_1\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_3x\theta_2y-\theta_2x\theta_3y \quad\ldots\quad (2)$$
$$\theta_2\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_2\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_3x\theta_2y+\theta_2x\theta_3y \quad\ldots\quad (3)$$
$$\theta_3\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_3\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_3x\theta_3y+\theta_2x\theta_2y \quad\ldots\quad (4)$$
$$\theta\ \{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_3\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta\ x\theta\ y+\theta_1x\theta_1y \quad\ldots\quad (5)$$
$$\theta_1\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_2\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_1x\theta\ y+\theta\ x\theta_1y \quad\ldots\quad (6)$$
$$\theta_2\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta_1\{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta_1x\theta\ y-\theta\ x\theta_1y \quad\ldots\quad (7)$$
$$\theta_3\{\tfrac{1}{2}(x+y),\tfrac{1}{2}\nu\}\theta\ \{\tfrac{1}{2}(x-y),\tfrac{1}{2}\nu\}=\theta\ x\theta\ y-\theta_1x\theta_1y \quad\ldots\quad (8)$$
$$2\theta\ (x+y,2\nu)\theta\ (x-y,2\nu)\quad=\theta\ x\theta_3y+\theta_3x\theta y \quad\ldots\quad (9)$$
$$2\theta_1(x+y,2\nu)\theta_1(x-y,2\nu)\quad=\theta\ x\theta_3y-\theta_3x\theta y \quad\ldots\quad (10)$$
$$2\theta_2(x+y,2\nu)\theta_2(x-y,2\nu)\quad=\theta_3x\theta_3y-\theta\ x\theta y \quad\ldots\quad (11)$$
$$2\theta_3(x+y,2\nu)\theta_3(x-y,2\nu)\quad=\theta_3x\theta_3y+\theta\ x\theta y \quad\ldots\quad (12)$$

These are taken as fundamental formulæ by Schellbach, and the following four groups deduced from them:—

$$\left.\begin{aligned} \theta x\theta_3 x &= \theta(o,2\nu)\theta(2x,2\nu), \\ \theta_1 x\theta_2 x &= \theta(o,2\nu)\theta_1(2x,2\nu), \\ \theta x\theta_1 x &= \tfrac{1}{2}\theta_2(o,\tfrac{1}{2}\nu)\theta_1(x,\tfrac{1}{2}\nu), \\ \theta_2 x\theta_3 x &= \tfrac{1}{2}\theta_2(o,\tfrac{1}{2}\nu)\theta_2(x,\tfrac{1}{2}\nu). \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (\alpha)$$

$$\left.\begin{aligned} &\theta(o)\theta_2(o) = \theta_1(\tfrac{1}{4}\pi,\tfrac{1}{2}\nu)^2 = \theta_2(\tfrac{1}{4}\pi,\tfrac{1}{2}\nu)^2, \\ &\theta(o)\theta_3(o) = \theta(o,2\nu)^2 = \theta(\tfrac{1}{4}\pi,\tfrac{1}{2}\nu)^2, \\ &\theta_2(o)\theta_3(o) = \tfrac{1}{2}\theta_2(o,\tfrac{1}{2}\nu)^2. \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (\beta)$$

$$\left.\begin{aligned} &ho^2\, hx^2 - go^2\, gx^2 = 1, \\ &ho^2 fx^2 + \quad gx^2 = go^2, \\ &go^2 fx^2 + \quad hx^2 = ho^2. \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (\gamma)$$

From (5) and (8), using the first of equations (α), we have at once

$$\theta o^2 . \frac{\theta(x+y)\,\theta(x-y)}{\theta x^2\,\theta y^2} = 1 - fx^2\,fy^2;$$

and similarly

$$\left.\begin{aligned} &\theta o^2 . \frac{\theta_1(x+y)\,\theta_1(x-y)}{\theta x^2\,\theta y^2} = fx^2 - fy^2, \\ &\theta_2 o^2 . \frac{\theta_2(x+y)\,\theta_2(x-y)}{\theta x^2\,\theta y^2} = hx^2\,hy^2 - 1, \\ &\theta_3 o^2 . \frac{\theta_3(x+y)\,\theta_3(x-y)}{\theta x^2\,\theta y^2} = 1 + gx^2\,gy^2. \end{aligned}\right\} \quad \ldots\ldots \quad (\epsilon)$$

Several of these methods and formulæ appear to be due to Krusemarck.

Section 9.—The following formulæ are derived by multiplication from (1) . . . (12) of last section:—

$$2\theta x\ \theta_2 x\ \theta y\ \theta_2 y = \theta o\theta_2 o\{\theta(x+y)\,\theta_2(x-y) + \theta(x-y)\,\theta_2(x+y)\} \quad . \quad . \quad (1)$$

$$2\theta_1 x\ \theta_3 x\ \theta_1 y\theta_3 y = \theta o\theta_2 o\{\theta(x+y)\,\theta_2(x-y) - \theta(x-y)\,\theta_2(x+y)\} \quad . \quad . \quad (2)$$

$$2\theta_1 x\ \theta_3 x\ \theta y\ \theta_2 y = \theta o\theta_2 o\{\theta_1(x+y)\,\theta_3(x-y) + \theta_1(x-y)\theta_3(x+y)\} \quad . \quad . \quad (3)$$

$$2\theta x\ \theta_2 x\ \theta_1 y\theta_3 y = \theta o\theta_2 o\{\theta_1(x+y)\,\theta_3(x-y) - \theta_1(x-y)\theta_3(x+y)\} \quad . \quad . \quad (4)$$

$$2\theta x\ \theta_1 x\ \theta_2 y\theta_3 y = \theta_2 o\theta_3 o\{\theta_1(x+y)\theta(x-y) + \theta(x+y)\theta_1(x-y)\} \quad . \quad . \quad (5)$$

$$2\theta_2 x\theta_3 x\ \theta y\ \theta_1 y = \theta_2 o\theta_3 o\{\theta_1(x+y)\theta(x-y) - \theta(x+y)\theta_1(x-y)\} \quad . \quad . \quad (6)$$

$$2\theta_1 x\theta_2 x\ \theta y\ \theta_3 y = \theta o\ \theta_3 o\{\theta_1(x+y)\theta_2(x-y) + \theta_1(x-y)\theta_2(x+y)\} \quad . \quad . \quad (7)$$

$$2\theta x\ \theta_3 x\ \theta_1 y\theta_2 y = \theta o\ \theta_3 o\{\theta_1(x+y)\theta_2(x-y) - \theta_1(x-y)\theta_2(x+y)\} \quad . \quad . \quad (8)$$

$$2\theta x\ \theta_3 x\ \theta y\ \theta_3 y = \theta o\ \theta_3 o\{\theta_3(x+y)\theta(x-y) + \theta_3(x-y)\theta(x+y)\} \quad . \quad . \quad (9)$$

$$2\theta_1 x\theta_2 x\ \theta_1 y\theta_2 y = \theta o\ \theta_3 o\{\theta_3(x-y)\theta(x+y) - \theta_3(x+y)\theta(x-y)\} \quad . \quad . \quad (10)$$

Let

$$2\mathrm{T} = 1 - fx^2\,fy^2 = \theta o^2 \frac{\theta(x+y)\,\theta(x-y)}{\theta x^2\,\theta y^2},$$

then

$$\mathrm{T}\{f(x+y)+f(x-y)\}=\frac{\theta o^2}{2}\cdot\frac{\theta_1(x+y)\,\theta(x-y)+\theta_1(x-y)\,\theta(x+y)}{\theta x^2\,\theta y^2}$$

$$=\frac{\theta o^2}{\theta_1 o\,\theta_3 o}\cdot\frac{\theta_1 x}{\theta x}\cdot\frac{\theta_2 y}{\theta y}\cdot\frac{\theta_3 y}{\theta y}$$

by (5), or

$$go\,ho\mathrm{T}\{f(x+y)+f(x-y)\}=fx\,gy\,hy \quad \text{(11)}$$

In the same way may be derived the following:—

$$go\,ho\,\mathrm{T}\{f(x+y)-f(x-y)\}=fy\,gx\,hx \quad \text{(12)}$$

$$go\,\mathrm{T}\{g(x-y)+g(x+y)\}=gx\,gy \quad \text{(13)}$$

$$go\,\mathrm{T}\{g(x-y)-g(x+y)\}=fx\,hx\,fy\,hy \quad \text{(14)}$$

$$ho\,\mathrm{T}\{h(x-y)+h(x+y)\}=hx\,hy \quad \text{(15)}$$

$$ho\,\mathrm{T}\{h(x-y)-h(x+y)\}=fx\,gx\,fy\,gy \quad \text{(16)}$$

$$go\,\mathrm{T}\{f(x+y)h(x-y)+f(x-y)h(x+y)\}=fx\,hx\,gy \quad \text{(17)}$$

$$go\,\mathrm{T}\{f(x+y)h(x-y)-f(x-y)h(x+y)\}=fy\,hy\,gx \quad \text{(18)}$$

$$ho\,\mathrm{T}\{f(x+y)g(x-y)+f(x-y)g(x+y)\}=fx\,gx\,hy \quad \text{(19)}$$

$$ho\,\mathrm{T}\{f(x+y)g(x-y)-f(x-y)g(x+y)\}=fy\,gy\,hx \quad \text{(20)}$$

$$go\,ho\,\mathrm{T}\{g(x+y)h(x-y)+g(x-y)h(x+y)\}=gx\,hx\,gy\,hy \quad \text{(21)}$$

$$go\,ho\mathrm{T}\{g(x+y)h(x-y)-g(x-y)h(x+y)\}=fx\,gx\,fy\,gy \quad \text{(22)}$$

From these formulæ the ordinary expressions for the addition and subtraction of elliptic functions may of course be easily deduced.

We also find

$$\left.\begin{array}{l}\theta_1'o=\theta o\,\theta_2 o\,\theta_3 o,\quad f'o=\theta_2 o\,\theta_9 o,\\ f'x=\theta o^2\,gx\,hx,\;\; g'x=-\theta_3 o^2\,fx\,hx,\;\; h'x=-\theta_2 o^2 fx\,gx.\end{array}\right\}\quad (\zeta)$$

It is obvious that from the above the following may be immediately formed by addition, &c.:—

$$\left.\begin{array}{l}go\,hof(x+y)=\dfrac{fx\,gy\,hy+fy\,gx\,hx}{1-fx^2fy^2}\\ =go^2\dfrac{fx\,gx\,hy+fy\,gy\,hx}{gx\,gy+fx\,fy\,hx\,hy}=go^2\,ho^2\dfrac{fx^2-fy^2}{fx\,gy\,hy-fy\,gx\,hx}\\ =\dfrac{ho}{go}\cdot\dfrac{fx\,gy\,hx+fy\,gx\,hy}{hx\,hy+fx\,fy\,gx\,gy}.\end{array}\right\}\quad (23)$$

$$\left.\begin{array}{l}go\,g(x+y)=\dfrac{gx\,gy-fx\,fy\,hx\,hy}{1-fx^2fy^2}=\dfrac{hx^2\,hy^2-1}{gx\,gy+fx\,fy\,hx\,hy}\\ =go^2\dfrac{fx\,gx\,hy-fy\,gy\,hx}{fx\,gy\,hy-fy\,gx\,hx}=\dfrac{gx\,gy\,hx\,hy-fx\,fy}{hx\,hy+fx\,fy\,gx\,gy}.\end{array}\right\}\quad (24)$$

$$\left.\begin{array}{l}ho\,h(x+y)=\dfrac{hx\,hy-fx\,fy\,gx\,gy}{1-fx^2fy^2}=\dfrac{fx\,fy+gx\,gy\,hx\,hy}{gx\,gy+fx\,fy\,hx\,hy}\\ =ho^2\dfrac{fx\,gy\,hx-fy\,gx\,hy}{fx\,gy\,hy-fy\,gx\,hx}=\dfrac{1+gx^2\,gy^2}{hx\,hy+fx\,fy\,gx\,gy}.\end{array}\right\}\quad (25)$$

From these formulæ we may deduce as follows:—

It follows from (23) that

$$\frac{ho}{go}f(x+y)=\frac{fx\,gx\,hy+fy\,gy\,hx}{gx\,gy+fx\,fy\,hx\,hy}.$$

Hence

$$\frac{go-ho\,f(x+y)}{go+ho\,f(x+y)}=\frac{(gy-fx\,hy)(gx-hx\,fy)}{(gy+fx\,hy)(gx+hx\,fy)}.$$

But from the identical equation

$$go^2-ho^2 fx^2+(go^2 fx^2-ho^2)fy^2$$
$$=go^2-ho^2 fy^2+fx^2(go^2 fy^2-ho^2)$$

we obtain from Section 8 (γ)

$$gx^2-hx^2 fy^2=gy^2-fx^2 hy^2,$$

or

$$\frac{gx-hx\,fy}{gy+fx\,hy}=\frac{gy-fx\,hy}{gx+hx\,fy},$$

and hence substituting

$$\sqrt{\left\{\frac{go-ho\,f(x+y)}{go+ho\,f(x+y)}\right\}}=\frac{gx-hx\,fy}{gy+fx\,hy}=\frac{gy-fx\,hy}{gx+hx\,fy};$$

and similarly

$$\sqrt{\left\{\frac{go-g(x+y)}{go+g(x+y)}\right\}}=\frac{fx\,hy+hx\,fy}{gy+gx}=\frac{gy-gx}{fx\,hy-hx\,fy},$$

$$\sqrt{\left\{\frac{ho-h(x+y)}{ho+h(x+y)}\right\}}=\frac{fx\,gy+fy.gx}{hy+hx}=\frac{hy-hx}{fx\,gy-gx\,fy}.$$

Section 10.—We now come to an entirely distinct series of theorems, which constitute the most important and interesting addition which has been made to this division of our subject since the publication of the 'Fundamenta Nova.'

It is known that the decomposition of algebraical fractions leads to the following proposition :—

$$\frac{\sin(x-a)\sin(x-b)}{\sin(x-\alpha)\sin(x-\beta)\sin(x-\gamma)}=\frac{\sin(\alpha-a)\sin(\alpha-b)}{\sin(\alpha-\beta)\sin(\alpha-\gamma)}\,\frac{1}{\sin(x-\alpha)}$$
$$+\frac{\sin(\beta-a)\sin(\beta-b)}{\sin(\beta-\alpha)\sin(\beta-\gamma)}\cdot\frac{1}{\sin(x-\beta)}+\frac{\sin(\gamma-a)\sin(\gamma-b)}{\sin(\gamma-\alpha)\sin(\gamma-\beta)}\,\frac{1}{\sin(x-\gamma)}.$$

Similar reasoning, when applied to the expression

$$F(x)=\frac{\theta_1(\lambda-x)\,\theta_1(\mu-x)\,\theta_1(\rho-x)}{\theta_1(\alpha-x)\,\theta_1(\beta-x)\,\theta_1(\gamma-x)},$$

leads to the theorem

$$\left.\begin{aligned}\theta'_1(o)\epsilon^{ix}F(x)=&\frac{\theta_1(\lambda-\alpha)\,\theta_1(\mu-\alpha)\,\theta_1(\rho-\alpha)}{\theta_1(\beta-\alpha)\,\theta_1(\gamma-\alpha)}\,\Sigma_{-\infty}^{\infty}\frac{q^s(\epsilon^{(2s\delta+\alpha)i}}{\sin(\alpha-x+s\pi i)}\\&+\frac{\theta_1(\lambda-\beta)\,\theta_1(\mu-\beta)\,\theta_1(\rho-\beta)}{\theta_1(\alpha-\beta)\theta_1(\gamma-\beta)}\,\Sigma_{-\infty}^{\infty}\frac{q^s\epsilon^{(2s\delta+\beta)i}}{\sin(\beta-x+s\pi i)}\\&+\frac{\theta_1(\lambda-\gamma)\,\theta_1(\mu-\gamma)\,\theta_1(\rho-\gamma)}{\theta_1(\alpha-\gamma)\,\theta_1(\beta-\gamma)}\,\Sigma_{-\infty}^{\infty}\frac{q^s\epsilon^{(2s\delta+\gamma)i}}{\sin(\gamma-x+s\pi i)}.\end{aligned}\right\}\quad\text{(A)}$$

where

$$\delta=\lambda+\mu+\rho-\alpha-\beta-\gamma.$$

The reader will find this important theorem, which appears to be due to Richelot, fully demonstrated in Schellbach. If we put $\mu=\beta$ and $\rho=\gamma$ in this equation and at the same time put y for $\lambda-\alpha$, and x for $a-x$, we have

$$\theta_1'o\,.\,\frac{\theta_1(x+y)}{\theta_1 x\,\theta_1 y}\Sigma_{-\infty}^{\infty}\frac{q^s\epsilon^{(x+2sy)i}}{\sin(x+s\nu i)}; \quad \ldots \ldots \quad (1)$$

putting in this $x-\frac{1}{2}\nu i$ for x and $y-\frac{1}{2}\nu i$ for y, we have

$$\theta_1'o\,.\,\frac{\theta_1(x+y)}{\theta x\,\theta y}=\Sigma_{-\infty}^{\infty}\frac{\epsilon^{(2s-1)yi}}{\sin(x+(s-\frac{1}{2})\nu i)} \quad \ldots \quad (2)$$

and similarly

$$\theta_1'o\,.\,\frac{\theta(x+y)}{\theta_1 x\,\theta y}=\ {}_{-\infty}^{\infty}\frac{\epsilon^{2syi}}{\sin(x+s\nu i)} \quad \ldots \ldots \quad (3)$$

$$\theta_1'o\,.\,\frac{\theta_3(x+y)}{\theta_2 x\,\theta y}=\Sigma_{-\infty}^{\infty}\frac{\epsilon^{2syi}}{\cos(x+s\nu i)} \quad \ldots \ldots \quad (4)$$

$$\theta_1'o\,.\,\frac{\theta_2(x+y)}{\theta_3 x\,\theta y}=\Sigma_{-\infty}^{\infty}\frac{\epsilon^{(2s-1)yi}}{\cos(x+(s-\frac{1}{2})\nu i)} \quad \ldots \quad (5)$$

$$\theta_1'o\,.\,\frac{\theta_3(x+y)}{\theta_1 x\,\theta_3 y}=\Sigma_{-\infty}^{\infty}\frac{(-1)^s\,.\,\epsilon^{2syi}}{\sin(x+s\nu i)} \quad \ldots \ldots \quad (6)$$

$$\theta_1'o\,.\,\frac{\theta(x+y)}{\theta_2 x\,\theta_3 y}=\Sigma_{-\infty}^{\infty}\frac{(-1)^s\,.\,\epsilon^{2syi}}{\cos(x+s\nu i)} \quad \ldots \ldots \quad (7)$$

$$\theta_1'o\,.\,\frac{\theta_1(x+y)}{\theta_3 x\,\theta_3 y}=i\Sigma_{-\infty}^{\infty}\frac{(-1)^s\,.\,\epsilon^{(2s-1)y_i}}{\cos(x+(s-\frac{1}{2})\nu i)} \quad \ldots \quad (8)$$

$$\theta_1'o\,.\,\frac{\theta_2(x+y)}{\theta_1 x\,\theta_2 y}=\Sigma_{-\infty}^{\infty}\frac{(-1)^s q^s\,\epsilon^{(x+2sy)i}}{\sin(x+s\nu i)} \quad \ldots \ldots \quad (9)$$

$$\theta_1'o\,.\,\frac{\theta_1(x+y)}{\theta_2 x\,\theta_2 y}=-i\Sigma_{-\infty}^{\infty}\frac{(-1)^s q^s\,.\,\epsilon^{(x+2sy)i}}{\cos(x+s\nu i)} \quad \ldots \quad (10)$$

From these important theorems the series given by Jacobi in his memoir "Sur la Rotation d'un Corps" are easily deduced. If we put $y=0$ in series (2) and reduce, we obtain

$$\theta_2 o\,\theta_3 o f x=4\sin x\Sigma_0^{\infty}\frac{q^{s+\frac{1}{2}}(1+q^{2s+1})}{1-2q^{2s+1}\cos 2x+q^{4s+2}},$$

and by similar means pointed out by Schellbach;

$$\theta o\,\theta_2 o\,g x=4\cos x\Sigma_0^{\infty}\frac{(-1)^s q^{s+\frac{1}{2}}(1-q^{2s+1})}{1-2q^{2s+1}\cos 2x+q^{4s+2}}.$$

$$\theta o\,\theta_3 o\,h x=\theta_3 o^2-8\sin^2 x\Sigma_0^{\infty}\frac{(-1)^s q^{2s+1}(1+q^{2s+1})}{(1-q^{2s+1})(1-2q^{2s+1}\cos 2x+q^{4s+2})}.$$

$$\theta o\,\theta_3 o\frac{gx}{fx}=\text{cotan}\,x+4\sin 2x\Sigma_0^{\infty}\frac{(-1)^s q^{2s}}{1-2q^{2s}\cos 2x+q^{4s}}.$$

$$\theta o\,\theta_2 o\frac{hx}{fx}=\frac{1}{\sin x}+4\sin x\Sigma_1^{\infty}\frac{(-1)^s q^s(1+q^{2s})}{1-2q^{2s}\cos 2x+q^{4s}}.$$

$$\theta_2 o\, \theta_3 o \frac{1}{fx} = \frac{1}{\sin x} + 4 \sin x \Sigma_1^\infty \frac{q^s(1+q^{2s})}{1-2q^{2s}\cos 2x + q^{4s}}.$$

$$\theta o\, \theta_3 o \frac{fx}{gx} = \tan x + 4 \sin 2x \Sigma_1^\infty \frac{(-1)^s q^{2s}}{1+2q^{2s}\cos 2x + q^{4s}}.$$

$$\theta_2 o\, \theta_3 o \frac{hx}{gx} = \frac{1}{\cos x} + 4 \cos x \Sigma_1^\infty \frac{q^s(1+q^{2s})}{1+2q^{2s}\cos 2x + q^{4s}}.$$

$$\theta o\, \theta_2 o \frac{1}{gx} = \frac{1}{\cos x} + 4 \cos \Sigma_1^\infty \frac{(-1)^s q^s(1+q^{2s})}{1+2q^{2s}\cos 2x + q^{4s}}.$$

$$\theta o\, \theta_2 o \frac{fx}{hx} = 4 \cos x \Sigma_0^\infty \frac{(-1)^s q^{s-\frac{1}{2}}(1+q^{2s-1})}{1+2q^{2s-1}\cos 2x + q^{4s-2}}.$$

$$\theta_2 o\, \theta_3 o \frac{gx}{hx} = 4 \cos x \Sigma_0^\infty \frac{q^{s-\frac{1}{2}}(1+q^{2s-1})}{1+2q^{2s-1}\cos 2x + q^{4s-2}}.$$

The reader will perceive that these series essentially differ from those in the 'Fundamenta Nova.' The series given in the 'Fundamenta' may be easily deduced from formulæ (1)....(10). As, however, my object is to exhibit the progress which the theory of elliptic functions has recently made, I carefully abstain from writing down any series which are given in Jacobi's great work.

Section 11.—We now return to theorem A of last section. Transforming the series in the second member of this equation by means of expression (1) in last section: since

$$\Sigma_{-\infty}^{\infty} \frac{q^s \epsilon^{2syi}}{\sin(x+s\nu i)} = \theta_1'(o)\epsilon^{-xi} \frac{\theta_1(x+y)}{\theta_1 x\, \theta_1 y},$$

whence

$$\Sigma_{-\infty}^{\infty} \frac{q^s \epsilon^{2s\delta i}}{\sin(\alpha - x + s\nu i)} = \theta_1'(o)\epsilon^{(x-\alpha)i} \frac{\theta_1(\alpha - x + \delta)}{\theta_1(\alpha - x)\theta_1\delta},$$

and similarly for

$$\Sigma_{-\infty}^{\infty} \frac{q^s \epsilon^{2s\delta i}}{\sin(\beta - x + s\nu i)} \text{ and } \Sigma_{-\infty}^{\infty} \frac{q^s \epsilon^{2s\delta i}}{\sin(\gamma - x + s\nu i)},$$

we obtain

$$\theta_1\delta F(x) = \frac{\theta_1(\lambda-\alpha)\,\theta_1(\mu-\alpha)\,\theta_1(\rho-\alpha)}{\theta_1(\beta-\alpha)\,\theta_1(\gamma-\alpha)} \cdot \frac{\theta_1(\alpha-x+\delta)}{\theta_1(\alpha-x)}$$
$$+ \frac{\theta_1(\lambda-\beta)\,\theta_1(\mu-\beta)\,\theta_1(\rho-\beta)}{\theta_1(\alpha-\beta)\,\theta_1(\gamma-\beta)} \cdot \frac{\theta_1(\beta-x+\delta)}{\theta_1(\beta-x)}$$
$$+ \frac{\theta_1(\lambda-\gamma)\,\theta_1(\mu-\gamma)\,\theta_1(\rho-\gamma)}{\theta_1(\alpha-\gamma)\,\theta_1(\beta-\gamma)} \cdot \frac{\theta_1(\gamma-x+\delta)}{\theta_1(\gamma-x)}.$$

For $x=0$ we have

$$\left.\begin{aligned} \frac{\theta_1\lambda\,\theta_1\mu\,\theta_1\rho}{\theta_1\alpha\,\theta_1\beta\,\theta_1\gamma} &= \frac{\theta_1(\alpha+\delta)}{\theta_1\delta} \cdot \frac{\theta_1(\lambda-\alpha)\,\theta_1(\mu-\alpha)\,\theta_1(\rho-\alpha)}{\theta_1\alpha\,\theta_1(\beta-\alpha)\,\theta_1\gamma-\alpha} \\ &+ \frac{\theta_1(\beta+\delta)}{\theta_1\delta} \cdot \frac{\theta_1(\lambda-\beta)\,\theta_1(\mu-\beta)\,\theta_1(\rho-\beta)}{\theta_1\beta\,\theta_1(\alpha-\beta)\,\theta_1(\gamma-\beta)} \\ &+ \frac{\theta_1(\gamma+\delta)}{\theta_1\delta} \cdot \frac{\theta_1(\lambda-\gamma)\,\theta_1(\mu-\gamma)\,\theta_1(\rho-\gamma)}{\theta_1\gamma\,\theta_1(\alpha-\gamma)\,\theta_1(\beta-\gamma)}, \end{aligned}\right\} \quad . \quad . \quad (1)$$

where, replacing α, β, γ by $\alpha+\frac{1}{2}\nu i, \beta+\frac{1}{2}\nu i, \gamma+\frac{1}{2}\nu i$, we have

$$\left.\begin{aligned}\frac{\theta_1\lambda\,\theta_1\mu\,\theta_1\rho}{\theta\alpha\,\theta\beta\,\theta\gamma} &= \frac{\theta_1\alpha+\delta}{\theta\delta}\cdot\frac{\theta(\lambda-\alpha)\,\theta(\mu-\alpha)\,\theta(\rho-\alpha)}{\theta\alpha\theta_1(\beta-\alpha)\,\theta_1(\gamma-\alpha)}\\ &+\frac{\theta_1(\beta+\delta)}{\theta\delta}\cdot\frac{\theta(\lambda-\beta)\,\theta(\mu-\beta)\,\theta(\rho-\beta)}{\theta\beta\,\theta_1(\alpha-\beta)\,\theta_1(\gamma-\beta)}\\ &+\frac{\theta_1(\gamma+\delta)}{\theta\delta}\cdot\frac{\theta(\lambda-\gamma)\,\theta(\mu-\gamma)\,\theta(\rho-\gamma)}{\theta\gamma\,\theta_1(\alpha-\gamma)\,\theta_1(\beta-\gamma)}.\end{aligned}\right\} \quad . \quad . \quad . \quad (2)$$

Putting $\rho=\gamma$ in (1), we have

$$\frac{\theta_1\lambda\theta\mu}{\theta_1\alpha\theta_1\beta}=\frac{\theta_1(\alpha+\delta)}{\theta_1\delta}\;\frac{\theta_1(\lambda-\alpha)\,\theta_1(\mu-\alpha)}{\theta_1\alpha\,\theta_1(\beta-\alpha)}+\frac{\theta_1(\beta+\delta)}{\theta_1\delta}\cdot\frac{\theta_1(\lambda-\beta)\,\theta_1(\mu-\beta)}{\theta_1\beta\theta_1(\alpha-\beta)};$$

and (2) replacing λ by $\alpha+\frac{1}{2}\nu i$, ρ by λ, and γ by α, we have

$$\frac{\theta_1\lambda\,\theta_1\mu}{\theta\alpha\theta\beta}=\frac{\theta(\alpha+\delta)}{\theta_1\delta}\cdot\frac{\theta(\lambda-\alpha)\,\theta(\mu-\alpha)}{\theta\alpha\,\theta_1\beta-\alpha}+\frac{\theta(\beta+\delta)}{\theta_1\delta}\cdot\frac{\theta(\lambda-\beta)\,\theta(\rho-\beta)}{\theta\beta\,\theta_1(a-\beta)},$$

where in each formula $\delta=\lambda+\mu-\alpha-\beta$.

Putting

$$\lambda-\alpha=a,\ \beta=b,\ \mu-\alpha=c,\ \lambda+\mu-\beta=d,$$

and then

$$2s=a+b+c+d,\ 2\sigma=a+b+c-d,$$

these formulæ become

$$\theta_1 a\,\theta_1 b\,\theta_1 c\,\theta_1 d=\theta_1\sigma\,\theta_1(s-a)\,\theta_1(s-b)\,\theta_1(s-c)-\theta_1 s\,\theta_1(\sigma-a)\,\theta_1(\sigma-b)\,\theta_1(\sigma-c),$$

$$\theta a\,\theta b\,\theta c\,\theta d\quad=\theta_1\sigma\,\theta_1(s-a)\,\theta_1(s-b)\,\theta_1(s-c)+\theta s\,\theta(\sigma-a)\,\theta(\sigma-b)\,\theta(\sigma-c).$$

From these it has been fully shown by Schellbach that the following formulæ may be derived, which were given by Jacobi under another shape in the thirty-ninth volume of Crelle:—

$$ho\,hx=hy\,h(x+y)+go\,gx\,fy\,f(x+y),$$
$$ho\,hy=hx\,h(x+y)+go\,fx\,gy\,f(x+y),$$
$$ho\,gx\,fy=go\,hx\,f(x+y)-fx\,gy\,h(x+y),$$
$$ho\,gy\,fx=go\,hy\,f(x+y)-gx\,fy\,h(x+y),$$
$$ho\,gx\,f(x+y)=fx\,hy\,g(x+y)+go\,hx\,fy,$$
$$ho\,gy\,f(x+y)=hx\,fy\,g(x+y)+go\,fx\,hy,$$
$$ho\,h(x+y)=hx\,hy-go\,fx\,fy\,g(x+y),$$
$$ho\,fx\,g(x+y)=gx\,hy\,f(x+y)-go\,fy\,h(x+y),$$
$$ho\,fy\,g(x+y)=hx\,gy\,f(x+y)-go\,fx\,h(x+y),$$
$$ho\,fx\,hy\,f(x+y)=go\,gy-gx\,g(x+y),$$
$$ho\,hx\,fy\,f(x+y)=go\,gx-gy\,g(x+y),$$
$$ho\,gx\,hy\,g(x+y)=go\,gy\,hx\,h(x+y)-fx\,f(x+y),$$
$$ho\,hx\,gy\,g(x+y)=go\,gx\,hy\,h(x+y)-fy\,f(x+y),$$
$$ho\,fx\,fy\,h(x+y)=gx\,gy-go\,g(x+y),$$
$$ho\,gx\,gy\,h(x+y)=fx\,fy+go\,hx\,hy\,g(x+y),$$
$$ho\,hx\,hy\,h(x+y)=1+go\,gx\,gy\,g(x+y).$$

Section 12.—We now proceed to give certain formulæ relative to the differential coefficients of the logarithms of functions θ, essentially the same functions, be it remembered, as those which Jacobi writes with the letter Z.

Schellbach's four fundamental equations are as follows:—

$$l''\theta_1 x - l''\theta_1 y = \theta_2 o^2\, \theta_3 o^2 \left(\frac{1}{fy^2} - \frac{1}{fx^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$l''\theta\, x - l''\theta\, y = \theta_2 o^2\, \theta_3 o^2 (fy^2 - fx^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$l''\theta_2 x - l''\theta_2 y = \theta o^2\, \theta_2\, o^2 \left(\frac{1}{gy^2} - \frac{1}{gx^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$l''\theta_3 x - l''\theta_3 y = \theta o^2\, \theta_3 o^2 \left(\frac{1}{hx^2} - \frac{1}{hy^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Of these, Schellbach has fully proved the first. The second is immediately derived from the first by putting $x - \frac{1}{2}\nu i$ for x, and $y - \frac{1}{2}\nu i$ for y. The third may be found by putting in the second $x + \frac{\pi}{2} - \frac{1}{2}\nu i$ for x, and $y + \frac{\pi}{2} - \frac{1}{2}\nu i$ for y. We thus obtain

$$l''\theta_2 x - l''\theta\, y = \theta_2 o^2 \theta_3 o^2 \left\{ f^2\left(y + \frac{\pi}{2} - \frac{1}{2}\nu i\right) - f^2\left(x + \frac{\pi}{2} - \frac{1}{2}\nu i\right) \right\}$$

$$= \theta_2 o^2\, \theta_3 o^2 \left\{ \frac{hy^2}{gy^2} - \frac{hx^2}{gx^2} \right\} = \theta_2 o^2\, \theta_3 o^2 \left\{ \frac{1 + go^2\, gy^2}{ho^2\, gy^2} - \frac{1 + go^2\, gx^2}{ho^2\, gx^2} \right\}$$

$$= \theta o^2\, \theta_2 o^2 \left\{ \frac{1}{gy^2} - \frac{1}{gx^2} \right\}.$$

Formula (4) may of course be demonstrated in the same way.

Putting $y - \frac{1}{2}\nu i$ for y in the second of these formulæ, we have

$$l''\theta x - l''\theta_1 y = \theta_2 o^2 \theta_3 o^2 \left(\frac{1}{fy^2} - fx\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

also we find

$$l''\theta x - l''\theta_2 y = \theta o^2\, \theta_2 o^2 \left(\frac{1}{gy^2} + gx^2\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$l''\theta x - l''\theta_3 y = \theta o^2\, \theta_3 o^2 \left(hx^2 - \frac{1}{hy^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Let $x = y$ in these formulæ, and we have

$$l''f(x) = \theta_2 o^2\, \theta_3 o^2 \left(fx^2 - \frac{1}{fx^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$l''gx = -\theta o^2\, \theta_2 o^2 \left(gx^2 + \frac{1}{gx^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$l''hx = -\theta o^2\, \theta_3 o^2 \left(hx^2 - \frac{1}{hx^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

From these Schellbach deduces the following series of formulæ by easy methods:—

$$\left.\begin{aligned} \theta_2 o^2\,\theta_3 o^2 fx^2 &= l''\theta o - l''\theta x, \\ \theta\, o^2\,\theta_2 o^2 gx^2 &= l''\theta x - l''\theta_3 o, \\ \theta\, o^2\,\theta_3 o^2\, hx^2 &= l''ox - l''\theta_2 o, \end{aligned}\right\}$$

$$\left.\begin{aligned} \theta_2 o^2\,\theta_3 o^2 \frac{1}{fx^2} &= l''\theta\, o - l''\theta_1 x, \\ \theta\, o^2\,\theta_2 o^2 \frac{1}{gx^2} &= l''\theta_3 o - l''\theta_2 x, \\ \theta o^2\,\theta_3 o^2 \frac{1}{hx^2} &= l''\theta_3 x - l''\theta_2 o, \end{aligned}\right\}$$

$$\left.\begin{aligned} \theta_2 o^2\,\theta o_3{}^2 \frac{gx^2}{hx^2} &= l''\theta o - l''\theta_3 x, \quad & \theta_2 o^2\,\theta_3 o^2 \frac{hx^2}{gx^2} &= l''\theta\, o - l''\theta_2 x, \\ \theta o^2\,\theta_2 o^2 \frac{fx^2}{hx^2} &= l''\theta_3 x - l''\theta_3 o, \quad & \theta\, o^2\,\theta_2 o^2 \frac{hx^2}{fx^2} &= l''\theta_3 o - l''\theta_1 x, \\ \theta o^2\,\theta_3 o^2 \frac{gx^2}{fx^2} &= l''\theta_2 o - l''\theta_1 x, \quad & \theta o^2 \theta_3 o^2 \frac{fx^2}{gx^2} &= l''\theta_2 o - l''\theta_2 x. \end{aligned}\right\}$$

We now come to a group of an entirely different kind,

$$\begin{aligned} l''(\theta x\,\theta_1 x) + (l'fx)^2 &= l''(\theta_2 o\,\theta_3 o), \\ l''(\theta x\,\theta_2 x) + (l'gx)^2 &= l''(\theta o\,\theta_2 o), \\ l''(\theta x\,\theta_3 x) + (l'hx) &= l''(\theta o\,\theta_3 o). \end{aligned}$$

These formulæ were discovered by Meyer, who gave them, in the thirty-seventh volume of Crelle's Journal, under the following form:—

$$\frac{\Theta' x}{\Theta x} + \frac{\Theta''\left(x+\frac{\pi}{2}\right)}{\Theta\left(x+\frac{\pi}{2}\right)} - 2\frac{\Theta' x\,\Theta'\left(x+\frac{\pi}{2}\right)}{\Theta x\,\Theta\left(x+\frac{\pi}{2}\right)} = \frac{\Theta''\frac{\pi}{2}}{\Theta\frac{\pi}{2}} + \frac{\Theta''(0)}{\Theta(0)},$$

$$\frac{\Theta'' x}{\Theta x} + \frac{\mathrm{H}'' x}{\mathrm{H} x} - 2\frac{\Theta' x\,\mathrm{H}' x}{\Theta x\,\mathrm{H} x} = \frac{\mathrm{H}''\frac{\pi}{2}}{\mathrm{H}\frac{\pi}{2}} + \frac{\Theta''\frac{\pi}{2}}{\Theta\frac{\pi}{2}},$$

$$\frac{\Theta'' x}{\Theta x} + \frac{\mathrm{H}''\left(x+\frac{\pi}{2}\right)}{\mathrm{H}\left(x+\frac{\pi}{2}\right)} - 2\frac{\Theta' x\,\mathrm{H}'\left(x+\frac{\pi}{2}\right)}{\Theta x\,\mathrm{H}\left(x+\frac{\pi}{2}\right)} = \frac{\mathrm{H}''\frac{\pi}{2}}{\mathrm{H}\frac{\pi}{2}} + \frac{\Theta'' 0}{\mathrm{O}0},$$

where the reader may see them fully demonstrated from the 'Fundamenta Nova' of Jacobi.

They are applied by him in a memoir in the fifty-sixth volume of Crelle, entitled "Ueber die rationale Verbindungen der elliptischen Transcendenten," to prove that if $\mathrm{U} = \frac{\Delta\phi^r \sin\phi^s \cos\phi^t}{(1+a\sin\phi)^m}$, where a is supposed a function of q, then $\mathrm{Z}x\,.\,\mathrm{U}$ can be determined from U by simple integration with respect to (x) only.

In the course of the investigation he gives the following expressions:—

$$\frac{dk}{dq}=\frac{k}{2q}\cdot\left\{\frac{2Kk'}{\pi}\right\}^2, \quad \frac{dk'}{dq}=-\frac{k'}{2q}\left\{\frac{2Kk}{\pi}\right\}^2.$$

I shall conclude this portion of my work by a remark of Riemann, that if $\vartheta u=\Sigma_{-\infty}^{\infty}\epsilon^{an^2+2nu}$, then if ($r$) and ($s$) be any two positive or negative integers, ϑu vanishes if $u=(r+\frac{1}{2})\pi i+(s+\frac{1}{2})a$. In mentioning the name of Riemann, I am glad to take the earliest opportunity of paying a humble tribute to the memory of one of the most illustrious mathematicians which either his country or the world has ever seen.

Report on Mineral Veins in Carboniferous Limestone and their Organic Contents. By Charles Moore, *F.G.S.*

A careful consideration of the phenomena attending mineral veins needs the aid of the physical geologist, the electrician, the chemist, the mineralogist, and also, as I shall presently show, that of the palæontologist, in order to arrive at correct conclusions respecting their age, the materials they contain, from whence those materials were derived, and the time when they were subsequently deposited in them. Unfortunately I do not profess to have any knowledge of some of these sciences, and the conclusions to which I have arrived will therefore be based upon general observations, such as could be given to the physical conditions of various mineral districts, and the manner under which some of the veins have been formed and refilled.

There are few subjects connected with the physical history of our globe which have presented greater difficulties in their elucidation, and few the study of which have, up to this time, had less satisfactory or certain results than the laws which have regulated our mineral deposits, the views entertained having the wide divergence between a Plutonic and a Neptunian origin for our minerals; and although the tendency of opinion is probably in the latter direction, it may be almost said that at this time there is no fixed view on a subject of such great economic importance.

The opinions of various authors may be chiefly classed under the heads of "*sublimation*" and "*segregation*," whilst those of Werner, that the minerals in the veins have been derived from the waters of the ocean, and those recently propounded by Mr. Wallace, that they owe their presence to atmospheric causes and conditions in connexion with segregation, deserve attention.

1st. By sublimation is meant that all our minerals have been entirely derived from the passage upwards of certain vapours yielding the minerals through the veins, which have been vents from the heated interior of the earth.

2nd. By segregation, that the minerals now found in veins were contemporaneous with, and deposited in very minute quantities in the horizontal strata which now form the walls of the veins, and that by some mode or other they have subsequently been removed from the surrounding rocks and redeposited as they are now found in the veins.

Minerals are only met with in the crust of the earth, in stratified beds, and in mineral veins.

Under the first condition, it will be very generally admitted that the materials from whence those minerals were derived must have been held in solution in the waters of the ocean at the different periods when the stratified beds containing them were being deposited, and that the lime, the silica, the iron, which will be found more or less abundantly in every formation, must have been, with few if any exceptions, precipitated contemporaneously. Although the ores of copper, tin, lead, and other rarer minerals which are found most frequently in veins may occasionally be detected in stratified beds, it is evident, from the mere traces of them that are obtained over the widest areas and in geological time, that the laws which were necessary to their deposition so abundantly in veins, were in their case to a considerable extent inoperative.

Physical conditions necessary to Mineral Veins.—It is only stating a truism to remark that the rocks in association with which our mineral veins are found are almost entirely of marine origin; that they once formed the bottom of ancient seas, and in their undisturbed conditions were laid down horizontally, and were continuous, and without the enormous rents and fissures which now traverse them in every direction. The mere contraction of the beds during solidification would not be sufficient to account for the phenomena, as in this case the fissures would not pass down continuously to any depth. It appears, therefore, clear that all veins must be due to the elevation or depression of the portion of the earth's crust in which they are found, and that they are younger than or formed subsequently to the consolidation of the rocks enclosing them, their age depending on the period of physical change.

It would be difficult for any one not acquainted with mining operations to realize the enormous forces that have been in operation in different ages to produce the dislocations necessary for the reception of our mineral lodes. To the physical geologist there can be few more remarkable phenomena than mining districts present, or than the study of a well-prepared map of any of our larger districts would show. As an instance, I may mention a map of the Alston district, in Cumberland, prepared by Mr. Wallace, in which it may be seen that, occupying very large areas, there is a complete network of fissures, the same veins being traceable through many miles of country, crossed by others at varying angles. I have also shown this to be the case in the Mendip district*, where the east and west veins in passing parallel with one another through that line of country are repeatedly intersected by cross courses, and to such an extent that numerous examples, especially towards Frome, may be seen in almost every limestone-quarry.

It being admitted that through the volcanic disturbances indicated the fissured character of our rocks has been produced, it will be desirable to consider the influence exercised by the ocean in refilling the veins thus caused.

On examining caverns and fissures of the Carboniferous Limestone which are now open, it can at once be seen, by the honeycombed and worn character of the roofs and sides, that they must at some period have formed channels or passages for large bodies of water. Although in most Carboniferous-limestone districts it is known that "swallet holes" occur, through which the water now passes down and traverses certain lines of open fissures below, which form the natural drainage of the country, the stream sometimes reappearing miles away from whence it entered, still these are excep-

* "Abnormal Conditions of Secondary Deposits," &c., Geol. Journ. Dec. 1867.

tional cases; the great majority of the open fissures are beyond and without this influence, and it must be obviously impossible, to any great extent, where the fissures have been refilled, that there could be the passage of any considerable bodies of water through them since they have obtained their present elevations, in some instances amounting to several thousand feet above the sea-level. It appears to me, therefore, more probable that the denudation to which they have been subject is due in great measure to the long-continued action of marine currents, whilst the fissures, the upper parts of which afford the most striking evidence of this condition, still remained open beneath the surface of the ocean. This might have been for greatly extended periods, as there is evidence throughout the Mendip and South Wales districts that the Carboniferous Limestones formed the floor of the sea through Triassic, Liassic, and Oolitic times.

After the disturbing influence by which the fissures were caused, their filling up by derived materials, and the time occupied thereby, must have depended upon local causes that were in operation in the several areas in which they occurred. In some instances, where little or no sedimentary matter was being derived from adjoining lands, or where no preexisting stratified deposits were being denuded, few materials for this purpose would be supplied, and a greater length of time would elapse before the fissures received their vein-stuff, of whatever kind, whilst on the contrary they would more or less speedily have received the deposits with which they are now filled, subject, in either case probably, to a scouring out and occasional modification of the material within their walls.

Contents of Fissures.—In working for various minerals, it is usually found that the more precious contents of the veins are either in vertical strings, in bunches or pockets, or more rarely in flats, and that they form but a very small part of the contents of the fissures. When attention is given to the other materials which form by far the greater bulk of the infilling, it will be found in some instances to be of a very varied character, those even in the same mine being most remarkable. Though in general there might be an agreement in the character of the deposit in the same mineral field or area, when separate districts are examined, the distinction is more marked; often the material brought into the vein is conglomeratic, consisting of both angular and rolled pebbles—in the former case probably derived from the adjacent walls of the vein, or from a source not far removed; in the latter case, which is not an unfrequent one, the pebbles are from rocks not contemporaneous, some of which have therefore a foreign origin, and, either in being brought from a distance or from the subsequent action of the water in the fissure, have been as much rounded as are some of those found in the drifts of our superficial quaternary deposits. The cavernous interstices left in such conglomerates are favourable to the deposition of minerals for which the veins are worked; and where this is not the case, they are usually cemented together by carbonate of lime, quartz, or some other material incident to the infilling.

Still more frequently, in many districts, from forming the great bulk of the infilling, the "dowky" portions, or the clays, of the veins are charged with varying deposits of a sandy nature, with marl or clay, or with a meterial assuming a variegated or finely conglomeratic character, showing an admixture brought from different sources, or by the denudation of beds of different mineralogical conditions, analogous to stratified deposits when brought together by opposing currents. The variety in the character of the vein-stuff is at times most marked; and there may be obtained from the same vein samples of "dowks" which, when washed, give almost every conceivable hue of colour, from the most delicate French white to the densest shades of black or indigo, all being due to the different chemical or mineralogical conditions of the matrix. Additional evidence is afforded of the derived nature of the "dowks" by the occasional presence in them of fossil wood. I have found a piece in the Charterhouse Mine, converted into jet, with the cellular portions containing galena; and another example is recorded from the Hudgill Burn Mine, the exterior of which was covered with galena. Whenever in a given area a series of fissures were open at the same time, and subject to the same conditions of deposition, it is quite possible that certain horizons of infilling might be found in them, though, from the peculiar circumstances attending them, their recognition would involve close observation.

Having said thus much of the fissures and their more unprofitable contents, I now proceed to consider the views that have been usually entertained as to the deposition of the minerals therein.

Views of Mineral Deposition.—Next to the one which I shall hereafter suggest of a purely marine origin for the minerals, I believe that of sublimation to have the greatest probability; but there are, I think, many reasons against this supposed cause.

It necessarily involves, what was most likely the fact, that the fissures originally continued downwards until they reached the source of volcanic action, which in some instances must have been seated at an enormous depth. The moment the fissures were opened, of whatever width, if within the influence of the ocean, they must have been filled by its waters, and liable more or less quickly to receive their now varied contents. Their lower depths would naturally be first filled. Where the rents passed through, as must often have been the case, soft and yielding beds, this might often have occurred quickly, in others only after a great lapse of time. Were the doctrine of sublimation true, we ought, I think, to have greater evidence of the continued passage upwards of volcanic fluids, in the very lowest depths, instead, as is most often the case, of finding our minerals high up in the veins, or occurring chiefly on given horizons in them, or even in pockets at their surfaces. It appears to me also that the "dowks" or clays through which so subtle and potent an agent must have been continually passing, charged with its varied minerals, must have shown much greater evidence of its effects than is now seen in them, and that they would more frequently have tended to precipitate the minerals before they could have passed so far upwards in the vein in which they are now more frequently found.

The doctrine of segregation, which at this time appears to have most believers, is, I think, open to greater objection than that of sublimation. Its disciples believe that, subsequently to the movements which have caused the fissures, a process has been going on which even now is collecting the various minerals together towards a fixed point, according to their natural affinities, extracting them from the adjoining rocks, and redepositing them in the veins. This view is purely imaginary and incapable of proof, and seems to me as impossible as the idea I had when a boy, that if you planted a stone, in process of time it might grow into a mountain. There seems to me no possibility how, under this supposition, any mineral can be withdrawn, and necessarily replaced by another totally different, involving a circulatory movement continually in progress in the matrix of some of our most extensive geological formations. Probably, as regards their chemical constituents, there are no more homogeneous rocks than the great series of the

Carboniferous Limestones, the veins of which yield a considerable proportion of our lead, calamine, and iron-ore; and chemical analysis will show that the constituents necessary to the production of these minerals are almost entirely absent from them over the widest areas. The limestones that come nearest in contact with the walls of strong mineral lodes ought, with this view, to yield the best evidence that the minerals have been thus segregated together; but it will be found that they are as free from the minerals that are in the veins as would be samples taken at any distance from the fissures.

Under this head it is desirable I should notice a view lately suggested by Mr. Wallace. This gentleman has lately published an elaborate work on 'The Laws which regulate the Deposition of Ores in Veins,' which, though having special reference to the Alston-Moor district, is proposed by him as a law explaining the ore-deposits in all mineral veins. His work shows an intimate knowledge of the complicated physical details of that extensive mining-region, in which, in opposition to sublimation, he remarks, that all the lead-veins are found most productive where furthest removed from the seat of Plutonic action, the richest deposits being in the upper part of the Carboniferous Limestone where no igneous rocks are found, and that in that district there is nothing to support the theory that lead is due to exhalations from below, or to matter injected in a fluid state among the consolidated sedimentary rocks. Instead of this he states that the more probable cause of the lead-ore at Alston is owing to segregation from, or decomposition of, the rocks which form the walls of the veins where they are found. In adopting the doctrine of segregation, he proposes, for the first time, to combine with it another cause, without which there would be no important deposits of minerals, viz. that of recent hydrous and atmospheric agency. Without the passage of large bodies of water downwards from the surface, derived from the rainfall of the district, and their free circulation in the veins, there would be no conditions favourable to the deposit of minerals; in all cases he states such deposits are found only where fluids most freely percolate the surface and circulate in the veins, and that these conditions only occur where the strata are situated at moderate depths from the surface, and at some considerable distance from the watershed of the mountain; that, combined with electrical action, these agents have been the means of extracting the minerals from the adjoining rocks; that the operation is still in progress, and that all has been accomplished since the Glacial period.

The examination I have given to mineral veins and their contents does not support this view. The chief material of all mineral veins I find to be of marine origin; all the organic contents are fossil, and their precise geological age can be arrived at without much difficulty. Wherever they contain land shells, as on the Mendips, or freshwater shells, which occur in the veins of Alston, and are wide-spread elsewhere, they are also fossil and of contemporaneous age with the other remains*. It is certain from this that the veins received their infilling when within the influence of the ocean, and before their present elevation, since which time, as I have before stated, I doubt if there could be any material alteration in their contents.

But supposing their vein-stuff to be postglacial, and that their deposit had been effected by large bodies of water passing down through them from the surface, ample evidence would have been present of the fact; for in the place of fossil organic remains, which in some instances indicate the exact age of the minerals, there would have been found recent land and freshwater

* See remarks on the presence of Land and Freshwater Shells, p. 369.

shells and plants abundantly. Of this, through a long examination of the contents of mineral veins, I have seen no evidence either in the Alston or any other mining-district.

Postpliocene caverns and fissures have, however, remained open to this time, in many instances, in our Carboniferous-limestone ranges; and although they have been within the influence of, and subject to, the effect suggested by Mr. Wallace, their organic contents consist chiefly of the extinct mammalia of that period, whilst their mineral deposits are confined to the stalactitic and stalagmitic deposits on their roofs and floors which have been slowly accumulating since the postpliocene period.

The Neptunian theory, first advanced by Werner for the origin of minerals, would probably before this have received greater attention but for the other extravagant ideas he connected with it. I shall now offer some suggestions regarding its probable truth.

It appears to me necessary, in the first place, that, for the production of minerals, there should be the following elements or conditions, viz. the presence of the minerals themselves in the waters of the ocean, open fissures communicating therewith, favourable electrical conditions, and time for their precipitation.

It has now been established, without doubt, by the highest chemical authorities, that many of our most important minerals are present in minute quantities in the waters of the ocean. This is admitted by those who believe in segregation, the difference being that they think it was first deposited and afterwards extracted from the parent rock, and redeposited in the veins, rather than originally collected in the veins themselves.

As regards the connexion subsisting between the ocean and the vein-fissures, I believe it will be recognized to be the case that, in the great majority of instances, the different veins come directly to the surface, and wherever a later rock has been deposited, which is only in exceptional cases, covering up the mouth of the vein, there will still be found a break in the sequence of the strata, which might give almost unlimited time for the precipitation of the minerals therein. Wherever systems of veins occur, it is probable there will be found connected therewith an abnormal condition and considerable breaks in the deposition of the rocks. I have shown this to be the case in connexion with the Carboniferous Limestone of the Mendip range, and its continuation through South Wales, in which districts it can be seen that those rocks were, through enormous periods, exposed to the influence of the ocean, possibly forming reef-like barriers around the edges of the carboniferous basin, the fissured veins and floor of this sea-bottom receiving at some periods materials of Rhætic or of Lower or Middle Lias age, whilst an occasional capping of the beds of Inferior Oolite, left in some Carboniferous Limestone trough, now and then cover up the mouths of the veins that had received all their contents prior to its deposition. Some most instructive examples are present in this district, in which it may be seen that whilst there are on the walls of the vein the usual vertical conditions of vein-stuff, such as calcspar, sulphate of barytes, &c., with occasional hæmatite iron-ore, calamine, and galena, the central portion of the vein is unmistakably of Liassic or Rhætic age. In all such instances there are combined the elements of open fissures communicating with the ocean, and greater or less time in the reception of their contents.

Various Ages of Minerals.—It will be found that minerals generally occur in the outcrops of lines of strata, possibly occupying, to some extent, the same relative positions, as regards the strata by which they are now surrounded, as in earlier times, and that the mineral-bearing rocks formed the floor or backbone on which the later beds were laid down. This is the case with Australian and Californian auriferous regions, the enormous denudation and consequent drifts of Tertiary age in the former case having laid bare the backbone of the auriferous-bearing rock below. I have already shown this to be the case with the Carboniferous Limestones of the west of England and South Wales, where, in connexion with them, veins and pockets of mineral-bearing lias are found. Liassic minerals, again, occur on what is probably a continuation of the same great barrier, which, passing under the south-eastern counties, crosses the channel to France, where they are seen on a floor of granite. The outcrops of some of the limestones of North Wales and the north of England have been exposed to the influence of seas certainly as late as the Coal-measures and the minerals found in the great mining-districts of Cornwall, whether in the killas or the granite itself, are found connected with, or resting upon, a great backbone of the latter rock.

It is also worthy of remark that the conglomerates usually skirting the edge of the limestone, which must long have been subject to the action of the ocean, are large receptacles of iron, calamine, and lead, the veins in which seldom, if ever, pass downwards into the limestone, and which, though open to the ocean, are cut off from sublimation beneath. The fissures in these great lines of submarine mountains must necessarily have been chiefly filled with marine matter, whether mineral or otherwise; sometimes, where the materials were friable, supplied by the walls of the fissure, but perhaps oftener derived. Wherever there has been a rapid filling up of the veins by a homogeneous material, the element of time is excluded, such as with the "dowky" portions of the veins, and in such cases workable minerals are seldom found. The same occurs where there is a sequence of deposition, and stratification follows without a break in natural order. If the above view be correct, it follows that the longer a fissure has been exposed to the influence of the ocean, the greater will be the probability of a larger supply of minerals therein. Where veins have been slowly filled, where they have been cavernous, or by subsequent movements have been opened on several occasions, where they contain conglomeratic infillings, or have been kept open by currents, favourable conditions to deposition occur; and it is a well-known law of mining that, at the junction where veins intersect, rich deposits or pockets of minerals are most usually found, from the fact that at such points there has been a scouring out of the fissures, and a longer time given for precipitation.

Palæontology of Mineral Veins.—The physical views I have suggested are strongly supported by the investigations I have for some time been pursuing regarding the presence of organic remains in mineral veins. During those investigations I have examined materials derived from Carboniferous-limestone veins and fissures from the mining-districts of Wharfedale, Wensleydale, Weardale, Teesdale, Swaledale, Alston Moor, Keswick, North and South Wales, and Somersetshire; and I am much indebted, for the facilities they have afforded me in their several districts, to Lord Bolton and Messrs. Wallace, Walton, Eddy, Bainbridge, Cain, Peart, Wasley, and Sopwith.

It is remarkable, considering the enormous mine-workings and the quantity of vein-stuff brought to the surface in every part of the world, that so few notices of the presence of fossils in them should have occurred. In his 'Elements of Geology,' p. 762, Sir Charles Lyell mentions that M. Virlet had found a Gryphæa in a lead-mine near Semur in France, and that a madrepore had been seen in a compact vein of cinnabar in Hungary, the presence of which were accounted for by their being transported thither during submarine earthquakes.

An examination of the veins in the former case might indicate the presence of many other shells, and probably show the age of the veins of that district to be Liassic or Oolitic. In the latter case, also, other remains might be found, and yield additional confirmation of the views I have propounded.

One reason for the non-discovery of organic remains has arisen from their being generally of small size, and that the vein-stuff in which they have to be sought for is often of a very intractable character, resisting the action of the water by which it has to be dissolved before they can be washed out of it, after which the residuum requires almost microscopic examination for their separation. In the process of washing away the "dowks," it is interesting to notice the very varied tints with which they colour the water, according to the mineralogical character of the material to be operated upon, which differs in separate districts, and on different levels or horizons in the same mine.

The organic remains thus obtained are occasionally even more varied, as regards genera and species, than if they had been derived from a given horizon of stratified deposits, arising perhaps from the length of time within which the fissure might have been open, and the necessarily mixed condition consequent upon the filling up of the vein. Some from the Carboniferous Limestone itself are associated with those which are foreign or derived. In the case of the Charterhouse Mine on the Mendips, those which are of Liassic age, and consequently derived, are in the proportion of about 90 to 30 from the older rocks within the walls of which they are found. In the Carboniferous-limestone districts of Holwell and Frome, Rhætic and Liassic organisms are also in large proportion; and the same may generally be said throughout the Mendip range and South Wales. In North Wales and the north of England, on the contrary, Carboniferous-limestone remains are the most frequent; those of later age are the exceptions, some of these being Entomostraca of Permian species, which may be common to the two series, and Foraminifera, which have a long range upwards. The precise later age of the vein-infillings is therefore, in their cases, not so clearly defined as in the south-west of England. In the Fallowfield Mine and the Silver Band Mines, *Flemingites gracilis*, a seed of the coal-period, occurs, whilst at Grassington and Mold small particles of coal are occasionally present in the "dowks," which at Fallowfield and in the Swaledale district are so like material from the coal-shales that it is reasonable to infer that the veins are contemporary with, or subsequent to, the coal-period.

Nothing can well be more remarkable than the Mendip veins with their infillings of secondary age, high up on the Carboniferous-limestone tableland, and with no stratified deposits of lias within several miles. In the case of the Charterhouse Mine, from the variety in the contents of the fissures, there is ample evidence that a considerable time must have elapsed within which they remained more or less open, and during which various oceanic influences were at work. At 270 feet, the lowest depth of the shaft, there is found a deposit of blue or greenish clay, 10 feet in thickness, which has yielded the Liassic fossils given below. This, on the same level, occasionally changes from a homogeneous marl to patches of a more conglomeratic material with enclosed water-worn pebbles. Higher up the vein it becomes a dense conglomerate. Above this, sandy-looking deposits occur, which, when washed, are seen to be almost entirely composed of the detached stems of encrinites very much abraded, with small washed pebbles of hæmatite iron-ore, showing that, after the deposit of the Lias in the vein below, a denudation of the Carboniferous Limestone had been going on; and above this, again, occurred calcspar and the largest deposits of lead-ore; all these changes, and others which might be mentioned, indicate the many conditions that were in operation before the fissure had finally received its contents, whilst still within the ocean's influence, and possibly before the final elevation of the Mendip range. In this district the minerals "prove" near the surface, but they are occasionally found below, and detached crystals of galena are not unfrequent in the Liassic clay at the bottom.

In the following list, which is extracted from my paper "On the Abnormal Condition of Secondary Deposits," &c., it will be seen what a large fauna occurs within the walls of the lead-vein, that most of the great palæontological groups are therein represented, and that they clearly indicate its precise geological age.

List of Organic Remains from Charterhouse Lead-mine, 270 feet from the Surface.

Of Liassic Age.

Chara liassina, *Moore.*
Drift-wood, Jet.
Cristellaria rotula, *Lamk.*
—— costata, *D'Orb.*
Dentalina communis, *D'Orb.*
—— obliqua, *Linn.*
—— obliquestriata, *Reuss.*
Frondicularia striatula, *Reuss.*
Involutina liassica, *Jones.*
——, sp.
Marginulina lituus, *D'Orb.*
Nodosaria raphanistrum, *Linn.*
—— radicula, *Linn.*
—— paucicostata, *Reuss.*
Planularia Bronni, *Roem.*
Textularia, sp.
Pentacrinites, joints of.
Cidaris Edwardsii.
Echinodermata, several species.
Ophioderma, joints of.
Serpula, sp.
Pollicipes rhomboidalis, *Moore.*
Crustacea, claws of.
Bryozoa, sp.
Argiope.
Crania.
Lingula.
Rhynchonella variabilis, *Schloth.*
Terebratula punctata, *Sow.*
Spirifer, fragments, several sp.
Thecidium Moorei, *Dav.*
—— triangularis, *D'Orb.*
Zellania Davidsoni, *Moore.*
—— Laboucherei, *Moore.*
Lima, sp.
Plicatula spinosa, *Sou*
Astarte, sp.
Cardinia multicostata.
Cucullæa.
Leda Heberti, *Martin.*
Nucula, sp.
Opis, sp.
Cerithium gratum, *Terq.*
—— rotundatum.
—— paludinare, *Terq.*
—— Semele, *D'Orb.*
Chiton.
Fissurella.
Melania alternata, *Terq.*
Nerinæa Mendipensis, *Moore.*
Orthostoma frumentum, *Terq.*
—— triticum, *Terq.*
Pleurotomaria expansa, *Sow.*
—— Mendipensis, *Moore.*
Straparollus tricarinatus, *Mart.*
—— Oppeli, *Mart.*
Solarium lenticulare, *Terq.*
Trochus nitidus, *Terq.*
—— edulus?, *Stol.*
——, sp.
Turbo, sp.
——, sp.
—— Piettei, *Martin.*
—— aranus, *Martin.*
—— Martini, *Terq.*
—— tumidus, *Moore.*
Turritella Humberti, *Martin.*
—— Howsei, *Moore.*
Ammonites, 2 sp.
Belemnites acutus, *Mill.*
Fish remains abundant, including teeth of *Acrodus*, *Hybodus*, *Lepidotus*, &c., representing about ten species.
Ichthyosaurus, tooth of.

Derived from the Carboniferous Limestone.

Helix Dawsonii, *Moore.*
Hydrobia, sp.
Planorbis Mendipensis, *Moore.*
Proserpina Lyelli, *Moore.*

Valvata anomala, *Moore.*
—— pygmæa, *Moore.*
Vertigo Murchisoniæ, *Moore.*
Bairdia plebeia, *Reuss.*
—— brevis, *Jones & Kirkby.*
Cythere bilobata, *Münst.*
—— fabulina, *Jones & Kirkby.*
—— intermedia, *Münst.*
—— ambigua, *Jones*, MS.
—— æqualis, *Jones*, MS.
—— spinifera, *Jones*, MS.
—— Thraso, *Jones*, MS.
Kirkbya plicata, *Jones & Kirkby.*
Moorea tenuis, *Jones*, MS.
Terebratula hastata, *Sow.*
Orthis Michelini, *Kon.*
Atrypa, sp.
Spirorbis.
Serpulæ.
Encrinites.
Bryozoa, various species.
Corals, several species.
Echinodermata.
Conodonts.

Considerable palæontological interest attaches to the presence, under these peculiar conditions, of such genera as *Helix*, *Proserpina*, and *Vertigo*, as, with one exception, they are the earliest recognized land shells, and also to *Valvata*, *Hydrobia*, and *Planorbis*, the oldest freshwater genera yet known. In the paper above mentioned, I referred to the difficulty that exists in always assigning the shells of different ages, when thus mixed together, to their true geological horizons. Although in general this difficulty does not occur, it may happen with those which are new, or have not been previously stratigraphically recognized.

It was not unnatural that I should have supposed these land and freshwater shells, when accompanied by a large Liassic fauna, to be of the same age; but with regard to the *Valvata anomala*, the *V. pygmæa*, and the *Planorbis Mendipensis*, the evidence I have since obtained of the presence of these shells in the mining-districts of the North, leads me to the conclusion that it is probable that these land and freshwater species are rather to be assigned to the earlier period of the Carboniferous Limestone, a fact that will still enhance their palæontological interest. The presence also of other freshwater genera, to be hereafter noticed, occurring in considerable numbers in the veins, induces me to think that there are some freshwater beds connected with the Carboniferous Limestone from whence they may have been derived which have yet to be discovered; and I hope my geological friends who are working in Carboniferous-limestone districts will turn their attention to this point; for of all formations, less, I believe, is really known or realized of the great physical, palæontological, and other changes which have occurred during the Carboniferous period than of most other geological deposits, and there yet remains a great work for some geologists to take up in this direction.

In other mining-districts organic remains are generally less plentiful than in the Mendip area; but I have not failed to detect them, more or less abundantly, except in one instance, in that of the Cononley Mine in the Airdale district. It often happens that, though they are wanting in some samples of the "dowks," they may still be obtained from others at higher or lower levels in the same mine. Although they have in all instances been selected promiscuously for examination, fossils have been found in more than one half of the samples.

The following lists of "dowks," with notes of their organic contents, are selected to show the general character of the vein-stuff after it has been prepared by washing.

Keld-Head Mines, Wensleydale.

48 ft. from surface. A very mineralized, brownish, or drab marl; when washed chiefly a residuum of quartz grains. Organisms rare, consisting of *Encrinites, Serpulæ-like tubes, Involutina.*

90 ft. Dowkey Vein, Ashbank Limestone, with occasional galena and iron pyrites. *Encrinites* very abundant. *Serpulæ, Orthis, Involutina*, rare.

192 ft. Keld-Head Vein, Ashbank Limestone, a drab marl, leaving a very quartzose residuum, with iron pyrites. *Encrinites* abundant; *Involutina* rare.

210 ft. Cobscar Vein, Undersill Limestone, a brownish marl, with yellow sandy patches. *Valvata anomala* (Moore), *Entomostraca, Echini, Bryozoa, Seed?, Encrinites*, abundant, *Brachiopoda*.

240 ft. West-Bank Vein, Ashbank Limestone, a greyish marl, with numerous *Foraminifera* of the genera *Involutina, Entomostraca*, many *Encrinites, Serpulæ, Bryozoa*, &c.

450 ft. Keld-Head Vein, Bottom Limestone, a blue marl, with galena, blende, iron pyrites, quartz, selenite. *Planorbis Mendipensis* (Moore) and other univalves; *Euomphalus, Entomostraca*, many *Encrinites, Echini, Serpulæ, Bryozoa, Discina nitida, Terebratula*, very numerous; *Involutinæ, Dentalina pauperata*, very rare.

Aysgarth Top Limestone, a dark-blue mineralized residuum with galena, blende, iron pyrites. *Entomostraca*, numerous *Foraminifera*.

Thornton's Scar Limestone, a blue marl. *Casts of bivalves, Encrinites* abundant, and many *Foraminifera*.

List of Fossils in Keld-Head Mines.

Seed?
Involutina silicea, *Terquem*.
—— polymorpha, *Terq*.
—— liassica, *Jones*, sp.
—— radiata, *Brady*.
—— lobata, *Brady*.
Dentalina pauperata, *D'Orb*.
Bairdia curta, *M'Coy*.
—— plebeia, *Reuss*, long var.
——, sp.
Cythere cuneolina, *J. & K.*, MS.
—— fabulina, *J. & K.*, MS.
——, n. sp.
Corals, sp.
Encrinites.
Echini, sp.
——, sp.
Serpula, sp.
Spirorbis caperatus, *M'Coy*.
Bryozoa, several sp.
Atrypa, sp.
Discina nitida, *Phil*.
Chonetes, sp.
Orthis, sp.
Lingula, sp.
Productus, sp.
Rhynchonella, sp.
Terebratula hastata, *Sow*.
Zellania, ? sp.
Bivalves, fragments, sp.
Hydrobia, n. sp.
Stoastoma ?, n. sp.
Valvata pygmæa, *Moore*.
—— anomala, *Moore*.
Planorbis Mendipensis, *Moore*.
Loxonema brevis, *M'Coy*.
Lacuna antiqua, *M'Coy*.
Macrocheilus tricinctus, *M'Coy*.
Murchisonia quadricarinata, *M'Coy*.
—— Larcombi, *M'Coy*.
—— tricincta, *M'Coy*.
——, sp.
——, sp.
——, sp.
Pleurotomaria multicarinata, *M'Coy*.
—— sulcata, *Phil*.
—— limbata, *Phil*.

Fallowfield and Brownley Hill, Cumberland.

90 feet from surface. Fallowfield Vein, a very micaceous grey marly residuum, with black carbonaceous particles, fragments of coal, crystals of selenite, iron pyrites. *Flemingites gracilis* (Carr.), porcelain-like casts of *Turbo* and *Turritella, Entomostraca, Foraminifera*.

270 ft. Fallowfield Vein, a dark marl, with iron pyrites. *Turbo, Turritella, Entomostraca, Encrinites*.

450 ft. Brownley Hill Old Vein, a black micaceous marl, with selenite. *Stoa-*

stoma? in considerable numbers; *Hydrobia*, n. sp., *Pisidium, Unio?, Spirifer, Dentalina, Serpulæ, Entomostraca, Bryozoa.*

480 ft. Brownley Hill Middle Vein, a black micaceous marl. No organisms.

600 ft. Brownley Hill West High Cross Vein, a dark mineralized micaceous slaty deposit, with encrinite-stems rarely.

80 ft. Guddamgill Burn Cross Vein, a black slaty marl, like Coal-measure shales. Encrinite-stems, remains rare.

Fossils in Fallowfield and Brownley Hill Veins. Brownley Hill 1400 *feet, Fallowfield* 100 *feet above Sea-level.*

Flemingites gracilis, *Carr.*
Involutina.
Dentalina pauperata, *D'Orb.*
Echini, sp.
Serpulæ.
Serpulites, sp.
Bryozoa, sp.
Encrinites.
Cythere fabulina, *J. & K.*, n. sp.
—— cuneolina, *J. & K.*, n. sp.
——, n. sp.
Pisidium, n. sp.
Unio ?, n. sp.
Bivalves, sp.
Spirifera, sp.
Stoastoma ?, n. sp.
Hydrobia, n. sp.
Valvata anomala, *Moore.*
Dentalium inornatum, *M'Coy.*
Turbo, sp.
Turritella, sp.
Conodonts.

Coal.

Grassington Mines, Wharfdale, Yorkshire.

24-fathoms level. New Rake Vein, residuum a yellow sandy ferruginous marl, with hematite iron-ore, quartz, &c., fragments of coal and coal-like shale. Encrinital stems.

28-ft. level from the shale, a brown and red-mottled marl, with a very mineralized residuum, manganese, iron-ore, quartz, &c. Tooth of *Petalodus, Conodonts, Echini, Serpulæ.*

60-ft. level, near the junction of Eddey's and Cannister's Veins, a yellow marl, residuum almost entirely composed of encrinital stems.

60 ft. on Eddey's Vein, a brown marl, with manganese, iron-ore, quartz, fish-teeth and scales, *Conodonts, Encrinites, Serpulæ.*

60 ft. on Middle Vein, a greyish marl, in great part encrinital. Small fish-palate and other fish-remains, *Conodonts.*

60 ft. at Moss Middle Vein, a yellowish marl, leaving a variegated irony residuum. Teeth of *Petalodus* and *Orodus*, and fish-scales, *Conodonts* of two forms, *Serpulæ, Encrinites, Involutina.*

60 ft. Old Moss Vein at Moss, a yellowish sandy marl. Scales or teeth of *Ctenoptychius*; organisms rare.

40 ft. Middle Vein, Coalgrove Head, a drab marl, chiefly encrinital. Tooth of *Orodus*, small vertebræ and fish fragments, vegetable-like fragments, *Conodonts, Bryozoa, Involutina.*

40 ft. Old Ralph's String Level, Coalgrove Head, a grey mottled marl. Fish-teeth, *Conodonts, Encrinites, Seed?, Involutina.*

18 ft. Cavendish Vein, at Sarah Top, Millstone-grit, a cream-coloured marl, with galena. No organisms.

37 ft. Cavendish Vein, Sarah Top, part of Millstone-grit, a brownish-looking sample, conglomeratic, with limy streaks in the laminæ. Hematite iron-ore, micaceous sandstone, lignite or coal, quartz, galena, leaving a large limy deposit in the water. Encrinital stems.

42 ft. No. 2 Vein, north of Middle Vein, Friendship, a brownish marl, with *Planorbis, Bryozoa, Serpulæ, Encrinites.*

42 ft. No. 4 Vein, south of Middle Vein, at Friendship, an ochreous marl, with *Hydrobia, Entomostraca, Conodonts, Serpulæ, Encrinites, Involutina, Nodosaria.*

45 ft. Alexander Vein, West Peru. *Hydrobia, Conodonts,* &c.

40 ft. Alexander Vein, West Peru, a brownish marl, with fish-remains, *Conodonts, Entomostraca, Rhynchonella,* &c.

45 ft. New Vein, West Peru, a brownish-mottled marl, with part of fish-jaw, teeth of *Petalodus* and *Orodus,* fish-vertebræ and scales. *Hydrobia, Discina nitida, Lingula, Conodonts, Dentalium inornatum, Encrinites, Bryozoa, Echini.* Crustacean fragments?

24 ft. No. 2 Vein, south of West Turffit's shaft, a grey clay, with *Psammodus* tooth, *Univalves, Bryozoa, Encrinites, Coral, Involutina.*

25 ft. On Ringleton's Vein, a brownish-mottled marl. Tooth of *Orodus, Hydrobia, Valvata anomala, Crania?, Conodonts, Entomostraca, Bryozoa, Dentalium, Serpulæ, Encrinites, Involutina.*

20 ft. New Rake Vein, a brownish-mottled marl. Piece of large tooth, fish-spines, and small teeth, *Valvata anomala, Hydrobia, Lithoglyphus, Planorbis, Conodonts, Entomostraca, Bellerophon, Encrinites,* &c.

24 ft. Branch, north from New Rake Vein, in shales and limestone, an irony-looking marl. Encrinital stem.

List of Fossils in the Grassington Mines, 1300 *feet above Sea-level.*

Vegetable-like fragments.
Seeds?
Involutina vermiformis, *Brady.*
—— aspera, *Brady.*
—— recta, *Brady.*
—— incuta, *Brady.*
—— nodosa, *Brady.*
—— cylindrica?, *Brady.*
—— polymorpha, *Terq.*
Nodosaria, sp.?
—— radicula, *Linn.*?
Corals, sp.
Encrinites.
Echini, remains.
Serpula.
Serpulites, sp.
Cythere nigrescens.
—— munda.
—— æqualis, sp. n.
—— bilobata, *Münst.*
—— intermedia, *Münst.*
—— Münsteriana, *J. & K.*
—— ambigua, *J. & K.,* MS.
—— n. sp.
Leperdita Okeni, *Münst.*
Crustacean fragment.
Conodonts.
Bryozoa, sp.
Discina nitida, *Phil.*
Lingula, sp.
Rhynchonella, sp.
Leptæna, sp.
Thecidium?, sp.
Zellania?, sp.
Terebratula hastata, *Phil.*
Bivalves, fragments.
Hydrobia, n. sp.
Lithoglyphus, sp.
Planorbis Mendipensis, *Moore.*
Valvata anomala, *Moore.*
Dentalium inornatum, *M'Coy.*
Turbo, sp.
Cladodus, tooth.
Psammodus, tooth.
Petalodus, tooth.
Orodus, tooth.
Part of fish-jaw.
Vertebræ and fish-scales.

———

Coal or coal-like shale.
Various minerals.

List of Fossils from the Alston Mines, 1240 *feet above Sea-level.*

Carteria, sp., nov. gen.
Encrinites.
Echini.
Serpula.
Serpulites.
Corals, sp.
Cythere pyrula, *J. & K.,* n. sp. MS.
—— nigrescens.

Cythere Moorei, *Jones.*
Leperdita Okeni, *Münst.*
—— parallela, *J. & K.*
Arca, sp.
Nucula, sp.
Bryozoa, sp.
Terebratula hastata, *Sow.*
Spirifera.
Buccinum imbricatum, *Sow.*
Cirrus Dionysii, *Goldf.*
Hydrobia, n. sp.
Dentalium inornatum, *M'Coy.*
Natica.
Macrocheilus curvilineus, *Phil.*
—— canaliculatus, *M'Coy.*
Murchisonia Larcombi, *M'Coy.*
Pleurotomaria sulcata, *Phil.*
—— interstrialis, *Phil.*
Turbo, sp.
Univalves, several sp.
Petalodus, tooth.

List of Fossils from Weardale Mines.

Carteria, sp., nov. gen.
Corals.
Encrinites.
Echini.
Spirorbis caperatus, *M'Coy.*
Serpula.
Leperdita Okeni, *Münst.*
Cythere, sp.
Atrypa, sp.
Orthis, sp.
Spirifera Urii, *Flem.*
Arca, sp.
Nucula, sp.
Bellerophon globatus?
Elenchus antiquus, *M'Coy.*
Loxonema brevis, *M'Coy.*
Murchisonia quadricarinata, *M'Coy.*
Turbo, sp.
Univalves, several other sp.
Conodonts.

Vegetable-like impressions.
Sponge-like bodies.

List of Fossils from Allenhead Mines.

Plantæ.
Sponge-like bodies.
Corals, sp.
Encrinites, sp.
Echini, sp.
Serpulæ.
Serpulites.
Leperdita Okeni, *Münst.*
Cythere pyrula, n. sp.
—— Geinitziana, *Jones.*
—— nigrescens.
—— Moorei, n. sp.
—— fabulina, *J. & K.*
Bairdia plebeia, *Reuss.*
—— elongata, *Münst.*
Atrypa, sp.
Chonetes, sp.
Terebratula hastata, *Phil.*
Productus, sp.
Spirifera, sp.
Bivalves, portions.
Arca, sp.
Psammodus, tooth.
Hydrobia, n. sp.
Valvata anomala, *Moore.*
Elenchus antiquus, *M'Coy.*
Loxonema brevis, *M'Coy.*
Murchisonia quadricarinata, *M'Coy.*
Natica.
Bellerophon.
Conodonts.

Coal-like fragments.

List of Fossils from the White and Silver Band Mines.

Flemingites gracilis, *Carr.*
Seed?
Spongiform bodies.
Encrinites, sp.
Serpulæ, sp.
Serpulites, sp.
Corals, sp.
Echini, sp.
Involutina silicea, *Terq.*
—— liassica, *Jones.*
Dentalina pauperata, *D'Orb.*
Bryozoa, sp.
Bivalves, in pieces.
Euomphalus?
Stoastoma?, sp.
Hydrobia, sp.
Valvata anomala, *Moore.*
Psammodus, tooth.
Conodonts, two kinds.

List of Fossils from Mount Pleasant Mine, Mold, Flintshire, about 1000 *feet above Sea-level.*

Seeds?
Encrinites.
Serpulæ.
Involutina.
Dentalina?
Cythere Wardiana, *J. & K.*, n. sp.
Chiton-like valves.
Bivalves, in fragments.
Terebratula, sp.
Spirifera, sp.
Hydrobia, sp.
Euomphalus, sp.
Ctenoptychius, tooth or scale.
Orodus cinctus, *Ag.*
Psammodus, teeth.
Petalodus, teeth.
Saurichthys-like teeth.
Cladodus, teeth.
Squaloraria-like scales.
Tooth, with serrated edges.
Reptilian-like tooth.
Scales, lozenge-shaped, of fishes.
Conodonts.

———

White siliceous fragments of stone, with numerous scattered fish-remains.

List of Fossils from the Coldberry and Red Grove Mines, Teesdale.

Seed?
Encrinites.
Echini.
Serpulites.
Involutina.
Cythere bilobata, *Münst.*
—— pyrula, *J. & K.*, MS.
Cytherella aspera, *Jones*, n. sp.
Corals.
Arca, sp.
Nucula, sp.
Impressions of bivalves in vein-stuff.
Terebratula hastata, *Phil.*
Bellerophon, sp.
Dentalium inornatum, *M'Coy.*
Hydrobia, n. sp.
Planorbis Mendipensis, *Moore.*
Valvata anomala, *Moore.*
Psammodus, tooth.
Spine-like bodies.

List of Fossils from a Vein at Weston-super-Mare.

Encrinites.
Leperdita Okeni, *Münst.*
Cythere pyrula, n. sp.
—— nigrescens.
—— fabulina, *J. & K.*
—— Moorei, n. sp.
Beyrichia arcuata.
—— subarcuata.
——? impressa, n. sp.
Kirkbya plicata, n. sp.
—— costata, *M'Coy.*
Kirkbya impressa, n. sp.
Bairdia plebeia, *Reuss.*
Glauconome grandis, *M'Coy.*
Buccinum imbricatum, *Phil.*
Melania, sp.
Natica variata, *Phil.*
Hydrobia, n. sp.
Univalves, several sp.
Fish-scales.

———

Galena and copper-ore.

Whilst the various mines and mineral deposits I have examined have certain species in common, it may be said that they have each special palæontological features of their own.

In the Keld-Head Mines organic remains are very abundant at about 450 feet from the surface, amongst which are many Foraminifera, chiefly of the genus *Involutina*, of which there are six species, and univalves of about twelve genera, the freshwater genera *Valvata anomala*, Moore, and *Planorbis Mendipensis*, Moore, being present, and also Entomostraca of several new species.

The Fallowfield mines, although not yielding a very long list of species, have their special interest in the presence of the land and freshwater genera *Stoastoma*?, *Hydrobia*, and *Pisidium*; *Involutina*, as in the Keld-Head mines, though rarely; and a single seed of the *Flemingites gracilis*, Carr. The richest samples from this mine are at 90 and 450 feet from the surface.

The Grassington mines are not only very rich in individual specimens, but have yielded the greatest number of species, amongst which are again freshwater remains of *Hydrobia*, *Planorbis*, *Valvata*, and *Lithoglyphus*. Entomostraca of at least ten species, Conodonts of several varieties, and fish-remains of the genera *Petalodus*, *Orodus*, &c.

The Alston mines have yielded about twelve species of univalves, though they are not in good condition; Foraminifera are present, but are rare, and fish-remains of the genera *Petalodus*.

The Weardale mines, and those of Allenheads, are comparatively not rich, the vein-stuff in them being much mineralized. Conodonts occur in the former, Entomostraca rather abundantly in the latter, and also, though rarely, the genus *Hydrobia*. In these veins, and also at Alston, I have detected, for the first time, large cells of a foraminiferous shell, for which Mr. Brady suggests the generic name *Carteria*.

In the White and Silver Band mines remains are somewhat rarely distributed, the richest deposit being a friable ochreous sandstone, on the "sun" side of the Silver Band Old Mine, which yielded many specimens of *Hydrobia*, and one or two of *Valvata anomala*, several genera of Foraminifera, including *Involutina* and *Dentalina*, with Conodonts and portions of teeth of *Psammodus*.

The Mount-Pleasant mines of Mold contain Foraminifera, and also the freshwater *Hydrobia*, though rarely, and Conodonts rather abundantly; but they are especially remarkable for the great variety of fish-remains they yield, which appear to represent at least ten different genera. Mixed with the "dowks" of the mine are occasionally small pieces of laminated stone, the surfaces of which exhibit numerous traces of fish-scales.

The researches I have been making have involved very considerable labour and minute investigation; but as they will to some extent have opened up a new field of inquiry, I hope they will not be without some results. Before concluding, I desire to refer to several of the more interesting palæontological facts which have been obtained.

Flemingites gracilis, Carr.—These are the almost microscopic sporangiæ or seeds of a coniferous tree of the Carboniferous period, which have been described and figured by my friend Mr. Carruthers in the 'Geological Magazine,' vol. ii. p. 443, my first acquaintance with which was by finding a single specimen in the Fallowfield Mine, followed soon after by another from the Silver-Band mines. It is remarkable, when a key is once obtained to the discovery of certain organic remains, how soon our knowledge of the class may be increased. In the instance of these minute seeds, I have since found them abundantly in the Carboniferous series of Staffordshire, and within the last few weeks more abundantly still in the Coal-measures of Radstock, Somersetshire. At this place there is a horizontal bed of some thickness, intercalated with the coal-seams, which appears to be almost wholly composed of these little organisms; and, extraordinary as it may seem, it is not far from the truth when I say that I could supply specimens of them by the ton weight!

Conodonts.—In many of the lists of fossils I have given, the presence of these curious organisms may be seen. Hitherto they have not been found by any one but myself above Lower Silurian rocks, though no doubt they may henceforth be detected in the strata of great thickness intervening between the Ludlow bone-bed and the Carboniferous period from whence my specimens come. I have not only found them in the lead-veins, but also in stratified beds of Carboniferous Limestone at Almondsbury near Bristol.

The series of these remarkable microscopic bodies I have discovered yield much greater variety than any hitherto obtained, and consequently present additional difficulty in determining their affinities. They are generally either lustrous or horny in their appearance, or dull, according to the matrix in which they are found. My collection of them affords certain well-marked recurrent types, which enable a certain amount of classification to be given to them; and though, taking the group as a whole, their forms are about as eccentric as can be imagined, they still do not appear to pass one into another. The simplest form is almost identical in shape with that of a minute conical fish-tooth. Next comes another, not unlike the central cusp of a hyboid tooth, with lateral bosses at the base. Another group possesses an arched base, the simplest form in which has an elevated central curved tooth, with a smaller projecting tooth on either side. A second form has four elevated slightly curved teeth, with smaller teeth at the sides and in the interspaces, whilst a still more elaborate one possesses a single elevated central curved tooth, with about twelve regularly arranged, close-set smaller ones on either side. A third group have their teeth arranged on an irregular or waved base, the forms of which are almost too eccentric for description. In one there are nine curved teeth, arranged somewhat symmetrically, graduating in height to the centre, but with a much larger fang at one end; a second form has five tapering teeth, followed by four others, much more depressed and extended beyond the base. One kind presents a miniature representation of the jaw of *Rhizodus*, with large teeth widely separated, and irregularly dispersed small teeth within. A remarkable form possesses a long curved tooth at one end, throwing off a semicircular spur, which passes under a base-line, on the top of which follow numerous small depressed regular teeth, the next two becoming much elevated, whilst the last is still more so, extending much beyond the basal end. Another series, which has a lengthened straighter base-line, is furnished in some instances with serrations as close-set and minute as are the bristles on an insect's limbs. In the width, form, and curvature of the teeth, these present various modifications. Although in the above short descriptions I have by no means exhausted the variety they present, I shall only notice here another kind, which is the most abundant, and similar to one previously found in the Ludlow bone-bed. This presents a somewhat club-shaped form, the thicker end having in the centre a depression, bounded on the margin by a raised edge, furnished with very minute serrations, which are united at about the centre of the body, and are continued beyond in a very thin slightly curved handle, which is also furnished with close comb-like teeth. A familiar illustration of this Conodont would be that of an old-fashioned rat-trap. Its base possesses a somewhat triangular hollow, indicating that it might have been attached at this part to some soft body.

These curious fossils were first found by Pander, in Silurian beds in Russia; and considering that they belonged to and were the teeth of fish, he created 13 genera and 56 species, according to the forms they presented. In almost every instance the specimens I have found differ from those of the Silurian beds, and present much more diversity. Several of the Russian varieties were, for the first time, noticed in the Ludlow bone-bed by Dr. Harley, who, in a paper in the 'Geological Journal,' 1861, p. 549, suggests that they may be minute spines attached to the tail of a crustacean, such as *Ceratiocaris*.

They have more recently been noticed by Professor Owen, in a note to the last edition of 'Siluria,' p. 544, in which he also points out the improbability of their being allied to fish. He then remarks that certain parts of small crustacea, such as the pygidium or tail of minute Entomostraca, resemble in shape the more simple Conodonts; but that against this view was the fact that no shells of Entomostraca or other crustaceans had ever been found in the Conodont beds, and that it was improbable therefore that they could have belonged to an organism as susceptible of preservation as their own substance. Although I may agree with the opinion of Professor Owen, that these bodies do not belong to Entomostraca, I do so for other reasons. In the first place, although his remarks may apply to the Silurian Conodonts, he is wrong in supposing that they do not occur in the same beds with Entomostraca; for it happens that most of my specimens from the Carboniferous Limestone are found in beds crowded with Entomostraca, which occur also in the lead-veins, these two sources having yielded me about 40 species. The great variety my series of Conodonts presents is decidedly against referring them to Entomostraca; and what is, I think, sufficiently conclusive is the fact that they are usually of greater size than the crustaceans, to which they would thus be attached. The conclusion to which he arrives respecting them is, that they were united to a soft perishable body, and that they have most analogy with the spines, hooklets, or denticles of naked Mollusks and Annelides. There is no doubt great difficulty attending their elucidation, and the above view, though not, I think, quite satisfactory, appears as probable as any other that has been advanced. One objection to it is the variety of forms they present, and that we have no existing analogues. To whatever they belonged, the creatures yielding them probably passed away with Palæozoic times, as I have found no trace of them in my examinations of any later deposits. It has always been my object, when seeking them in the Carboniferous Limestone, to find their association with some other organized body, but in this I have always failed. They invariably occur as separate detached specimens, and without any arrangement as regards one another.

Entomostraca.—The bivalve crustacea included in this family, although not individually numerous, are present in nearly every vein I have examined. They have been in the hands of my friend Professor Rupert Jones, who has provisionally determined about 29 species from the veins, including those of Charterhouse and Weston, the great majority of which are new. They include the genera *Bairdia, Beyrichia, Cythere, Cytherella, Kirkbia,* and *Moorea*, the genus *Cythere* alone having as many as seventeen species.

Foraminifera.—Our knowledge of some of this very beautiful class of microzoa will be considerably extended by those I have been fortunate enough to obtain from the lead-vein deposits. This will especially apply to the genus *Involutina*, which until lately was chiefly known by a single species of *I. liassica*, Jones, sp., many specimens of which I have found in the Liassic deposit in Charterhouse Mine. More recently M. Terquem's researches in the Lias of the north-west of France have brought to light several new forms belonging to the same type, four of which, viz. *I. polymorpha, I. aspera, I. silicea,* and *I. nodosa,* all supposed to belong to the secondary age, are represented in my gatherings from the Carboniferous-Limestone veins. My series not only carries back the above secondary species to deposits of Palæozoic times, but associated with them are nine others, so that under these peculiar conditions there are not less than fourteen species of this hitherto little-known genus. *Dentalina pauperata,* D'Orb, a now living species, which has been traced back through Tertiary, Liassic, and Permian formations, not only in this series goes back to the Carboniferous Limestone, but I have also obtained it in the Wenlock shales, an evidence of a delicate microscopic shell having existed through a long series of ages to our own times. The *Tinoporus lævis*, P. & J., another recent species, will probably be added to the list, though it requires more examination, together with the recent species *Textularia sagittula*, Defrance, and the genus *Fusulina*. The cells of the new genus *Carteria* have since been found somewhat abundantly on the decomposed edges of the Carboniferous-limestone rock of Elfhills. Thus there are twenty-one species of Carboniferous-limestone Foraminifera unexpectedly making their appearance for the first time in mineral veins, three of which have lived on to this day.

Land and Freshwater Shells.—Not the least important fact in my mine explorations has been the discovery of a land and freshwater fauna. Until I obtained the three genera of *Helix*, *Vertigo*, and *Proserpina*, with the freshwater genera *Planorbis* and *Valvata*, in the Charterhouse Mine, the only known terrestrial shell below the secondary beds was the *Pupa vetusta*, Daw., found by Sir Charles Lyell and Dr. Dawson in the Coal-measures of Nova Scotia. To the above genera I have now to add those of *Hydrobia*, *Stoastoma* ?, *Lithoglyphus*, and *Pisidium*, from the mines of the north of England, some of which I have little doubt are older than the *Pupa vetusta* of the coal-beds. There is thus the fact of the presence of nine genera of land and freshwater shells in the lead-veins of this country.

In addition to the list of organic remains which follows, numbering about 112 species from the north of England and North-Wales mines, eight, which are not in common, have been obtained from Weston, and to these again are to be added 89 in the list previously given from Charterhouse, so that in true and workable mineral veins I have found 209 species. In the Carboniferous Limestone of the Frome district precisely similar phenomena occur, though the fissures are not worked. These Rhætic and Liassic veins have yielded me about 70 species, so that, including the districts I have enumerated, I have obtained from vein-fissures, with their deposits of different ages, about 279 species of organic remains.

Under these peculiar circumstances, I have discovered the oldest known Mammalia, the oldest land and freshwater Mollusca, about 52 species of fish, and about 8 of Reptilia, besides the other groups to which reference has been made.

The list of species from Charterhouse Mine previously given and those from Weston are not included in the following list. The species of Foraminifera marked "*Brady*" are new to science, and descriptions of them will be found in Mr. H. B. Brady's "Notes on the Foraminifera" immediately following this Report, as well as a provisional notice of the new genus *Carteria*.

List of Species.	Mines.							
	Grassington.	Fallowfield &c.	White and Silver Band.	Teesdale.	Allenheads.	Alston.	Keld Heads.	Mount Pleasant.
Flemingites gracilis, *Carr*	..	*	*					
Seeds ?	*	..	*	*	..	..	*	*
Plantæ, impressions on shale	*	..	..	..	*			
Sponge-like bodies	..	..	*	..	*			

TABLE (*continued*).

List of Species.	Mines.							
	Grassington.	Fallowfield &c.	White and SilverBand.	Teesdale.	Allenheads.	Alston.	Keld Heads.	Mount Pleasant.
Nodosaria radicula, *Linn.* ?	*							
——, sp. ?	*							
Textularia sagittula, *Defrance*								
Tinoporus, sp. ?	. .	. .	. .	*				
Dentalina pauperata, *D'Orb.*	. .	*	*	. .	. .	. .	*	
Fusulina ?, young	. .	. .	. .	. .	. .	. .	. .	*
Involutina polymorpha, *Terquem*	*	. .	. .	. .	. .	. .	*	
—— aspera, *Terq.*	*	. .	. .	. .	. .	. .	*	
—— silicea, *Terq.*	. .	. .	*	. .	. .	. .	*	
—— nodosa, *Terq.*	*	. .	*					
—— Liassica, *Jones*, sp.	. .	. .	. .	. .	. .	. .	*	
—— radiata, *Brady*	. .	. .	. .	. .	. .	. .	*	
—— subrotunda, *Brady*	. .	. .	. .	*				
—— lobata, *Brady*	. .	. .	. .	. .	. .	. .	*	
—— crassa . . Brady								
—— vermiformis, *Brady*	*							
—— incerta, *Brady*	*							
—— recta, *Brady*	*							
—— cylindrica, *Brady*	*							
—— obliqua, *Brady*								
Carteria, sp., nov. gen.	. .	. .	. .	. .	*	*		
Corals, sp.	*	. .	. .	*	*	*	*	
Encrinites, sp.	*	. .	. .	. .	*	*	*	*
Echinodermata, sp.	*	*	*	*	*	*	*	*
—— sp.	*	. .	. .	*	*	*	*	*
Serpula	*	. .	. .	*	*	*	*	
Serpulites	*	*	*	*	*	*	*	*
Spirorbis caperatus, *M'Coy*	. .	. .	. .	. .	. .	. .	*	
Crustacea, fragment	*							
Bairdia plebeia, *Reuss*	*	. .	. .	. .	*	. .	*	
—— curta, *M'Coy*	. .	. .	. .	. .	. .	. .	*	
—— elongata, *Münst.*	. .	. .	. .	. .	*			
——, sp.	. .	. .	. .	. .	. .	. .	*	
Beyrichia	*							
Cythere bilobata	*	. .	. .	*				
—— pyrula, n. sp.	. .	. .	. .	*	*	*		
—— nigrescens	*	. .	. .	. .	*	*		
—— munda, n. sp.	*							
—— æqualis, n. sp.	*							
—— intermedia, *Münst.*	*							
—— fabulina, *J. & K.*	*	*	. .	. .	*	. .	*	
—— ambigua, *Jones*, n. sp.	*							
—— Moorei, *Jones*, n. sp.	. .	. .	. .	. .	*	*		
—— cuneolina, *J. & K.*, n. sp.	. .	*	. .	. .	. .	. .	*	
—— Muensteriana, *J. & K.*	*							
—— Wardiana, *J. & K.*, n. sp.	. .	. .	. .	. .	. .	. .	. .	*
——, n. sp.	*	. .	. .	. .	. .	. .	*	
——, Geinitziana, *Jones*	. .	. .	. .	. .	*			
Cytherella aspera, *Jones*, n. sp.	. .	. .	. .	*				
Leperdita Okeni, *Münst.*	. .	. .	. .	. .	*	*		
—— parallela, *J. & K.*	. .	. .	. .	. .	. .	*		
Bryozoa, various sp.	*	*	*	. .	. .	*	*	
Atrypa, young	. .	. .	. .	. .	*	. .	*	
Chonetes, sp.	. .	. .	. .	. .	*	. .	*	

TABLE (*continued*).

List of Species.	Mines.							
	Grassington.	Fallowfield &c.	White and SilverBand.	Teesdale.	Allenheads.	Alston.	Keld Heads.	Mount Pleasant.
Discina nitida, *Phil.*	*	..	..	..	..	..	*	
Leptæna, sp.	*							
Lingula, sp.	*	..	..	..	..	..	*	
Productus, sp.	..	..	..	..	..	..	*	
Orthis, sp.	..	..	..	..	*	..	*	
Rhynchonella, sp.	..	..	..	..	..	..	*	
Spirifera, sp.	..	*	..	..	*	*	..	*
Thecidium ?	*							
Zellania ?	..	..	..	..	..	..	*	
Terebratula hastata, *Phil.*	..	..	..	*	*	*	*	*
Brachiopoda, sp.	..	..	..	..	*	*		
Bivalves, fragments	*	*	*	..	*	..	*	*
Arca, sp.	..	..	..	*	*	*		
Nucula, sp.	..	..	..	..	..	*		
Pisidium, sp.	..	*						
Stoastoma ?, sp.	..	*	*	..	..	..	*	
Hydrobia	*	*	*	*	*	*	*	*
Lithoglyphus	*							
Planorbis Mendipensis, *Moore*	*	..	..	*	..	..	*	
Valvata anomala, *Moore*	*	*	*	*	*	..	*	*
—— pygmæa, *Moore*	..	..	..	..	..	..	*	
Buccinum imbricatum, *Sow.*	..	..	..	..	..	*		
Cirrus Dionysii, *Goldf.*	..	..	..	..	..	*		
Dentalium inornatum, *M'Coy*	*	..	..	*	..	*		
Elenchus ambiguus, *M'Coy*	..	..	..	..	*			
Lacuna antiqua, *M'Coy*	..	..	..	..	..	..	*	
Loxonema brevis, *M'Coy*	..	..	..	..	*	..	*	
Murchisonia Larcombi, *M'Coy*	..	..	..	..	..	*	*	
—— quadricarinata, *M'Coy*	..	..	..	..	*	..	*	
Macrocheilus curvilineus, *Phil.*	..	..	..	..	..	*		
—— canaliculatus, *M'Coy*	..	..	..	..	..	*		
—— tricinctus, *M'Coy*	..	..	..	..	..	..	*	
Natica	..	..	..	..	*	*		
Pleurotomaria sulcata, *Phil.*	..	..	..	..	..	*	*	
—— interstrialis, *Phil.*	..	..	..	..	..	*		
—— multicarinata, *M'Coy*	..	..	..	..	..	..	*	
—— limbata, *M'Coy*	..	..	..	..	..	..	*	
Turritella, sp.	..	*						
Turbo, sp.	*	*	..	..	..	*		
Bellerophon, sp., young	..	..	..	..	*			
Euomphalus, sp.	..	..	*					
Goniatites, sp.	..	..	..	..	*			
Cladodus, teeth	*	..	..	..	..	..	..	*
Ctenoptychius, tooth	..	..	..	..	..	..	..	*
Orodus, teeth	*	..	..	..	..	..	..	*
Petalodus, teeth	*	..	..	..	..	*	..	*
Psammodus, teeth	*	..	*	*	*	..	..	*
Saurichthys, tooth	..	..	..	..	..	..	..	*
Squaloraia-like scales	..	..	..	..	..	..	..	*
Jaw of Fish, portions	*							
Fish-scales	*	..	..	..	..	..	..	*
Fish-vertebræ	*							
Tooth, serrated edges	..	..	..	..	..	..	..	*
Conodonts	*	*	..	..	*	..	..	*

Notes on the Foraminifera of Mineral Veins and the adjacent Strata.
By Henry B. Brady, *F.L.S.*

The following "notes" on the Foraminifera obtained by Mr. Charles Moore in his investigations on the palæontology of mineral veins are necessarily incomplete. When presented there had been neither time nor opportunity for any close comparison of the specimens with the fossil Rhizopoda of periods immediately preceding and succeeding the horizon at which the veins occur. Hitherto the Foraminifera of the Carboniferous epoch have never been seriously studied, partly from the difficulty of obtaining rocks that can be disintegrated without injury to the fossil microzoa, and partly from the obscurity in which the early types are involved, owing to the obliteration of many of their structural peculiarities.

Under these circumstances it is not surprising that a large proportion of the specimens in the collection represent forms not previously described. Excepting those belonging to the genus *Involutina*, the Foraminifera are remarkable for their want of well-defined characters—zoological and physical causes having alike contributed to obscure the peculiarities they may have had when living.

The *Nodosarinæ* are represented by examples of two forms, namely, a single specimen identical in contour with *Nodosaria radicula*, Linné, sp., having well-defined subglobular chambers, and two or three shells having the general characters of *Dentalina pauperata*, D'Orbigny,—a cylindrical, slightly arcuate, and tapering test, with little or no constriction at the septa. The roughened and possibly partially sandy investment which all these specimens present, throws some difficulty in the way of placing them amongst the *Nodosarinæ*; but inasmuch as the doubtfully arenaceous appearance may be due to the subcrystalline structure of the matrix on the one surface or the mineral infiltration of the chambers on the other, whilst in all morphological relations their characters are completely Nodosarian, separation from the group seems scarcely justifiable.

The *Textulariæ* in the collection are very irregular in their growth, and by no means constantly biserial. They resemble some of the varieties of *T. sagittula*, Defrance, more than any other described species; but it may be necessary, or at least convenient, to assign a distinctive name to this primitive and variable form.

One or two obscure shells, regarded originally as *Tinoporus lævis*, P. & J., are more probably a new species of *Involutina*, having an analogous acervuline mode of growth.

Some other minute and very obscure organisms in Mr. Moore's collection appear to be young examples of *Fusulina*, a genus of Carboniferous Foraminifera well known in its mature condition.

A number of bodies of larger size, shaped like spheres drawn out at two opposite portions of their periphery, and distinctly arenaceous in their structure, have been regarded as joints of a gigantic *Lituola*, pending material for more complete examination. The produced ends appear to have been slender stoloniferous tubes; and a number of the chambers may have been joined together, forming a moniliform test of some length*.

But the most interesting portion of the collection consists of the series of specimens of the genus *Involutina*, which place the relations of that type in

* Since the examination of the specimens from mineral veins, the author has learnt that the same fossil has been discovered in the Carboniferous Limestone of Northumberland by Sir W. C. Trevelyan. The anticipations above expressed are found in the main to be correct, but it has been thought necessary to separate the organism from *Lituola* proper, and the new generic term *Carteria* has been employed for it.

an entirely new light. The varieties of this genus described by M. Terquem from specimens found in the Lias formation of the north-east of France, comprised only a few outspread, discoidal, rotalian forms of finely arenaceous texture and variable septation—a series, in point of fact, structurally allied to *Trochammina*, but with some morphological resemblance to *Rotalia*.

The modifications, both in structure and mode of growth, exhibited in the forms about to be described, place the type on a much extended basis; and it will be seen how large a number of the simpler Foraminifera have their analogues in the varieties of this polymorphic genus.

So far from being, as hitherto supposed, an essentially Liassic type, the genus *Involutina* has its fullest and most characteristic development in the Carboniferous period.

Of already described species the following have been found in mineral veins and the adjacent stratified rocks:—

Involutina Liassica, Jones, sp.	*Involutina nodosa*, Terquem.
„ *polymorpha*, Terquem.	„ *aspera*, Terquem (?).
„ *silicea*, Terquem.	

In addition to these there are a large number of forms not before noticed, of which brief descriptions are now presented. The definition of their characters must be regarded as provisional to some extent, and founded on Mr. Moore's specimens. The elucidation of the type is as yet by no means complete; but, through the kindness of Mr. Young of Glasgow, Mr. Leipner, and Mr. W. W. Stoddart of Bristol, materials for more extended observations have been placed at the author's disposal, which will form the basis of a future memoir.

Genus Involutina, Terquem.

I. cylindrica, n. sp. Test elongate, cylindrical, arcuate, tapering; septation imperfect.

I. incerta, n. sp. Test biconcave, helicoid, the terminal portion leaving the spire at an angle; septation very obscure.

I. recta, n. sp. Test crozier-shaped; earlier chambers arranged spirally, later ones in a single straight series; chambers somewhat ventricose; septa constricted and well defined.

I. lobata, n. sp. Test lenticular, rotalian, lower surface sometimes concave; periphery rounded; chambers ventricose; septa constricted.

I. radiata, n. sp. Test nautiloid, lenticular; periphery sharp, subcarinate; chambers long, narrow, often curved; septal lines not constricted, but in many cases marked by a radiate sutural limbation.

I. crassa, n. sp. Test rotalian, turgid, subglobose; chambers numerous, ventricose; terminal chamber especially large and inflated.

I. obliqua, n. sp. Test inequilateral, compressed, formed of long curved chambers, coiled irregularly on an oblique axis; septation indefinite; terminal chamber investing one-half of the shell.

I. subrotunda, n. sp. Test subspherical, formed by the acervuline growth of minute chamberlets on a central disk.

In addition to these, two other more obscure varieties have been met with, requiring further investigation. One of these, provisionally named *I. vermiformis*, resembles *I. cylindroides*, but has a test of uneven diameter and irregular twisted contour, suggesting an uncoiled spiral with rudimentary septa. The other, *I. macella*, has a large complanate nautiloid test, the chambers marked by depressions, the septation very indistinct.

Report of the Rainfall Committee for the year 1868–69, *consisting of* C. Brooke, *F.R.S.* (*Chairman*), J. Glaisher, *F.R.S.*, Prof. Phillips, *F.R.S.*, J. F. Bateman, *C.E.*, *F.R.S.*, R. W. Mylne, *C.E.*, *F.R.S.*, T. Hawksley, *C.E.*, Prof. Adams, *F.R.S.*, C. Tomlinson, *F.R.S.*, Prof. Sylvester, *F.R.S.*, *and* G. J. Symons, *Secretary.*

The attention of the Rainfall Committee has during the past year been largely devoted to various arrangements and details calculated to secure increased uniformity and accuracy amongst their observers; a very considerable number of stations have been visited during the past year by our Secretary, and the observers have been further instructed on any points in which their practice was incorrect; besides which the following code of rules has been drawn up for their guidance.

I. Site.—A rain-gauge should not be set on a slope or terrace, but on a level piece of ground, at a distance from shrubs, trees, walls, and buildings—at the very least, as many feet from their base as they are in height. Tall-growing flowers, vegetables, and bushes must be kept away from the gauge. If a thoroughly clear site cannot be obtained, shelter is most endurable from N.W., N., and E., less so from S., S.E., and W., and not at all from S.W. or N.E.

II. Old Gauges.—Old established gauges should not be moved nor their registration discontinued until at least two years after a new one has been in operation, otherwise the continuity of the register will be irreparably destroyed. Both the old and the new ones must be registered at the same time.

III. Level.—The funnel of a rain-gauge must be set quite level, and so firmly fixed that it will remain so in spite of any gale of wind or ordinary circumstance.

IV. Height.—The funnel of gauges newly placed should be 1 foot above grass.

V. Rust.—If the funnel of a japanned gauge becomes so oxidized as to retain the rain in its pores, or threatens to become rusty, it should have a coat of gas-tar or japan black.

VI. Float Gauges.—If the measuring-rod is detached from the float, it should never be left in the gauge. If it is attached to the float, it should be pegged or tied down, and only allowed to rise to its proper position at the time of reading. To allow for the weight of the float and rod, these gauges are generally so constructed as to show 0 only when a small amount of water is left in them. Care must always be taken to set the rod to the zero or 0.

VII. Can- and Bottle-Gauges.—The measuring-glass should always be held upright; the reading is to be taken midway between the two apparent surfaces of the water.

VIII. Time of Reading.—Nine a.m. daily; if only taken monthly, then 9 a.m. on 1st.

IX. Date of Entry.—The amount measured at 9 a.m. on any day is to be set against the previous one, because the amount registered at 9 a.m. of, say, 17th contains the fall during 15 hours of the 16th, and only 9 hours of the 17th. (*This rule, approved of by the Meteorological Societies of England and Scotland, cannot be altered, and is particularly commended to the notice of observers.*)

X. Mode of Entry.—If less than one-tenth (·10) has fallen, the cipher must *always* be prefixed; thus, if the measure is full up to the seventh line, it must be entered as ·07, that is, no inches, no tenths and seven hundredths.

For the sake of clearness, it has been found necessary to lay down an invariable rule that there shall always be two figures to the right of the decimal point. If there be only one figure, as in the case of one-tenth of an inch (usually written ·1), a cipher must be added, making it ·10. Neglect of this rule causes much inconvenience. All columns should be cast up *twice*. When there is no rain, a line should be drawn rather than ciphers inserted.

XI. Caution.—The amount should always be written down before the water is thrown away.

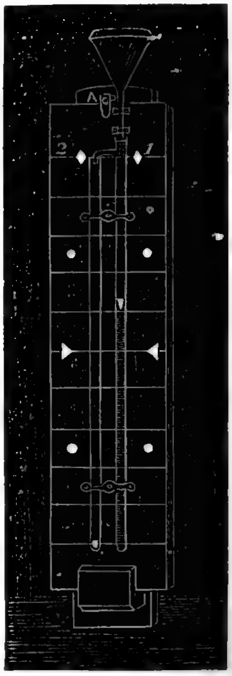
XII. Small Quantities.—The unit of measurement being ·01, observers whose gauges are sufficiently delicate to show less than that, are, if the amount is under ·005, to throw it away; if it is ·005 to ·010 inclusive, they are to enter it as ·01.

XIII. Every observer should train some one as an assistant; but where this is not possible, instructions should be given that the gauge should be emptied at 9 A.M. on the 1st of the month, and the water bottled, labelled, and tightly corked, to await the observer's return.

XIV. Heavy Rains.—When very heavy rains occur, it is desirable to measure immediately on their termination; and it will be found a safe plan, after measuring to return the water to the gauge, so that the morning registration will not be interfered with. Of course if there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being, in accordance with Rule XI., *previously* written down.

XV. Snow.—In snow three methods may be adopted; it is well to try them all. (1) Melt what is caught in the funnel, and measure that as rain. (2) Select a place where the snow has not drifted, invert the funnel, and turning it round, lift and melt what is enclosed. (3) Measure with a rule the average depth of snow, and take one-twelfth as the equivalent of water. Some observers use in snowy weather a cylinder of the same diameter as the rain-gauge, and of considerable depth. If the wind is at all rough, all the snow is blown out of a flat-funnelled rain-gauge.

Fig. 1.



The desirability of more accurate information of the maximum fall of rain in the minimum time has recently been strongly felt. It will be supplied by the use of the instrument shown in figure 1. Its principle is very simple, consisting merely in the employment of a collecting area about twenty times that of the measuring-tube; an inch of rain is therefore expanded to a length of nearly 2 feet, and the rising rain-water in the tube carries on its surface a small white glass ball which renders the reading of the gauge visible from a considerable distance; an overflow pipe is also provided, by which the measurement is continued up to 2 inches.

In the year 1863 Mr. Symons read a short paper before the Mathematical Section of this Association, at the Newcastle-upon-Tyne Meeting, wherein he briefly notified the inauguration of the now well-known Calne rain-gauge experiments. The observations having been stopped in the year 1868, in consequence of the removal of Colonel Ward from Calne, considerable attention has been given to the discussion of the very voluminous record sheets. Those connected with the variation in the amount of rain collected at various heights above the ground are in the hands of the Rev. J. M. Du Port, M.A., for examination.

Our last Report contained particulars of the remarkable accuracy of the whole of the instruments; in the present we give the amounts collected by all the gauges in the magnitude series during the five years, an analysis thereof, and the results obtained at Calne, and an interim note on those indicated at Strathfield Turgis Rectory, Reading, to which, as explained in our last Report, the gauges were removed in the spring of 1868.

Table I. contains the monthly amounts for the whole period, Table II. is an abstract of the same; Table III. gives the ratio of the fall collected by each gauge to that collected by the gauge 12 inches in diameter, Table IV. is an abstract of the same.

TABLE I.—Castle House, Calne, Wilts; lat. 51° 27′ N., long. 1° 59′ W.

	Magnitude Series 1 foot above ground. Depth of Rain collected.											
	1 in. upright.	2 in. upright.	4 in. upright.	5 in. upright.	5 in. with flange.	6 in. upright.	8 in. upright.	12 in. upright.	24 in. upright.	5 in. square upright.	10 in. square upright.	5 in. Snowdon pattern upright.
1863.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
August	2·572	2·706	2·852	2·762	2·890	2·866	...	2·921	2·913	2·638	2·903	
September ...	2·693	2·811	2·864	2·913	2·926	2·940	...	2·951	2·913	2·711	2·853	
October	3·255	3·411	3·458	3·473	3·478	3·529	...	3·540	3·509	3·217	3·483	
November ...	2·072	1·956	2·155	2·198	2·167	2·250	...	2·192	2·171	2·118	2·174	
December ...	·975	1·017	1·064	1·139	1·139	1·189	1·167	1·158	1·148	1·016	1·139	
	11·567	11·901	12·393	12·485	12·600	12·774	1·167	12·762	12·654	11·700	12·552	
1864.												
January	1·607	1·580	1·620	1·614	1·658	1·674	1·682	1·635	1·619	1·542	1·624	
February ...	·988	1·012	1·093	1·093	1·110	1·141	1·143	1·089	1·083	1·029	1·096	
March.........	2·366	2·453	2·545	2·533	2·554	2·449	2·566	2·474	2·487	2·398	2·483	
April	1·747	1·772	1·792	1·819	1·813	1·832	1·856	1·831	1·793	1·761	1·819	
May	1·008	1·032	1·099	1·104	1·110	1·108	1·119	1·088	1·072	1·043	1·084	
June	1·328	1·485	1·628	1·620	1·608	1·678	1·673	1·582	1·561	1·500	1·517	
July	·475	·565	·655	·647	·638	·679	·695	·661	·648	·637	·643	
August	·476	·552	·634	·653	·637	·692	·671	·618	·619	·604	·583	
September ...	2·405	2·465	2·586	2·609	2·651	2·700	2·713	2·583	2·543	2·458	2·544	
October	2·081	2·062	2·117	2·082	2·133	2·116	2·176	2·116	2·098	2·104	2·122	
November ...	1·695	1·688	1·784	1·767	1·806	1·855	1·880	1·834	1·829	1·785	1·810	
December ...	2·307	2·421	2·461	2·413	2·547	2·499	2·580	2·543	2·534	2·571	2·576	
	18·483	19·087	20·014	19·954	20·265	20·423	20·754	20·054	19·886	19·432	19·901	
1865.												
January	3·113	3·257	3·435	3·614	3·591	3·481	3·558	3·416	3·400	3·462	3·397	
February ...	2·715	2·768	2·729	2·738	2·907	2·833	2·901	2·839	2·860	2·863	2·825	
March.........	·741	·816	·891	·857	·893	·903	·936	·870	·862	·873	·857	
April	·632	·688	·719	·735	·738	·740	·738	·714	·706	·700	·705	·647
May	2·079	2·164	2·285	2·284	2·317	2·315	2·320	2·226	2·200	2·223	2·205	2·198
June	1·400	1·530	1·568	1·532	1·543	1·568	1·565	1·543	1·526	1·564	1·559	1·553
July	2·622	2·751	2·857	2·871	2·909	2·965	2·946	2·823	2·842	2·817	2·796	2·924
August	3·948	3·997	4·124	4·173	4·185	4·229	4·239	4·112	4·115	4·080	4·069	4·257
September ...	·055	·106	·122	·130	·125	·141	·153	·120	·115	·118	·113	·158
October	5·331	5·360	5·456	5·258	5·427	5·375	5·479	5·443	5·414	5·452	5·443	5·585
November ...	3·073	3·087	3·165	3·209	3·174	3·316	3·134	3·213	3·195	3·153	3·186	3·348
December ...	2·298	2·353	2·352	2·365	2·358	2·520	2·443	2·435	2·455	2·405	2·456	2·558
	28·007	28·877	29·703	29·766	30·167	30·386	30·412	29·754	29·690	29·710	29·611	

TABLE I. (*continued*).

	Magnitude Series 1 foot above ground. Depth of Rain collected.											
	1 in. upright.	2 in. upright.	4 in. upright.	5 in. upright.	5 in. with flange.	6 in. upright.	8 in. upright.	12 in. upright.	24 in. upright.	5 in. square upright.	10 in. square upright.	5 i Snc don ter upri
1866.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·237	3·665	3·760	3·623	3·786	3·856	3·910	3·656	3·753	3·648	3·678	3·8
February ...	3·683	3·925	4·119	3·977	4·051	4·186	4·193	4·068	4·145	4·001	4·047	4·2
March.........	1·792	1·859	1·970	1·963	2·044	1·998	2·046	2·047	2·014	1·970	1·987	2·1
April	1·910	2·029	2·156	2·206	2·224	2·218	2·230	2·145	2·126	2·117	2·114	2·2
May	1·035	1·047	1·139	1·160	1·166	1·218	1·175	1·119	1·115	1·097	1·085	1·1
June	2·805	2·845	2·976	2·985	3·014	3·046	3·077	2 927	2·904	2·916	2·845	3·0
July	1·247	1·343	1·452	1·466	1·478	1·502	1·515	1.394	1·408	1·397	1·354	1·4
August	2·052	2·188	2·395	2·419	2·423	2·481	2·513	2·332	2·342	2·292	2·241	2·4
September ...	6·354	6·448	6·688	6·647	6·685	6·781	6·799	6·641	6·633	6·525	6·538	6·8
October	2·007	2·028	2·101	2·108	2·126	2·117	2·146	2·098	2·118	2·083	2·082	2·1
November ...	2·251	2·204	2·216	2·095	2·307	2·407	2·415	2·334	2·335	2·285	2·297	2·4
December ...	2·867	2·737	2·782	2·859	2·890	3·049	3·027	2·941	2·974	2·837	2·958	3·0
	31·240	32·318	33·754	33·508	34·194	34·859	35·046	33·70 2	33·867	33·168	33·226	34·9
1867.												
January	3·146	3·370	3·404	3·268	3·591	3·448	3·545	3·441	3·784	3·417	3·519	3·4
February ...	2·075	2·066	2·070	1·796	2·176	2·003	2·097	2·104	2·140	1·991	2·073	2·0
March.........	2·361	2·965	3·042	3·135	3·140	3·050	3·068	3·192	3·317	2·620	3·328	2·88
April	3·093	3·135	3·211	3·126	3·284	3 206	3·272	3·187	3·210	3·124	3·118	3·21
May	1·788	1·740	1·820	1·819	1·828	1·867	1·850	1·765	1·808	1·750	1·695	1·79
June	2·021	2·186	2·217	2·158	2·237	2·231	2·237	2·148	2·176	2·075	1·990	2·20
July	3·442	3·691	3·733	3·733	3·806	3·756	3·803	3·645	3·651	3·530	3·511	3·69
August	2·925	3·000	3·019	3·071	3·077	3·034	3·031	2·953	2·941	2·873	2·814	3·06
September ...	1·720	1·727	1·773	1·771	1·801	1·792	1·818	1·760	1·758	1·667	1·630	1·73
October	2·785	2·807	2·795	2·824	2·831	2·831	2·875	2·828	2·830	2·771	2·710	2·35
November ...	1·228	1 200	1·225	1·308	1·300	1·313	1·298	1·282	1·258	1·269	1·253	1·30
December ...	1·610	1·711	1·663	1·630	1 740	1·683	1·720	1·717	1·721	1·694	1·652	1·70
	28·194	29·598	29·972	29·639	30·811	30·214	30·614	30·022	30·594	28·781	29·293	29·96

TABLE II.—Strathfield Turgis Rectory, Winchfield, Hants; lat. 51° 20′ N., long. 1° 3′ W

	Magnitude Series 1 foot above ground.											
	1 in. upright.	2 in. upright.	4 in. upright.	5 in. upright.	5 in. with flange.	6 in. upright.	8 in. upright.	12 in. upright.	24 in. upright.	5 in. square upright.	10 in. square upright.	8 in. with flange.
1868.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March, part of	·450	·489	·515	·482	·500	·482	·508	·502	·535	·470	·472	·514
April	2·420	2·406	2·445	2·411	2·446	2·419	2·459	2·411	2·495	2·394	2·358	2·482
May	·834	·878	·917	·923	·937	·941	·911	·919	·960	·899	·888	·939
June	·510	·494	·510	·507	·520	·508	·495	·501	·512	·505	·499	·511
July	2·063	2·028	1·939	1·818	1·934	1·886	1·943	1·916	1·896	1·944	1·903	1·966
August	3·086	3·087	3·181	3·120	3·144	3·182	3·167	3·164	3·211	3·151	3·076	3·212
September ...	3·494	3·537	3·550	3·506	3·558	3·570	3·539	3·553	3·687	3·464	3·542	3·597
October	2·152	2·142	2·215	2·186	2·217	2·229	2·219	2·225	2·250	2·181	2·185	2·242
November ...	1·714	1·738	1·782	1·737	1·780	1·747	1·807	1·752	1·834	1·758	1·790	1·810
December ...	4·659	4·790	4·983	4·943	5·028	4·996	4·967	4·986	5·083	4·897	4·904	5·031
Total	21·382	21·589	22·037	21·633	22·064	21·960	22·015	21·929	22·463	21·663	21·617	22·304

TABLE III. Abstract.—Castle House, Calne, Wilts; lat. 51° 27′ N., long. 1° 59′ W.

Magnitude Series 1 foot above ground
Depth of rain collected.

	1 in.	2 in.	4 in.	5 in.	5 in. with flange.	6 in.	8 in.	12 in.	24 in.	5 in. square.	10 in. square.	5 in. Snowdon pattern.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Part of 1863..	11·567	11·901	12·393	12·485	12·600	12·774	...	12·762	12·654	11·700	12·552	
1864..	18·483	19·087	20·014	19·954	20·265	20·423	20·754	20·054	19·886	19·432	19·901	
1865..	28·007	28·877	29·703	29·766	30·167	30·386	30·412	29·754	29·690	29·710	29·611	
1866..	31·240	32·318	33·754	33·508	34·194	34·859	35·016	33·702	33·867	33·168	33·226	34·939
1867..	28·194	29·598	29·972	29·639	30·811	30·214	30·614	30·022	30·594	28·781	29·293	29·969
Total 1863–67	117·491	121·781	125·836	125·352	128·037	128·656	...	126·294	126·691	122·791	124·583	
Total 1864–67	105·924	109·880	113·443	112·867	115·437	115·882	116·826	113·532	114·037	111·091	112·031	
Total 1866–67	59·434	61·916	63·726	63·147	65·005	65·073	65·660	63·724	64·461	61·949	62·519	64·908
Abstract.—Strathfield Turgis, Winchfield, Hants.												
Part of 1868 ...	21·382	21·589	22·037	21·633	22·064	21·960	22·015	21·929	22·463	21·663	21·617	

TABLE IV.—Castle House, Calne, Wilts; lat. 51° 27′ N., long. 1° 59′ W.

Magnitude Series 1 foot above ground.
Ratio of the amounts collected.

	1 in.	2 in.	4 in.	5 in.	5 in. with flange.	6 in.	8 in.	12 in.	24 in.	5 in. square.	10 in. square.		Range.
1863.								The amount measured in this gauge has been taken as the standard of comparison=100.					
ugust	88−	93	98	95	99	98			100+	90	99		12
eptember ...	91−	95	97	99	99	100+			99	92	97		9
ctober	92	96	98	98	98	100+			99	91−	98		9
ovember ...	95	89−	98	100	99	103+			99	97	99		14
ecember ...	84−	88	92	98	98	103+	101		99	88	98		19
1864.													
anuary	98	97	99	99	101	102	103+		99	94−	99		9
ebruary ...	91−	93	100	100	101	105+	105+		99	95	101		14
March.........	96−	99	103	102	103	99	104+		100	97	100		8
pril	95−	97	98	99	99	100	101+		98	96	99		6
May	93−	95	101	101	102	102	103+		98	96	99		10
une	84−	94	103	102	102	106+	106+		99	95	96		22
uly	72−	85	99	98	97	103	105+		98	97	97		33
ugust	77−	89	103	106	103	112+	109		100	97	94		35
eptember ...	93−	95	100	101	103	105+	105+		98	96	98		12
ctober	98	97−	100	98	101	100	103+		99	99	100		6
ovember ...	93	92−	97	96	99	101	103+		100	97	99		11
ecember ...	91−	95	97	95	100	99	101+		100	101+	101+		10

TABLE IV. (*continued*).

Magnitude Series 1 foot above ground.
Ratio of the amounts collected.

	1 in.	2 in.	4 in.	5 in.	5 in. with flange.	6 in.	8 in.	12 in.	24 in.	5 in. square.	10 in. square.	5 in. Snowdon pattern upright.
1865.												
January	91−	95	101	106+	105	102	104	*Note.*—The amount measured in this gauge has been taken as the standard of comparison=100.	100	101	100	
February ...	96−	98	96−	96−	102+	100	102+		101	101	100	
March.........	85−	94	102	99	103	104	108+		99	100	98	
April	88−	96	101	103	103	104+	103		99	98	99	91
May	93−	97	103	103	104+	104+	104+		99	100	99	99
June	91−	99	101+	99	100	101+	101+		99	101+	101+	101+
July	93−	97	101	102	103	105+	104		101	100	99	104
August	96−	97	100	101	102	103	103		100	99	99	104+
September ...	46−	88	102	108	104	118	127		96	98	94	132+
October	98	98	100	97−	100	99	101		99	100	100	103+
November ...	96−	96−	98	100	99	103	98		99	98	99	104+
December ...	94−	97	96	97	97	103	100		101	99	101	105+
1866.												
January	89−	100	103	99	104	105	107+		103	100	101	105
February ...	91−	97	101	98	100	103	103		102	98	99	104+
March.........	88−	91	96	96	100	98	100		98	96	97	103+
April	89−	95	101	103	104+	103	104+		99	99	98	103
May	92−	94	102	104	104	109+	105		100	98	97	103
June	96−	97	102	102	103	104	105+		99	100	97	103
July	90−	96	104	105	106	108	109+		101	100	97	104
August	88−	94	103	104	104	106	108+		101	98	96	105
September ...	96−	97	101	100	101	102+	102+		100	98	98	102+
October	96−	97	100	101	101	101	102		101	99	99	104+
November ...	96	95	95	90−	99	103	104		100	98	99	105+
December ...	97	93−	95	97	98	104+	103		101	96	101	104+
1867.												
January	92−	98	99	95	104	100	103		110+	99	102	101
February ...	99	98	98	85−	103+	95	100		102	95	99	95
March.........	74−	93	95	98	98	95	96		104	82	104	90
April	97−	98	101	98	103+	101	103+		101	98	98	101
May	101	99	103	103	104	106+	105		102	99	96−	102
June	94	102	103	101	104+	104+	104+		101	97	93−	103
July	94−	101	102	102	104+	103	104+		100	97	96	101
August	99	102	102	104+	104+	103	103		99	97	95−	104+
September ...	98	98	101	101	102	102	103+		100	95	93−	101
October	99	99	99	100	100	100	102+		100	98	96−	101
November ...	96	94−	95	102+	101	102+	101		98	99	98	102+
December ...	94−	100	97	95	101+	98	100		100	99	96	99
Mean	91·4	95·6	99·7	99·6	101·5	102·6	103·6	100·0	100·0	97·1	98·3	

TABLE V.—Strathfield Turgis Rectory, Winchfield, Hants; lat. 51° 20′ N., long. 1° 3′ W.

Magnitude Series 1 foot above ground. Ratio of the amounts collected.													
	1 in.	2 in.	4 in.	5 in.	5 in. with flange.	6 in.	8 in.	12 in.	24 in.	5 in. square.	10 in. square.	8 in. with flange.	Range.
1868.													
March, part of	90—	98	103	96	100	96	101	Standard of comparison.	106+	94	94	102	16
April	100	100	101	100	101	100	102		103+	99	98—	103+	5
May	91—	96	100	100	102	102	99		104+	98	97	102	13
June	102	99—	102	101	104+	101	99—		102	101	100	102	5
July	108+	106	101	99—	101	99—	101		99—	101	99—	103+	9
August	98	97—	100	99	99	100	100		101+	100	97—	101	4
September ...	98—	100	100	99	100	101	100		104+	98—	100	101	6
October	97	96—	100	98	100	100	100		101+	98	98	101+	5
November ...	98—	99	102	99	102	100	103		105+	100	102	103	7
December ...	93—	96	100	99	101	100	100		102+	98	98	101	9
Mean	97·5	98·5	100·5	98·7	100·6	100·3	100·4	...	102·5	98·8	98·6	101·7	8

TABLE VI. Abstract.—Castle House, Calne; lat. 51° 27′ N., long. 1° 59′ W.

Magnitude Series 1 foot above ground.												
	1 in.	2 in.	4 in.	5 in.	5 in. with flange.	6 in.	8 in.	12 in.	24 in.	5 in. square.	10 in. square.	5 in. Snowdon pattern
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Part of 1863..	90·6	93·3	97·2	97·9	98·8	100·0	..	Standard of comparison.	99·1	91·7	98·5	
1864..	92·2	95·2	99·7	99·5	100·1	101·8	103·4		99·2	96·9	99·4	
1865..	94·3	97·1	100·0	100·1	101·4	102·2	102·2		99·8	99·9	99·5	
1866..	92·7	95·8	100·1	99·6	101·4	103·4	104·0		100·4	98·3	98·5	103·7
1867..	93·8	98·6	98·8	98·7	102·6	100·6	102·0		101·9	95·8	97·6	99·8
Average 1863–67	93·1	96·5	99·7	99·3	101·4	101·9	..	..	100·4	97·3	98·7	
1864–67	93·3	96·8	100·0	99·4	101·7	102·1	102·9	..	100·5	97·9	98·7	
1866–67	93·4	97·3	100·0	99·2	102·1	102·2	103·1	..	101·2	97·3	98·3	101·9
Abstract.—Strathfield Turgis, Winchfield, Hants.												
Part of 1868 .	97·5	98·5	100·5	98·7	100·6	100·3	100·4	..	102·5	98·8	98·6	

From these Tables it appears:—

(1) That the variation in this ratio for the same gauge in different months is often greater than that between different gauges in the same month.

(2) That (excluding the gauge 1 inch in diameter, which everywhere collects less *pro rata* than any other) the gauges while at Calne only differed

5·8 per cent., the largest quantity being recorded by those gauges which were most easily managed, viz. those 5, 6, and 8 inches in diameter.

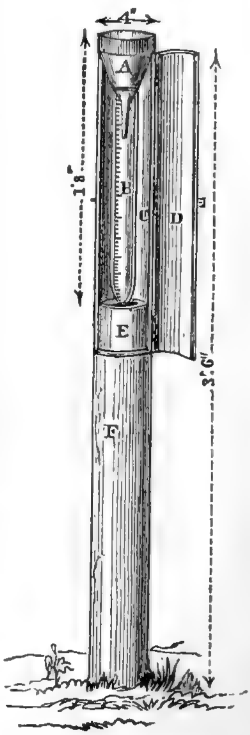
(3) That at Strathfield Turgis the agreement has been still closer, all but the 1 inch and the 24 inch agreeing within 1·5 per cent.

This last result might partly have been anticipated from two causes,—(*a*) Colonel Ward's health appears to have compelled him frequently to employ a substitute, and (*b*) Mr. Griffith commenced with the preliminary difficulties removed, and information as to possible sources of inaccuracy which previous experimentalists had had to discover by continuous observation.

Considering the absence of any trustworthy published observations upon the subject until those under notice were commenced, the lengthy articles published upon it in some of the scientific journals, and the almost universal ignorance upon it which recently prevailed, it is by no means an unimportant matter to have brought to a definite issue. Moreover, considering the various sizes of the gauges used simultaneously in different parts of the country, it is especially satisfactory to find that, instead of having, as was anticipated, a correction to apply to the observed values, when measured by a gauge of any but a standard size, to convert them into the equivalent indications of that standard size, no such correction is necessary; for all the most usual sizes, 5, 6, 8, and 12 inches diameter, agree within $1\frac{1}{2}$ per cent.

It seems probable that the small quantity registered by the 1-inch gauge is solely due to the great difficulty of emptying the last drop—by no means an unimportant matter with so diminutive a gauge, for a single grain weight of water corresponds to 0·008 inch, or nearly one ton of water per acre. The excess collected by the gauge 24 inches in diameter is probably explained by the influence of the large mass of metal of which it is composed; for after nights of heavy dew it generally contains more than any other, and this would naturally result from its greater radiating-power.

Fig. 2.



Some slight alterations were made at Strathfield Turgis, on January 1, 1869; and with their conclusion on January 1, 1870, the investigation there of the question of the influence of magnitude will probably be terminated.

The results of the examination of rain-gauges during the year are given in exactly the same form as in the last Report, and we are not aware that they call for any comment beyond referring, for explanation, to our Report for 1867, p. 466, and the plate there given. Gauge No. 278 being unlike any of those previously engraved, we add the annexed sketch, fig. 2. A is a funnel 4 inches in diameter, B a divided glass tube into which the rain passes. F a stout post, the upper part of which is hollowed out at C, half the outer portion, D, being hinged to afford access to the glass; E is a pad to keep B close up to A.

It will be noticed that the errors of some of the larger float gauges are not given in detail, the testing apparatus not being adapted to them.

It has been the practice of the Committee in their various Reports to adopt, for convenience of comparison, a decennial grouping of returns, such as 1840–49, 1850–59, &c. We are now on the eve of completing one of these decennial periods, and it behoves us therefore to consider how we may best secure for the ensuing period the attainment of the objects for which we were originally appointed. One of these is expressed in the first grant in the following words:—"For the purpose of constructing and transmitting rain-gauges to districts where observations are not at present made."

Even to those least acquainted with the subject, it will be apparent how much more desirable, as well as easy, it is to compare simultaneous observations than those wherein both the observed values *and* their times are different. Your Committee have therefore felt it to be their duty to examine how far the existing stations adequately represent the true rainfall of the British Isles. The result shows that their number and distribution, though incomparably superior to that which existed when your Committee were appointed some years since, is still capable of great improvement; tracts of land the rainfall of which as water-supply for towns is of high importance are without adequate observations, while other places are, if possible, too well provided.

To take Devonshire as an example; excepting two gauges at the Convict Prison, one on the northern edge at Chagford, and one on the south at Lee Moor Clay Works, Dartmoor (that wettest of Devonshire districts) has no representative, Exmoor has none at all, and there is no gauge between Torquay and Plymouth. On the other hand, Sidmouth has four or five observers, and Exeter an equal number.

Similar cases of unequal representation occur in various parts, and should be removed. The Tyneside Naturalists' Club are about to establish a series of gauges along the Cheviots, the Cardiff Naturalists' Society are doing the same in South Wales, and other instances could be quoted.

We have already shown that there is a special reason for endeavouring to equalize the representation during the ensuing autumn, so that the new observers whom we hope to obtain may have a few months' practice before the commencement of the decennial period 1870–79.

We hope that the landed proprietors of Great Britain and Ireland are becoming sufficiently aware of the importance of rainfall statistics in engineering and draining operations to see their own advantage in helping us by having observations regularly made by careful persons under their own supervision. There are, however, some districts for which your Committee will have not only to provide the instruments but also to pay some small fee to the observers. To meet this special charge we have to ask for a special grant, in addition to the small ordinary one required for current expenses in the examination of gauges and other kindred matters.

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. OWNER. Observer.	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.	
						Above ground.	Above sea-level.
	1868.					ft. in.	feet.
264.	Sept. 4.	NORFOLK. Thorpe Hamlet Parsonage, Norwich. *MRS. COOKE.* *Mrs. Cooke.*	XI	Negretti & Zambra	9 a.m.	1 0	33
265.	Sept. 4.	NORFOLK. Thorpe, Norwich. *W. BIRKBECK, ESQ.* *W. Birkbeck, Esq.*	III	Casella	9 a.m.	1 0	137
266.	Sept. 4.	NORFOLK. St. Catherine's Close, Norwich. *C. EVANS, ESQ.* *C. Evans, Esq.*	XII	Casella	10 a.m.	2 2	123
267.	Sept. 5.	NORFOLK. East Dereham. *G. H. COOPER, ESQ.* *G. H. Cooper, Esq.*	X	Negretti & Zambra	weekly.	1 3	161
268.	Sept. 5.	NORFOLK. Honingham. *THE LADY BAYNING.* *The Lady Bayning.*	III	Knight	9 a.m.	0 9	88
269.	Sept. 7.	NORFOLK. Mattishall Vicarage. *THE REV. J. M. DU PORT.* *The Rev. J. M. Du Port.*	X	Negretti & Zambra	9 a.m.	1 3	165
270.	Sept. 7.	NORFOLK. Hockering. *THE REV. M. J. ANDERSON.* *The Rev. M. J. Anderson.*	X	Negretti & Zambra	9 a.m.	1 3	140
271.	Sept. 8.	SUFFOLK. Gisleham, Lowestoft. *THE REV. H. JODRELL.* *The Rev. H. Jodrell.*	III	Casella	9 a.m.	1 3	36
272.	Sept. 11.	SUFFOLK. Carlton Colville, Lowestoft. *G. EDWARDS, ESQ.* *G. Edwards, Esq.*	X	Negretti & Zambra	monthly.	0 8	6
273.	Sept. 12.	NORFOLK. Geldeston, Beccles. *E. T. DOWSON, ESQ.* *E. T. Dowson, Esq.*	XII	Casella	9 a.m.	1 1	30
274.	Sept. 14.	SUFFOLK. Somerleyton Hall, Lowestoft. *SIR F. CROSSLEY, BART.*	X	Negretti & Zambra	7 a.m.	3 0	60

RAIN-GAUGES (*continued from last Report*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
5·01	·1	500	—·001	E. House 40°.	On lawn, sloping slightly to W., good position.	264.
5·00	·2	1000	—·002			
5·00	·3	1500	—·003			
4·99	·4	1980	+·001			
M 5·000	·5	2480	correct.			
5·02	·1	504	—·002	S.S.W. Fir 25°.	On crest of hill, sloping gently to the Yare in S.	265.
4·98	·2	1020	—·006			
5·00	·3	1510	—·005			
5·00	·4	2020	—·007			
M 5·000	·5	2520	—·008			
5·00	·01	50	correct.	S.W. Tree 25°.	On dwarf post on large lawn.	266.
5·00	·10	500	—·001			
4·98	·20	1000	—·002			
5·01	·30	1490	—·001			
M 4·998	·40	1980	correct.			
	·50	2480	—·001			
8·02	....	....	....	N.E. Fir 32°.	On slight mound on lawn; ground level. Observer absent and measuring-glass not accessible.	267.
7·98						
8·00						
8·02						
M 8·005						
5·00	·1	495	correct.	N.W. Angle of House 55°.	On edge of flower-bed; ground level.	268.
5·00	·2	990	correct.			
5·00	·3	1520	—·007			
5·00	·4	2020	—·007			
M 5·000	·5	2520	—·008			
7·98	·01	80	+·004	E. Trees 45°.	In kitchen garden, somewhat sheltered; ground level.	269.
8·02	·1	1260	+·001	S.E. ,, 45°.		
8·02	·2	2550	+·001	S.W. ,, 25°.		
7·98	·3	3830	+·002			
M 8·000	·4	5030	+·004			
8·00	·01	127	correct.	N. Trees 60°.	On lawn, surrounded by trees; to be moved to another position where nothing will rise 30° above gauge except one tree in S.E.	270.
7·98	·1	1250	+·001	N.E. ,, 60°.		
8·00	·2	2560	—·002	E. ,, 60°.		
8·00	·3	3820	—·001	S.W. ,, 40°.		
M 7·995	·4	5050	+·002			
5·00	·1	500	—·001	N.E. Trees 40°.	In kitchen garden, and rather sheltered.	271.
5·00	·2	1050	—·012	S.W. ,, 22°.		
5·00	·3	1520	—·007	N.W. ,, 40°.		
4·99	·4	2030	—·012			
M 4·997	·5	2510	—·006			
8·00	·1	1340	—·006	S.W. Rose-bush 50°.	Open position, except as noted; ground level and as noted in other columns; gauge only 6 ft. above mean sea-level, and therefore only 3 ft. above high-water mark.	272.
7·96	·2	2550	—·001			
8·01	·3	3910	—·009			
8·00	·4	5050	+·001			
M 7·992	·5	6330	correct.			
5·00	·01	50	correct.	....	Very good open position in terraced garden.	273.
5·00	·10	500	—·001			
5·00	20	1000	—·002			
4·99	·30	1490	—·001			
4·998	·40	1980	correct.			
	·50	2480	—·001			
8·03	·1	1300	—·002	....	Gauge fixed on a stool in centre of large lawn; quite open.	274.
8·00	·2	2550	—·001			
8·00	·3	3850	—·003			
7·98	·4	5080	correct			
M 8·003	·5	6310	+·003			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Height of gauge. Above sea-level.
						ft.	in.	feet.
275.	1868. Sept. 14.	SUFFOLK. Somerleyton Rectory, Lowestoft. *THE REV. C. J. STEWARD.* *The Rev. C. J. Steward.*	III	Cary	9 a.m.	0	3	56
276.	Sept. 14.	SUFFOLK. Hopton Hall, Lowestoft. *C. CORY, ESQ.*	X	Negretti & Zambra	....	0	3	47
277.	Sept. 15.	SUFFOLK. Acle, Yarmouth. *THE REV. R. W. KENNION.* *The Rev. R. W. Kennion.*	X	Negretti & Zambra	....	0	7	40
278.	Sept. 16.	NORFOLK. Runham. *THE REV. E. GILLETT.* *The Rev. E. Gillett.*	See Fig. p. 390	Sawyer	9 a.m.	6	3	31
279.	Sept. 17.	NORFOLK. Filby, Yarmouth. *MR. G. CRISP.* *Mr. G. Crisp.*	XI	Negretti & Zambra	9 a.m.	2	4	11
280.	Oct. 27.	HAMPSHIRE. Strathfield Turgis Rectory, Winchfield. *G. J. SYMONS, ESQ.* *The Rev. C. H. Griffith.*	XII	Casella	9 a.m.	1	0	209
281.	Oct. 27.	HAMPSHIRE. Strathfield Turgis Rectory, Winchfield. *G. J. SYMONS, ESQ.* *The Rev. C. H. Griffith.*	III	Bryson	9 a.m.	1	0	209
282.	Nov. 2.	NOTTINGHAM. Highfield House, Nottingham. *E. J. LOWE, Esq., F.R.S.*	X	Negretti & Zambra	10 a.m.	25	0	....
283.	1869. Mar. 27.	HAMPSHIRE. Wote Street, Basingstoke. *T. SWEETING, ESQ.* *T. Sweeting, Esq.*	XII	Apps	9 a.m.	1	0	265
284.	Mar. 27.	HAMPSHIRE. Eastlands, Basingstoke. *G. STEPHENS, ESQ.* *G. Stephens, Esq.*	III	Wheeler...........	9 a.m.	1	0	300
285.	April 7.	YORKSHIRE. Saddleworth Station. *L. & N.-W. RAILWAY.* *The Station Master.*	VI	Crosley	monthly.	5	0	640

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
5·00	·1	500	−·001	....	In kitchen garden, open position; suggested its being raised a little to avoid in-splashing.	275.
5·01	·2	1000	−·001			
5·02	·3	1500	−·002			
5·00	·4	2000	−·002			
M 5·008	·5	2500	−·003			
8·00	·1	1290	−·001	S.E. Tree 32°.	Sunk in a large pot, on lawn; quite clear, except as noted.	276.
8·00	·2	2600	−·005			
7·98	·3	3940	−·011			
8·00						
M 7·995						
8·00	·1	1260	correct.	N.E. Laburnum 55°.	On edge of carriage drive, and near a light iron railing.	277.
8·01	·2	2580	−·004	S.W. House 32°.		
7·90	·3	3850	−·004			
8·03	·4	5130	−·006			
M 7·985	·5	6380	−·004			
4·03	·1	300	+·006	N.E. Trees 50°.	In garden, position not the best available; suggested removal on January 1, 1869.	278.
4·02	·2	600	+·012	S.W. ,, 28°.		
4·00	·5	1550	+·015	N.W. ,, 50°.		
4·00	1·0	3150	+·014			
M 4·012						
5·02	·1	500	−·001	N. House 54°.	Very much sheltered; to be raised 3 ft., which will make it nearly clear.	279.
4·98	·2	1000	−·001	S.E. Trees 30°.		
5·01	·3	1500	−·002	N.W. ,, 47°.		
5·00	·4	1990	−·001			
M 5·003	·5	2480	correct.			
3·01	·1	160	+·010	....	In experimental rain-gauge enclosure; clear of everything.	280.
3·00	·2	350	+·004			
3·00	·3	540	−·002			
2·99	·4	720	−·004			
M 3·000	·5	900	−·004			
4·69	·1	450	−·004	....	Close to No. 280.	281.
4·65	·2	900	−·008			
4·68	·3	1345	−·012			
4·66	·4	1800	−·016			
M 4·670	·5	2250	−·024			
7·87	....	....	....	....	On N.E. parapet of house. Glass not measured.	282.
8·02						
7·83						
7·96						
M 7·920						
5·02	·1	520	−·004	S.E. Pear 55°.	Part of pear-tree will be cut off; position will then be very good.	283.
5·00	·2	1020	−·004			
5·01	·3	1500	correct.			
5·04	·4	2010	−·003			
M 5·017	·5	2510	−·003			
5·00	·1	500	−·001	W. House 32°.	In kitchen garden; ground level, and position good.	284.
5·00	·2	1000	−·001			
5·02	·3	1500	−·002			
5·00	·4	1990	−·001			
M 5·005	·5	2480	+·001			
9·97	....	....	....	....	On a stone column on the top of a railway-cutting; nearly level with the chimnies of the station.	285.
9·97						
9·98						
9·96						
M 9·970						

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Above sea-level.
	1869.					ft.	in.	feet.
286.	April 7.	YORKSHIRE. Friesland Vicarage, Greenfield. *THE REV. G. VENABLES.* *The Rev. G. Venables.*	XI	Negretti & Zambra	9 a.m.	3	6	550
287.	April 7.	YORKSHIRE. Standedge. *L. & N.-W. RAILWAY.*	I	....	monthly.	2	0	1150
288.	April 8.	YORKSHIRE. Harden Moss, Meltham. *HUDDERSFIELD WATER WORKS.*	X	Negretti & Zambra	....	1	0	1200
289.	April 8.	YORKSHIRE. Bilberry Reservoir, Holmfirth.	I	....	monthly.	1	6	800
290.	April 8.	YORKSHIRE. Boshaw Whams.	I	....	monthly.	1	9	950
291.	April 8.	YORKSHIRE. Holme Styes Reservoir, Holmfirth.	I	....	....	2	0	850
292.	April 8.	YORKSHIRE. Dunford Bridge Reservoir. *DEWSBURY WATER WORKS.* *Mr. G. Whitfield.*	II	Newman?	....	2	0	1100
293	April 8.	YORKSHIRE. Dunford Bridge Station. *M. S. & L. RAILWAY.*	VIII	Casartelli	8½ A.M.	3	2	954
294.	April 8.	YORKSHIRE. Carlcotes. *M. S. & L. RAILWAY.*	VIII	Casartelli	9 a.m.	3	0	1075
295.	April 9.	YORKSHIRE. Meltham Grange. *HUDDERSFIELD WATER WORKS.*	X	Negretti & Zambra	....	1	1	925
296.	April 9.	YORKSHIRE. Scope, Meltham. *E. C. GOODDY, ESQ.* *Mr. J. Taylor.*	VIII	Casartelli	Var.	3	8	1125

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
5·02 5·02 5·00 5·04 M 5·020	·1 ·2 ·3 ·4 ·5	490 970 1460 1955 2460	+·002 +·006 +·008 +·009 +·008	E. Church 42°. S. House 28°. W. Trees 30°.	Fixed on dwarf post in the garden, which is somewhat shut in by the railway embankment; ground hilly.	286.
8·05 8·03 8·05 7·98 M 8·028	....	....	nearly correct.	....	Very exposed position on a slight slope, but nothing rises more than 5° above the gauge, which is *very* much weather-worn.	287.
7·96 8·02 7·99 8·01 M 7·995	....	....	....	....	On level piece of moor, quite exposed, but surrounded by a 5-ft. iron hurdle fence 6 ft. square. Glass not accessible.	288.
8·02 7·98 8·01 7·99 M 8·000	....	....	correct	N.E. Wall and rising ground 21°.	On a flat bank on a steep hill-side facing S.W. Orifice so large as unduly to facilitate evaporation.	289.
6·92 0·97 6·95 6·94 M 6·945	....	....	correct	....	In a flat field E. of the reservoir; very open. When visited the top was not properly on the cylinder, and much loss must have resulted.	290.
7·00 6·80 6·92 6·62 M 6·835	....	....	....	....	In a box made of inch-wood, the sides of which being level with the rim of the gauge produce in-splashing. The orifice of the gauge being very large will compensate for this error. Hilly ground.	291.
11·81 12·02 11·93 12·01 M 11·943	....	....	correct	....	On west end of embankment, very exposed position.	292.
8·48 8·50 8·46 8·50 M 8·485	·1 ·2 ·3 ·4 ·5	1400 2760 4200 5550 7000	+·002 +·007 +·006 +·011 +·010	....	A short distance E. of station, on flattish ground. Hills rise to a considerable height in N.E.	293.
8·55 8·46 8·42 8·48 M 8·478	·1 ·2 ·3 ·4 ·5	1430 2780 4150 5570 7050	correct +·005 +·009 +·009 +·005	N.N.E. Tree 33°.	In field. The box holding this gauge was tilted nearly 5° to S.W., and had been so for some little time; had it levelled.	294.
7·83 8·02 7·98 8·10 M 7·982	....	....	....	....	Good position in large flat field. Glass not accessible.	295.
8·50 8·51 8·48 8·50 M 8·498	·1 ·2 ·3 ·4 ·5	1460 2900 4310 5700 7050	−·002 −·003 −·001 +·002 +·008	....	Near the centre of the moor, slight ridge in W.S.W., but its elevation only 10°. Position good.	296.

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Height of gauge. Above sea-level.
	1869.					ft.	in.	feet.
297.	April 9.	YORKSHIRE. Broadstone Reservoir. *DEWSBURY WATER WORKS.*	II	....	....	2	0	1065
298.	April 9.	YORKSHIRE. Ingbirchworth. *BARNSLEY LOCAL BOARD.* *Mr. Brown.*	X	Negretti & Zambra	....	1	0	950
299	April 9.	YORKSHIRE. Penistone Station. *M. S. & L. RAILWAY.*	VIII	Casartelli	9 a.m	3	6	717
300.	April 14.	YORKSHIRE. Redmires. *SHEFFIELD WATER WORKS CO.*	X	Negretti & Zambra	....	4	3	1100
301.	April 14.	YORKSHIRE. Redmires. *SHEFFIELD WATER WORKS CO.*	VI	Watkins & Hill.	....	4	3	1100
302.	April 15.	LANCASHIRE. Blackstone Edge. *ROCHDALE CANAL COMPANY.*	I	....	monthly.	2	6	1200
303.	April 15.	YORKSHIRE. Longwood Reservoir. *HUDDERSFIELD WATER WORKS.*	VI	....	....	4	11	600
304.	April 16.	YORKSHIRE. Fartown, Huddersfield. *CAPT. CHICHESTER.* *Capt. Chichester.*	III	Casella	9 a.m.	0	8	300
305.	April 16.	YORKSHIRE. Dalton, Huddersfield. *J. W. ROBSON, ESQ.* *J. W. Robson, Esq.*	XI	Negretti & Zambra	9 a.m.	0	3	350
306.	April 16.	YORKSHIRE. Dalton, Huddersfield. *J. W. ROBSON, ESQ.* *J. W. Robson, Esq.*	X	Negretti & Zambra	9 a.m.	0	3	350
307.	April 19.	MIDDLESEX. Grove House, Tottenham. *C. ASHFORD, ESQ.* *C. Ashford, Esq.*	III	Smith & Beck ...	9 a.m.	2	0	....

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
12·02	....	....	....	....	Gauge leaky, and not in use, level with reservoir bank.	297.
11·98						
12·00						
12·01						
M 12·002						
8·06	·1	1200	+·004	W. House 20°.	In cottage garden N. of reservoir; country gently undulating.	298.
7·82	·2	2520	—·001	N. Tree 40°.		
7·93	·3	3770	correct.			
8·01	·4	5050	—·002			
M 7·955	·5	6290	—·001			
8·50	·1	1350	+·006	....	Gauge tilted $\frac{3}{4}$ of an inch to S.E.; position bad, being close to the top corner of a wall which drops 25 ft. abruptly below the gauge.	299.
8·50	·2	2850	+·001			
8·50	·4	5700	+·001			
8·46	·5	7040	+·008			
M 8·490						
8·00	·1	1300	—·003	....	In garden on N. bank of reservoir, rather exposed.	300.
8·00	·2	2600	—·005			
8·00	·3	3810	correct.			
8·00	·4	5050	+·002			
M 8·000	·5	6260	+·007			
10·00	....	....	....	....	15 ft. E. of No. 300.	301.
10·00						
10·00						
10·00						
M 10·000						
10·00	....	....	....	....	On west side of the Edge, in a very exposed part of the moor. Measuring-rod absent; apparently a good gauge.	302.
10·05						
10·01						
9·98						
M 10·010						
10·00	....	....	....	....	At S.E. corner of lower reservoir bank; rapid fall to E. and S.	303.
9·88						
9·94						
10·00						
M 9·955						
5·00	·1	495	correct.	S.W. House 35°.	In garden N.E. of house, open position, undulating ground.	304.
4·99	·2	980	+·002			
4·99	·3	1490	—·001			
5·00	·4	1980	correct.			
M 4·995	·5	2450	+·005			
4·98	·1	490	+·001	N.E. Hedge 30°.	In level and rather sheltered garden.	305.
5·03	·2	1000	—·002			
5·00	·3	1510	—·005			
5·00	·4	2000	—·003			
M 5·002	·5	2500	—·004			
8·00	·1	1350	—·007	N.E. Hedge 30°.	Close to No. 305.	306.
7·99	·2	2500	+·003			
8·02	·3	3820	—·001			
8·00	·4	5120	—·003			
M 8·003	·5	6300	+·004			
5·02	....	....	....	S.W. Apple 42°.	In large garden rather full of trees; no better position. Testing-glass broken. To be revisited.	307.
5·00						
4·98						
5·02						
M 5·005						

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.	
						Above ground.	Above sea-level.
	1869.					ft. in.	feet.
308.	May 3.	DERBYSHIRE. Woodhead Station. *M. S. & L. RAILWAY.* *Station Porter.*	VIII	Casartelli	9 a.m.	3 6	878
309.	May 3.	CHESHIRE. Woodhead Reservoir. *MANCHESTER WATER WORKS.*	XII	....	9 & 9	0 6	850
310.	May 3.	CHESHIRE. Woodhead Reservoir. *MANCHESTER WATER WORKS.*	II	Newman	6 a.m.	0 10	680
311.	May 4.	CHESHIRE. Torrside. *MANCHESTER WATER WORKS.*	II	Newman	7 a.m.	1 6	600
312.	May 4.	CHESHIRE. Rhodes Wood Reservoir. *MANCHESTER WATER WORKS.*	II	Newman	6 a.m.	1 0	520
313.	May 17.	MIDDLESEX. Squires Mount, Hampstead. *R. FIELD, ESQ.* *R. Field, Esq.*	III	Private	9 a.m.	1 0	380
314.	May 17.	MIDDLESEX. Squires Mount, Hampstead. *R. FIELD, ESQ.* *R. Field, Esq.*	III	Casella	9 a.m.	1 0	380
315.	May 17.	MIDDLESEX. Squires Mount, Hampstead. *R. FIELD, ESQ.* *R. Field, Esq.*	III	Casella	9 a.m.	1 0	380
316.	May 17.	MIDDLESEX. The Grove, Hampstead. *H. SHARPE, ESQ.* *H. Sharpe, Esq.*	XII	Casella	9 a.m.	50 0	470
317.	May 17.	MIDDLESEX. The Grove, Hampstead. *H. SHARPE, ESQ.* *H. Sharpe, Esq.*	XII	Apps	9 a.m.	2 0	440
318.	July 5.	HAMPSHIRE. Highfield Park, Winchfield. *H. MARSON, ESQ.* *H. Marson, Esq.*	XII	Apps	9 a.m.	1 6	250

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
8·50	·1	1450	−·001	....	On slight mound, in gorge, 300 yards W. of W. entrance to the Woodhead Tunnel.	308.
8·50	·2	2850	+·001			
8·50	·3	4250	+·003			
8·50	·4	5650	+·006			
M 8·500	·45	6450	correct.			
5·02	·1	470	+·005	....	Near keeper's house, Woodhead reservoir; on ground sloping to S.W.	309.
4·94	·2	980	+·001			
5·00	·3	1490	−·002			
4·98	·4	1990	−·004			
M 4·985	·5	2460	+·001			
11·95	....	....	nearly correct, but see remarks.	....	In valley near the reservoir; quite open; rod attached.	310.
12·05						
12·00						
11·93						
M 11·983						
12·02	....	....	correct.	....	In valley near keeper's house; good position.	311.
12·01						
12·02						
12·02						
M 12·017						
12·02	....	....	nearly correct.	....	Open situation in valley, running E.W.; rod attached, and rim curved.	312.
11·94						
12·00						
12·01						
M 11·993						
5·00	·1	498	correct.	N. Bush 40°.	The grounds being much wooded, this and the two following gauges are so arranged that from whatever point the rain has fallen, one of the gauges will be uninfluenced thereby, and the observations are tabulated accordingly.	313.
5·00	·2	990	correct.	E. Trees 73°.		
5·02	·3	1500	−·003	W. Trees 38°.		
4·98	·4	1990	−·001			
M 5·000	·5	2480	correct.			
5·02	·1	498	correct.	N. Bushes 49°.		314.
4·98	·2	990	correct.	N.E. Elms 58°		
5·03	·3	1500	−·002	W. Poplars 46°.		
4·98	·4	1990	−·001			
M 5·002	·5	2480	correct.			
5·00	·1	498	correct.	N. Trees 58°.	....	315.
5·00	·2	990	correct.	E. Elms 42°.		
5·00	·3	1500	−·003	S.W. Poplars 88°.		
5·00	·4	1990	−·001			
M 5·000	·5	2480	correct.			
5·00	·1	498	−·001	....	On corner of gallery surrounding tower of house; very exposed position.	316.
5·00	·2	998	−·001			
5·03	·3	1500	−·003			
4·96	·4	1980	correct.			
M 4·998	·5	2470	+·002			
5·00	·1	498	correct.	N.E. Wall 28°.	In small garden, rather shut in by walls and trees.	317.
5·00	·2	998	−·001	S.E. Tree 40°.		
5·00	·3	1500	−·003	S. Shed 32°.		
5·00	·4	2000	−·003			
M 5·000	·5	2480	correct.			
5·03	·1	495	+·001	S.W. Apple 41°.	In level garden; very good position except as noted.	318.
5·00	·2	1000	correct.			
5·03	·3	1500	−·001			
5·00	·4	2005	−·002			
M 5·015	·5	2500	−·001			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.	
						Above ground.	Abov sea-level.
	1869.					ft. in.	feet.
319.	July 8.	BERKSHIRE. Forbury Gardens, Reading. *BOARD OF HEALTH.* *Mr. Davis.*	XI	Negretti & Zambra	9 a.m.	1 1	15c
320.	July 8.	BERKSHIRE. Russell Street, Reading. *DR. WORKMAN.* *Dr. Workman.*	III	Knight	9 a.m.	1 6	15

Interim Report of the Committee on the Laws of the Flow and Action of Water containing Solid Matter in Suspension, consisting of T. Hawksley, Professor Rankine, *F.R.S.,* R. B. Grantham, Sir A. S. Waugh, *F.R.S., and* T. Login.

Your Committee considered, in the first place, what experiments would be necessary in order to furnish the data required for the determination of the laws of the flow and action of water containing solid matter in suspension, and what would be the probable cost of these experiments. Their estimate of that cost was £5000, and they came to the conclusion that this was beyond the means of the Association. They had no authority to apply to the Government in the name of the British Association; but in their individual capacity they addressed a memorial to Her Majesty's Secretary of State for India, representing the practical value of such experiments, and especially their importance to the interests of India. That memorial was accompanied by a general description of the experiments required, and an estimate of their cost; and copies of all these documents are appended hereto. The Government, however, declined to accede to the application.

Your Committee beg leave to represent that, if reappointed, and invested with power to apply to the Government in the name of the British Association, their future application might meet with better success.

Appendix.

I. Flow of Water with Solid Matter in Suspension.

Sketch of proposed Course of Experiments.—1. It is proposed to apply for the temporary use of a piece of ground near London, and, if possible, in the neighbourhood of the Kew Observatory.

2. A canal to be constructed with a smooth bottom and sides of plate glass about 500 feet long, 5 feet broad, and 3 feet deep, and capable of being covered when required.

3. At one end of the canal will be a reservoir supplied with water by means

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
4·98	·1	500	−·001	S. Wellingtonia 38°.	In the gardens near the station; good position.	319.
5·01	·2	1000	−·002			
5·00	·3	1480	+·001			
5·00	·4	1975	+·001			
M 4·997	·5	2480	−·001			
4·98	·1	500	−·001	S.W. Apple 51°. W.N.W. „ 35°.	In garden in rear of house on slight bank, and sheltered as noted; no material improvement in position practicable, except by cutting down one or two good trees.	320.
5·02	·2	1010	−·002			
4·98	·3	1505	−·004			
5·01	·4	2020	−·008			
M 4·998	·5	2505	−·006			

of a small pumping steam-engine, and containing mechanism for diffusing solid matter of different kinds in the water.

4. The water will be made to flow along the canal at first pure, and then with different proportions of different kinds of solid matter in suspension, and with different depths of current.

5. Observations will be made of:—

A. The declivity of the surface of the water.

B. The velocity of the current at the surface, bottom, sides, and intermediate points, also the mean velocity.

C. The mode of motion of the particles as seen through the plate-glass sides of the trough.

D. The rate at which solid matter is either deposited or swept away by the current under various circumstances.

E. The temperature of the water.

F. The direction and velocity of the wind when the trough is exposed to it.

6. Experiments to be made to determine the quantities of solid matter contained in samples of water taken from different points in the length, breadth, and depth of the trough.

7. Observations and experiments to be made with the inner surface of the trough roughened in various ways.

8. Also with weirs and other obstacles of different forms and in different positions.

9. The results of the observations and experiments to be compared with those of observations (so far as these have been recorded) made upon actual rivers and on the great scale.

10. The whole results to be submitted to mathematical analysis, in order to deduce general laws and practical rules from them.

11. The rough estimate of the outlay required for materials, work, and pay of assistants and workmen till the next Meeting of the British Association is £1500.

This is exclusive of the pay of the engineer from the Public Works Department of India, to whom it is proposed to entrust the superintendence; but it is believed that the entire series of experiments and investigations will not exceed £5000.

II.

To His Grace The Duke of Argyll, K.T., Her Majesty's Secretary of State for India. The Memorial of Thomas Hawksley, Civil Engineer, Vice-President of the Institution of Civil Engineers; Major-General Sir Andrew Scott Waugh, Knight; William J. Macquorn Rankine, Civil Engineer, Regius Professor of Civil Engineering and Mechanics in the University of Glasgow; Richard Boxall Grantham, Civil Engineer, Member of the Institution of Civil Engineers; and Thomas Login, Civil Engineer, Member of the Institution of Civil Engineers.

Sheweth,—That your Memorialists respectfully solicit Your Grace's attention to a subject of great importance in the construction of artificial rivers for irrigation and drainage.

That at a Meeting of the British Association in August last at Norwich, a paper was read by Mr. Login, one of your Memorialists, on the abrading and transporting power of water, in which he laid before the Association the results of his experience in India regarding the power of flowing water for holding solid matter in suspension.

The subject was considered to be of so much practical importance, that your Memorialists were appointed a Committee to report upon it to the Mechanical Section of the British Association; but they have found the present state of scientific knowledge to be so vague and imperfect that it is in their judgment necessary to obtain, in the first instance, a complete series of experimental data.

To institute experiments would, however, require some expenditure for apparatus and attendance beyond the means of the Association.

Moreover, since the results of the investigations would, in the opinion of your Memorialists, be of great public utility, they venture, independently of the Association and solely in their individual capacities, to lay this matter before Your Grace in the hope that the Indian Department of Her Majesty's Government will take the subject matter of this Memorial into their consideration, and if deemed expedient direct that the requisite investigation may be undertaken at the public expense.

(Signed) T. Hawklsey, V.P.Inst.C.E.
Andrew Scott Waugh, Major-Gen. R.E., F.R.S.
W. J. Macquorn Rankine, C.E., LL.D., F.R.S.
Richard B. Grantham.
T. Login.

Interim Report by the Committee on Agricultural Machinery, consisting of the Duke of Buccleuch, *F.R.S.*, The Rev. Patrick Bell, David Greig, J. Oldham, William Smith, *C.E.*, Harold Littledale, The Earl of Caithness, *F.R.S.*, Robert Neilson, Professor Rankine, *F.R.S.*, F. J. Bramwell, Rev. Professor Willis, *F.R.S., and* Charles Manby, *F.R.S.*; P. Le Neve Foster *and* J. P. Smith, *Secretaries.*

This Committee have to report that several of its members have been engaged in collecting and arranging the information necessary in order to enable a final report to be prepared; but that, in consequence of the great extent and variety of the subjects to be reported on, and the very recent date of the trial of implements by the Royal Agricultural Society, and by the Highland Agricultural Society of Scotland, on the results of which trials the Report must to a great extent be based, it has been found impossible to complete a final Report in time for the present Meeting. A short Report upon reaping-machines has been furnished by Mr. Oldham; but the Committee consider it advisable to defer publishing it until it can be included in a general Report, especially as some important trials of reapers have been made since it was written.

Your Committee beg leave to represent that, if reappointed, they are confident of being able in due time to present a satisfactory Report to the Association.

Report on the Physiological Action of the Methyl and Allied Series. By BENJAMIN W. RICHARDSON, *M.A., M.D., F.R.S.*

IN introducing the present Report to the Association, I would, as preliminary to new matter of research, record that the substance known as bichloride of methylene (the properties of which I was led to study as a part of the work entrusted to me in previous years) has, during the past twelve months, increased very greatly in practical importance. The bichloride has been used for general anæsthesia on a large scale in Guy's, the London, Charing Cross, Ophthalmic, and Samaritan Hospitals. It has also been largely employed for the same purpose in the provinces of England. In France its action has been carefully studied, and one of the graduation theses at Strasbourg has been devoted to the subject of its action. In Italy the bichloride has made its way, and in Germany it is employed by the distinguished Von Graefe (who learned its application from Dr. Taylor of Nottingham), and by several other eminent surgeons.

Respecting the action of the bichloride of methylene and its advantages over other anæsthetics as yet discovered and rendered applicable, I have received special reports from the following gentlemen:—Peter Marshall, Esq., Administrator at the Charing Cross Hospital, Dr. Junker, Administrator at the Samaritan Free Hospital, J. Rendle, Esq., Administrator at Guy's, J. Adams, Esq., of the London Hospital, J. Bader, Esq., Ophthalmic Surgeon at Guy's, Dr. Taylor, Surgeon to the Ophthalmic Hospital of Nottingham, and Mr. Wood of Brighton.

I am happy to add that up to this date (August) no accident has occurred in the administration of the bichloride. I have never held that it is free from danger, and I reported in regard to it, at first, that it could not be considered as the safest agent of its kind until it had been administered twenty thousand times with a totality of less than ten deaths as the result. I hope, however, now that it may even go safely through this very severe ordeal; for at the lowest estimate it has been administered 4500 times in England alone without a fatal catastrophe. In the experience which has sprung from the administration of this anæsthetic, one very interesting and valuable practical truth has come forth, viz. that with skill on the part of the administrator the most rapid and safest insensibility can be induced with a quantity not exceeding sixty minims; thus for small operations, or, I had better said, short operations, such as tooth-extraction, operation for cataract, &c., the required anæsthesia can be induced in from twenty to forty seconds, with perfect recovery in from three to five minutes. The mode of administering, in order to produce these effects, is simple: the inhaler I showed last year is modified by being lengthened, and the fluid is not introduced as spray, but is poured directly into the inhaler. The inhaler itself is made of leather, and is lined with loose demette; it is perforated at the end furthest removed from the mouth, so as to admit air. For this modification of inhaler, and for demonstrating the extremely rapid action of the bichloride with it on the human subject, we are indebted to Mr. Rendle. The method has been successfully employed now in four hundred operations. I may be pardoned for dwelling on this practical fact for one reason alone; for this reason, that it shows the true value of a correct theory in estimating the properties of chemical substances on living animal bodies, based on the physical characters, purely, of the substances themselves. From the chemical composition of the bichloride of methylene, from its boiling-point, and the density of its vapour, I was able to claim for it its probable place as an anæsthetic before it was subjected to the test of experience, and especially to claim for it that its power to take effect would be as rapidly developed as would be the recovery from it when it was withdrawn. The practice has proved the theory to have been in this case safely founded; and the fact may be accepted as an encouragement to all who are or may be striving to reduce our knowledge of the action of medicinal agents to fixed principles. For my part I am certain (and I think the after pages of this Report will help to prove the idea) the day is at hand when the mere chemical and physical characters of any substance being known to the physiologist, he will be able to foresee clearly what are the physiological values of the substance, and to calculate the symptoms and changes it will induce in the animal economy from pure theoretical formulas and with perfect precision.

Methylal.

The substance methylal, $C_3 H_8 O_2$, to which I called attention last year, deserves another brief word. I confirm what I said concerning it last year, viz. that it is a slowly acting anæsthetic, producing by its inhalation a sleep which is very deep and prolonged. I would add to this Report that methylal may be taken internally in the same proportion as common ether (it could be used also in the form of hypodermic injection), and that, as it is soluble in water, it promises to be a very valuable addition to our list of anodyne remedies. During the past months Liebreich of Berlin has brought out the substance chloral ($C_2 H Cl_3 O$) as a body which possesses the power of inducing long-continued sleep. I have not yet been able to obtain chloral for experiment *.

PLAN OF NEW RESEARCHES.

In the new researches to which I have devoted my attention since last Meeting, I have aimed, while studying the action of several compounds which have not previously been considered by the physiologist, to bring the present work, together with the past, into systematic arrangement, to group under their proper chemical heads the agents submitted to inquiry, and to ascertain whether any distinctive physiological characteristics could be discovered as connected with distinct chemical series of organic bodies. I commenced, therefore, by placing before myself a set of Tables which I now put before the

* After the reading of this Report Dr. Richardson was supplied, at Exeter, with a specimen of chloral by Daniel Hanbury, Esq. He was thus enabled, at the request of the Section, to bring up a supplementary report on chloral during the Meeting.

Section. I have grouped in these Tables certain representatives of different series in their natural place and in five divisions, viz. nitrites, hydrides, alcohols, chlorides, and iodides. Under each division the two first representatives of the series are tabled, and the fourth and fifth. The propylic compounds, which would form the third representatives, are omitted in every case, owing to the difficulty of obtaining perfectly reliable specimens. The substances named in italics have been considered in previous Reports.

	Name.		Chemical composition.	Vapour-density, $H_2=1$.	Specific gravity. Water 1000.	Boiling-point.		Percentage of iodine in iodides.
	Old.	New.				C.	F.	
						°	°	
HYDRIDES.	*Methyl* ...	Protylen	$C\ H_3\ H$	8	Gas.	......	......	
	Ethyl ...	Deutylen	$C_2\ H_5\ H$	15	Gas.	......	......	
	Butyl ...	Tetrylen	$C_4\ H_9\ H$	29	Gas.	.....	......	
	Amyl ...	Pentylen	$C_5\ H_{11}\ H$	36	·625	30	86	
NITRITES.	*Methyl* ...	Protyl ...	$C\ H_3\ NO_2$	30·5	Gas.	......	......	
	Ethyl ...	Deutyl...	$C_2\ H_5\ NO_2$	37·5	·917	18	64	
	Butyl ...	Tetryl ...	$C_4\ H_9\ NO_2$	51·5	......	64	147	
	Amyl ...	Pentyl...	$C_5\ H_{11}\ NO_2$	58·5	·877	96	205	
ALCOHOLS.	*Methylic*	Protylic	$C\ H_4\ O$	16	·814 at 0° C.	60	140	
	Ethylic .	Deutylic	$C_2\ H_6\ O$	23	·792 at 16° C.	78	172	
	Butylic .	Tetrylic	$C_4\ H_{10}\ O$	37	·803 "	110	230	
	Amylic...	Pentylic	$C_5\ H_{12}\ O$	44	·811 "	132	270	
CHLORIDES.	*Methyl*...	Protyl ...	$C\ H_3\ Cl$	25·25	Gas.			
	Ethyl ...	Deutyl...	$C_2\ H_5\ Cl$	32·25	·921 at 0° C.	11	52	
	Butyl ...	Tetryl ...	$C_4\ H_9\ Cl$	46·25	·880 at 16° C.	70	158	
	Amyl ...	Pentyl...	$C_5\ H_{11}\ Cl$	53·25	......	102	216	
IODIDES.	Methyl...	Protyl ...	$C\ H_3\ I$	71	2·240 at 16° C.	42	108	89·4
	Ethyl ...	Deutyl...	$C_2\ H_5\ I$	78	1·946 "	72	162	81·4
	Butyl ...	Tetryl ...	$C_4\ H_9\ I$	92	1·604 "	120	248	69·4
	Amyl ...	Pentyl ...	$C_5\ H_{11}\ I$	99	1·511 "	146	295	64·1

While in this manner studying the various substances in great groups, I have tried also to study peculiarities of action in members of the same group, with special reference, in each case, to the effect of the aggregation of carbon and increase of weight.

To these observations I have been able to add others, which refer to the individual peculiarities of some special compounds; and when those peculiarities have suggested a practical and useful application, I have noted the facts with care, and embodied them in my remarks.

Lastly, as in the course of my research many opportunities were offered of studying the dangers in the administration of some of the chemical bodies named in the Table, I took advantage of such opportunities to test by experiment the best means of counteracting those dangers when they occur. This therefore forms a concluding and special part of the present Report.

In preparing for experiments, certain rules were followed which it is right at once to name.

In all cases where the substance to be examined was a gas, it was administered by inhalation; in cases where the substance was a very volatile liquid, it was administered by inhalation chiefly; and in cases where the substance was less easily volatilizable, it was administered not merely in the form of vapour, but either by the mouth or by subcutaneous injection.

As it soon became apparent that, under all forms of administration, the results were materially modified by temperature, care was taken to secure, in analogous experiments, the same ranges of temperature. This was effected by means of specially constructed chambers, into which the air could be admitted in measured quantities, and in which the air or atmosphere could be maintained for any length of time at a nearly fixed degree, the variations at the extremest being under three degrees in Fahrenheit's scale. (The chamber was defined in a diagram. In it the air could be raised to 120° Fahr. and sustained at that heat, or reduced to 10° below freezing-point and kept at that low temperature steadily.)

Another chamber was also used in experiments where inhalation of an atmosphere charged with a foreign gas or vapour was not wanted; this consisted of a simple metal chamber with a double lining, through which warm or cold air could be passed at pleasure. Within it was slung a cradle lined with thick felt, made after the manner of a hammock. In this chamber the air could be readily raised to a temperature of 160°, or even 200° Fahr.; but the chamber was not air-tight, and was not adapted for holding in circuit atmospheres of common air mixed with vapours or gases. It was always well ventilated with pure air, and was used for inducing recovery, or for proving the conditions adverse or favourable to recovery from certain of the agents employed when they were administered in excess.

The classes of animals subjected to the vapours or fluids were batrachians, birds, small herbivorous and carnivorous mammals. In every instance where comparative inquiries were made the utmost care was taken to estimate mere apparent differences of phenomena from the same agent from differences in the character or constitution of the animal submitted to the action of the agent. The natural temperatures of all the warm-blooded animals was recorded from time to time, and the mean temperature was calculated and adopted as the natural standard.

Advantage was taken of different seasons of the year, and of extreme natural variations of heat and cold, for the carrying on of many of the inquiries. This point of practice, followed out at first without reference to any other than the present research, was found to have a distinct and important bearing on the general question of the use and administration of chemical medicinal agents.

I now pass to the first part of this Report, taking up the study of the groups of substances in the order of the Tables.

PART I.—THE NITRITE SERIES.

In previous Reports I have called the attention of the Section to the action of the nitrites of methyl, ethyl, and amyl. I have experimented during the past year with the nitrite of butyl, and have thus completed the elementary study of the group up to the amyl or pentylic series. The specimen of nitrite of butyl I used was made for me by Professor Wanklyn. It is obtained by the action of nitrous acid upon butylic alcohol.

Nitrite of butyl is a slightly coloured fluid, having an odour like nitrite of amyl, but it is not so overpowering. Its physiological action is nearly the same as that of nitrite of amyl, but less intense and protracted; it quickens the pulse, produces suffusion of the countenance, causes great oppression on the brain, and those singular noises or sounds in the head which resemble the sounds produced by the rushing of water. The breathing also is affected, and the respiratory muscles are influenced as after running sharply until out of breath. In a case where a young friend of mine (who has naturally a very hard and quick pulse) inhaled the nitrite, I noticed, during the time when the face was suffused, that the pulse, which previously had been beating at 80 per minute, did not rise to more than 86 beats, but became much relaxed and even feeble, regaining its tone within a few seconds after the agent was withdrawn. For practical purposes, the nitrite of butyl presents to me no advantages over the nitrite of amyl, and it has the disadvantage that it is more easily decomposed.

General Review of the Nitrites in regard to Physiological Action.

With these observations on nitrite of butyl we may, I think, consider that the physiological properties of the nitrites is, in an elementary sense at least, understood. They all present a beautiful unity of action, varied only in increasing force and persistency of action as the weight of each representative in the series increases with and from increase of carbon. The summary of their action is briefly as follows: they act instantaneously on the nervous system of organic life, reducing the power or force of that system, and reducing, as a result, the vascular tension; thus they cause relaxation of extreme vessels, and that suffusion of blood which is the most prominent visible sign of their effect; thus they cause intense action of the heart, followed by quickened respiration, due to the liberation of the heart from the tension to which it is normally subject; thus, administered internally, they cause (and this is specially the case with nitrite of ethyl or nitric ether) free secretion of organs, such as the kidneys, which are under the control of the organic nervous centres.

Acting in the manner thus stated on the vascular tension, they produce an action on the voluntary muscles and on the brain, leading to paralysis of muscular and mental power, when carried to extremity. But this paralysis is in every sense a secondary action of the nitrites; they produce no anæsthesia showing primary action in the cerebral organs; they cause no convulsion of the voluntary muscles showing primary action on the cerebrum, cerebellum, or spinal cord. Unconsciousness and muscular prostration, when they follow, are due to destruction of organic nervous control over the vessels which supply the great nervous centres with blood; and the final general prostration is syncope, syncope as pure as that emotional syncope which awaits fear or intense anger, or the equivalent of these, sudden loss or removal of blood from the centres of volitional power.

I hope I do not seem to press these facts unduly; for in reality, when the whole question is seen by the experimental physiologist, it cannot be too strongly urged. In the organic nitrites we hold in our hands a series of chemical agents which exert an influence over a specific set of organs in animal bodies, and over those organs in one specific way. Further, these agents, against our wills, act through precisely the same means and in precisely the same manner as do the more obscure, because more refined, influences which excite daily in us what we call emotions. An act which shall call forth a blush, an act which shall call forth the pallor of terror, an act which shall produce involuntary secretion, an act which shall make the heart beat with an intensity that is painfully felt,—all and any of these acts, which would be called psychical, have their precise physical analogues in the actions of the organic nitrites. In this study the physiologist meets the psychologist on common ground; his facts as to effects from the physical cause are as sure as are facts from the effects of mental causes; but how either the physical or the psychical impression is made remains yet to be discovered. It may in either case be an immediate impression conveyed by the nervous expanses of the senses direct to the organic nervous sympathetic chain. It may be in either case an indirect impression conveyed from within the body, and, as one would imagine by the blood, to that nervous chain. But why the nervous chain should thereupon lose its controlling power, what molecular change is communicated to it to make it lose its power, we cannot answer at present. We must be content to wait, satisfied for the moment with the possession of a truth which fifty years ago the most sanguine physiologist would not have dreamed of, that there is a class of organic bodies by which we are able to induce, in a simple physical way, what have been called up to this time emotional phenomena.

One other observation deserves a moment's expression, inasmuch as it explains a well-known symptom which many persons have experienced. If the heart be thrown into sudden action by any external cause, by breathing, for example, the vapour of nitrite of amyl, there is produced in the head a peculiar pulsating burring sound, which sometimes amounts to a whistle or coo. In some forms of disease, especially in debility following upon emotional distress or anxiety, this sound becomes persistent and intensely distressing. In both cases the sound is produced by the same cause. The vascular tension reduced at those points of the body where the vessels pass through rigid canals or openings, there is vibration set up in the resistant parts, which vibration produces audible sound. In the entrance of the internal carotid artery into the skull by the carotid canal, we have a perfect arrangement for the production of this pulsating murmur; and as the canal is in close and solid connexion with the organ of hearing, the murmur is clearly and often painfully audible whenever the artery (if I may use the expression) is not under guard, *i. e.* is not under the full control of the organic nervous power.

THE PHYSIOLOGICAL ACTION OF HYDRIDES.

The first of the hydrides named in the Table, and the last, have been studied in regard to their physiological action and values.

Hydride of Methyl or Protylen.—This body, known commonly as fire-damp in mines, and as marsh-gas on land, is made by heating together acetate of soda, caustic potassa, and well-dried lime. Its properties and composition will be seen in the Table. I have already (at Dundee) reported on the action of this hydride and have little to add to what was there recorded. To make it produce rapid anæsthesia the gas must be inhaled nearly undiluted with air. It produces no excitement, and recovery from its effects, if the inhalation be stopped in time, is extremely rapid: a few seconds are, indeed, sufficient to restore consciousness and muscular power. The gas can only kill by a process of gradual negation of respiration, by replacing air required for the oxidation of the blood. It has no irritating properties, and is breathed without causing spasm. I repeat here what I was able to state at Dundee, that death from fire-damp must be of the easiest kind, must in fact be as easy as going to sleep, a circumstance which accounts probably for the sleep-like placidity and posture in which the dead have been found after fatal accidents from inhaling this substance. From the circumstance that the hydride is found in the air of marshes, it has been taxed as the cause of malarious fevers. There is no evidence whatever to support this view—no evidence whatever that the gas is anything more than an immediate and simply negative poison, the effects of which cease so soon as the animal body has been removed from its influence. It is certainly possible that a person exposed for several hours to the gas mixed with air would be reduced in power, and would suffer from reduction of temperature; but from this he would recover, if there were no other conditions acting injuriously at the same time. It is fair, therefore, to assume that in the atmosphere which generates malarial fever, the hydride is only a coincident with the true cause of fever, and that either dampness or the presence of some other organic poison is at work to produce the more serious and persistent consequences of exposure to marsh-air.

Hydride of methyl in the pure state might be used as nitrous oxide is often used, viz. to produce insensibility to pain by gaseous suffocation; but the principle of the method is rude and unworthy of science.

Hydride of Amyl.—Hydride of amyl may be made by adding iodide of amyl to water with zinc, and applying heat at 288° F. (=$142\frac{2}{9}$° C.) for some hours. On distillation a fluid comes over composed of amylene and the hydride; the mixture is left in contact with caustic potassa for twenty-four hours, and is then rectified from a water-bath at 35° C. The distillate is immersed in a freezing-mixture, and treated with anhydrous and fuming sulphuric acid, which retains the amylene, and the hydride is distilled over. This, which is Frankland's process, is described in full in Watts's Chemical Dictionary; but to get by this plan any sufficient quantity of fluid for a series of physiological researches would be practically out of the question. Fortunately the hydride forms one of the parts of American petroleum, and from a specimen of this petroleum Dr. Versmann has been able to distil for me a sufficient quantity of the fluid for my purposes. The specimen presents all the characteristics of the hydride; the specific gravity is 0·625, and it boils at 86° F. (=30° C.). As a fluid it is colourless and odourless; it is very agreeable to breathe, and creates no irritation. There is a specimen before the Section.

A distillation from petroleum, having all the properties of hydride of amyl, was tried in America about two years ago as a general anæsthetic, and was reported on favourably. I therefore subjected the hydride to careful experiment, and found it to be truly a general anæsthetic that might admit of practical application. In order to produce decided effects, 40 per cent. of the vapour of the hydride must be present in the inspired air; and so volatile is the fluid that constant repetition of it is necessary, unless it be placed in a receiver admitting very little air. Administered by inhalation to pigeons, in sufficient quantity to produce determinate insensibility, the period required for the production of symptoms was found to be under a minute, and the insensibility to be profound in a period a little less than two minutes. The insensibility in the bird is attended with some convulsive movement and drawing back of the head. Recovery from the effects of the hydride is rapid, not so rapid as in the case of the hydride of methyl, but still rapid, the animal regaining its full consciousness and muscular power within two minutes. The temperature of the body remains nearly unchanged. The inclination is towards a reduction of temperature, but it does not exceed the fourth of a degree on Fahrenheit's scale. The blood undergoes no obvious change.

To observe the extreme effects of the hydride, animals, after they had become insensible, were allowed to sleep into death. The process of death is gentle, and the respiration and circulation cease nearly simultaneously, the respiration failing a little first. The temperature of the body falls during the last few minutes of life from 1° to $1\frac{1}{2}$° of Fahrenheit's scale. The pupil dilates. After death the heart is found well charged with blood on both sides, and the organ on exposure to the air starts into vigorous action. The blood on the left side is darkened in colour, but the coagulation is natural, and the corpuscles are uninfluenced. The lungs, as is common when both sides of the heart are left full of blood, are natural in colour; they are not blanched, as after chloroform, nor congested, as after ether. The brain is natural. The muscular irritability is long retained.

To put the hydride to further test, I inhaled the vapour of it myself from a Vulcanite inhaler, such as I employ for bichloride of methylene: the vapour was very agreeable to breathe, caused no cough and no irritation, but a sensation as of a gentle warmth or glow in the chest. After six inspirations I felt evidences of change in the cerebral circulation, giddiness, and inability to stand, with the common swaying movement, or sense of movement, which marks the first degree of anæsthetic sleep. In a little time I lost consciousness for a few moments; but the inhaler being removed I quickly recovered, and in three minutes was perfectly well. Neither nausea, nor headache, nor chilliness followed.

Owing to the low boiling-point of this hydride, it admits of being employed by the physiologist for many inquiries bearing on the restoration of animal life after some forms of death. Thus, after destroying in frogs, by the action of extreme cold, those functions or acts which constitute what is called life, the process of recovery is best determined by regulating the slow restoration or return of heat, and by preventing a suddenness of reaction which ordinarily is fatal. Now, by immersing the animal in the hydride of amyl, and then warming, there is no danger of warming too quickly, as the fluid boils at 86° Fahr.; neither is there any necessity for removing the animal until, by the escape of a bubble of gas from the mouth, the first indications of restoring respiration are afforded; then the animal removed will, in most cases, recover in the open air. I have seen the frog recover after immersion under this hydride for a period of seven minutes.

On the whole, I am of opinion that pure hydride of amyl might, if it were needed, be employed as a general anæsthetic, and that, for short operations especially, it would be effective. I do not, however, put it above the other anæsthetics, but would rather assign to it the same position as belongs to ethylic ether, amylene, and nitrous oxide gas.

I must not, however, pass over some other minor but, in the aggregate, important uses of this agent. At a very moderate cost now, a hydride may be obtained which, though not absolutely answering to its pure chemical character, is sufficiently pure for the purposes I shall name, and which must, when the value of it is made known, ensure, I think, its employment by all practitioners of the healing art. I will notice some of its applications in detail, but by no means all of them.

From the fact that the hydride boils at a temperature twelve degrees below the natural temperature of the human body, it is very useful as a fluid for producing, in form of spray, rapid local insensibility. In most persons it produces insensibility, in this manner, in a period of from one to two seconds, and for mere punctures or slight incisions it answers well; but for larger essays it is too volatile, and does not cover a sufficient surface. It is advisable, therefore, to dilute it with absolute ether, by which means the best compound that can be employed for producing rapid local insensibility is secured.

The hydride of amyl dissolves some juices and fats with great facility. Camphor and spermaceti dissolve in it freely, and the vegetable and animal oils mix with it. Advantage may be taken of these properties for making a solution I have placed before the Section, and which is most valuable for relieving the pain of burns. The solution is made by saturating the hydride with spermaceti, then adding camphor until that ceases to dissolve, and finally mixing the compound which has been produced with an equal quantity of olive-oil. When this solution is applied on wool, over a burned surface, the cold produced by the evaporation of the hydride gives instant relief; while the thin layer of fatty substance left behind effectually excludes the air, and forms a false pellicle or skin, which greatly promotes cure.

Iodine dissolves readily in the hydride, as is seen in another solution which is before us. The solution thus formed is the best of all solutions of iodine, for a variety of purposes; when the solution is applied to the skin, the hydride psses away at once, and the iodine is left in a thin and even layer. The solution is also useful for deodorizing; for this purpose pieces of cloth may be saturated in it, and when the iodine is deposited on the fabric it may be suspended in the air, when the iodine is quickly diffused mechanically, but evenly, through the air. Iodine inhalation, weak solutions of the compound being used, may be readily and elegantly applied by means of this compound.

If strong solution of ammonia be well shaken with hydride of amyl, and then allowed to stand, small bubbles of gas are steadily evolved, and after a time the hydride containing a large quantity of ammonia may be decanted off; this ammoniated hydride is an excellent antiseptic, and can be used with advantage by the anatomist for the preservation of animal structures in the fresh state in a closed jar. The same solution charged with camphor can be used by the student of natural history as a preservative of his specimens. Lastly, the ammoniated hydride can be applied medicinally by inhalation in cases where the physician wishes to administer ammonia rapidly, as in scarlet fever and in states of great prostration. The ammonia can be so diluted in this manner as to be rendered agreeable for inhalation.

I could enumerate other uses of the hydride of amyl, but must pass them by with the further remark that, so soon as its value is known and appreciated, it must become as common an agent in medicine as ammonia, or ether, or alcohol.

Review of the Hydrides.

Reviewing the action of the class of hydrides up to the hydride of amyl, we may consider each body of the series to be, in a physiological sense, negative in character. Very stable as chemical compounds, practically insoluble in the blood, boiling at a lower temperature than the living body, producing no irritation, they inflict no injury on the living economy unless they are inhaled in such quantities as to exclude air. Then they produce, like amylene, a temporary insensibility, their power in this respect increasing with the increase of the carbon in the series; but, owing to the insolubility of the agents in the blood, the insensibility is in all cases of very brief duration, and would quickly be a fatal insensibility if, by continuous administration, it were prolonged.

THE ALCOHOL SERIES.

Methylic Alcohol.

At the Meeting at Dundee I reported at length on the action of methylic alcohol. I have now to add to the Report then made respecting it some observations in relation to its influence on the animal temperature. In its effects, in this particular, methylic alcohol resembles chloroform, but in a more striking degree. In birds (pigeons) I found, when the third degree of intoxication was produced, that in so short a period as ten minutes the temperature was reduced four degrees Fahr., and that the decline of temperature continued during the whole period of recovery, reaching at the lowest a decline of eight degrees on Fahrenheit's scale. The temperature begins to rise about two hours after the first indications of recovery; but a period of from seven to eight hours is required to restore the body, even under favourable conditions, to the natural temperature. In one case these effects of reduction of temperature were observed when the external temperature of the air was 80° Fahr. ($26\frac{2}{3}$° C.).

Ethylic Alcohol.

Much research has been made of late years on the physiological action of ethylic or common alcohol, much controversy has followed research, and points unsettled are too numerous to mention. Feeling it quite impossible to enter into one point of controversy without involving myself in many others, I determined simply to make one or two new and independent inquiries, and to place on record the results. What I have done relates to the influence exerted by alcohol on animal temperature, the condition of the organs of the body during extreme alcoholic intoxication, and the mode of death when the poison is carried to the fatal degree.

On the particular points of temperature, I have to record that in the progressive stages of alcoholic intoxication, the tendency in all cases is to a decrease of animal heat. In the progress towards complete intoxication under alcohol, however administered, there are, as under chloroform, four distinct degrees or stages. The first is a stage of simple exhilaration, the second of excitement, the third of rambling insensibility, and the fourth of entire unconsciousness, with muscular prostration. The duration of these stages can be modified in the most remarkable manner by the mode of administration; but whether they are developed and recovered from in an hour or a day, they are always present except in cases where the quantity of alcohol administered is in such excess that life is endangered or instantly destroyed. In the first or exhilarative stage the temperature undergoes a slight increase; in birds a degree Fahrenheit, in mammals half a degree. With the stage of excitement, in the second stage, during which there is vomiting in birds, or attempts at vomiting, the temperature comes back to its natural standard and soon begins to fall; and during the third and into the fourth degree the decline continues. In the fourth degree the temperature falls to its first minimum, and in birds comes down from five and a half to six degrees; in rabbits from two and a half to three degrees. In this condition the animal temperature often remains until there are signs of recovery, viz. conscious or semiconscious movements, upon which there may be a second fall of temperature of two or even three degrees in birds. In this course of recovery I have seen, for instance, the temperature of a pigeon which had a natural standard of 110° reduced to 102°. Usually with this depression of force there is desire for sleep, and with perfect rest in a warm air there is return of animal heat; but the return is very slow, the space of time required to bring back the natural heat being from three to four times longer than that which was required to reduce it to the minimum.

In these fluctuations of temperature the ordinary influences of the external air play an important part as regards duration of fluctuations, and to some extent as regards extremes of fluctuation.

The introduction of alcohol into the body in frequent and small quantities, so as not to produce any of the stages of true intoxication, is attended with a reduction of temperature limited to one and a half degree in small mammalia. The effect is definite on the administration, and occurs under varying circumstances—before food, after food, and in atmospheres of different warmths. It is most definite when the alcohol is administered by the hypodermic method.

When the alcoholic sleep from ethylic alcohol is pushed to the fullest extent, a very long time elapses after perfect unconsciousness is developed before the respiratory, circulatory, and even some of the voluntary muscles cease to act. The movement of the voluntary muscles is not, however, by an act of consciousness; it is not reflex, and it cannot be excited by the touch. It is usually an automatic movement, and will continue in the limbs for a long time. At last nothing remains to give evidence of the continuance of life except the motion of the heart and diaphragm, the persistency of the action of which is amongst the most curious facts in physiology. The final act rests with the heart; the heart continues to contract when the breathing has ceased, and is found contracting on the right side in both auricles and ventricles, on opening the body, when all the outward indications of motion are over.

I notice particularly that prolonged tremors do not seem to be produced by ethylic alcohol.

The appearances immediately after death from ethylic alcohol intoxication are very distinctive. The brain is found charged with fluid blood, the sinuses distended with exudation of serum in the ventricles and in the membranes. The small vessels of the brain are greatly injected. The lungs are white, free from congestion, and well inflated with air. The heart is full of blood on both sides, and its air-vessels are engorged. The liver is natural, and the gall-bladder is not distended. The inner surface of the stomach, even when the intoxication is induced by the gradual inhalation of the vapour or by subcutaneous injection, is very much congested, and a strong odour of the alcohol pervades any contents that may be within the stomach. The spleen is normal, and the alimentary tract below the stomach is normal. The kidneys are intensely congested, blood exuding freely from the cortical part, in points or specks. The bladder is usually empty. The blood on the left, as well as on the right side of the heart, is dark, but on exposure to air it soon reddens, and coagulation is firm. The corpuscles undergo great changes, even before death; they are shrunken, crenate, and some are elongated and flattened, with truncated ends.

Butylic Alcohol.

Butylic alcohol, obtained by fractional distillation from fusel-oil, or from the oil of beet-root, or from molasses left after distillation of ethylic alcohol, differs, as our Table shows, from ethylic alcohol in the proportion of carbon and hydrogen. Compared with common alcohol, its vapour-density is as 37 to 23, its specific gravity is as ·803 to ·792, and its boiling-point is as 230° F. to 172°. It is a heavier alcohol: it mixes indifferently with water, but is not unpleasant to take when diluted and sweetened. Applied to the lips and tongue in the pure state, it burns more than ethylic alcohol, and it leaves a very peculiar and prolonged local numbness, not unlike the numbness left by tincture of aconite. The knowledge of this fact may prove of service in the application of the alcohols for the local relief of pain.

The physiological action of butylic alcohol is that of ethylic alcohol exerted in a slower and more marked degree, and with some symptoms added. The period required for producing intoxication is full double that required by the ordinary spirit, and the time required for recovery is longer still. The variations of temperature run parallel with those which we have seen under ethylic alcohol, and indeed, with the exception of time, there is a complete parallelism up to the third degree of intoxication and the stage of recovery. In the third degree, after the temperature is depressed to the minimum of that degree, distinct tremors of the muscles appear. They come on at regular intervals spontaneously; but they can be excited by a touch at any time, and in the intervals, when they are absent, there is frequent twitching of muscles. The tremors themselves are not positively muscular contractions, but are rather vibrations through the whole muscular system, and are connected with extreme want of true contractile power. While they are present the temperature declines, and a difference of a full half degree may be observed both before and after each paroxysm. When the tremors are once established, they may continue without further administration of alcohol for ten and twelve hours steadily; and so slowly do they decline, that I have seen them occurring in the pigeon thirty-six hours after the intoxication. They subside by remission of intensity and prolongation of interval of occurrence.

There cannot, I think, be a doubt that these tremors, produced in animals by the heavier alcohol, are identical with the tremors observed in the human subject during the alcoholic disease known as *delirium tremens*. What the nature of the muscular movement is, what unnatural relationships exist between the nervous system, the muscles, and the blood to cause them, these are questions of singular interest. Involuntary, developed even against the will, excited by any external touch that sets up prostration, attended with great reduction of temperature, and remaining so long as the temperature is low, they indicate clearly an intense depression of animal force, a condition in which all the force that remains seems to be expended on the organic acts of life, on the support of the motions of the heart, the muscles of respiration, and the functions of the secerning glands. The voluntary systems of nerve and muscle are indeed well nigh dead, and recovery rests entirely on the maintenance of the organic nervous power.

In the extreme stage of intoxication from butylic alcohol the arterial blood loses its red colour, and the blood, which flows with difficulty from veins, is of dirty hue. Coagulation occurs readily, but the clot is loose, and yields much coloured serum. The corpuscles are closely massed together in rolls, several appearing as if they made one distinct column. The fibrine separates in masses or bands, forming a coarse network or mesh very distinctive in character.

Amylic Alcohol.

I have already reported, at the Birmingham Meeting of the Association, on amylic alcohol. In its effects, as a reference to my Report will show, it differs only from butylic alcohol in that the symptoms are even more prolonged. The tremors are most persistent, and complete recovery, as indicated by restoration of the natural temperature, is not often attained in a shorter interval than three days. At the same time, owing probably to the comparative insolubility of this alcohol by the blood, it is very difficult to destroy life with it by simple gradual administration. When to the ordinary observer recovery seems impossible, when there is perfect insensibility, when there is perfect paralysis of voluntary muscle, when even tremors cannot be excited, and when the only evidence of life is a feeble respiration at intervals of many seconds, recovery may be made certain.

Review of the Alcohols.

Reviewing the alcohols as a class, we find that their physiological action, less extended in regard to particular organs than the nitrites, and more extended than the insoluble hydrides, is expressed both on the organic and cerebro-spinal centres, reducing the active functions of both systems, and at last so reducing the function of the cerebral hemispheres as to remove consciousness altogether. The leading peculiarity of the action is the slowness with which those centres which supply the heart and diaphragm with power are affected. In this lies the comparative safety of alcohol; acting evenly and slowly, the different systems of organs fall together, with the exception of the two on which the continuance of mere animal life depends. But for this every deeply intoxicated man would die.

The alcohols are strictly anæsthetics; and indeed the first published case of surgical operation under anæsthetic sleep was performed, in 1839, by Dr. Collier on a person who was rendered insensible by breathing the fumes of alcohol. But the anæsthesia is not commendable; it is too slow and too prolonged. Methylic alcohol, if it could be entirely purified and made inodorous, might be used, and with methylic ether it would be one of the safest of agents; but as yet its inhalation is disagreeable.

The difference of action of the alcohols, as they ascend in the series and as the carbon increases, is most striking. The slowness of action, the prolongation of action step by step, from the lighter to the heavier compounds, is a fact as definite as any in physiology. Curious is it also that neither the methylic nor the ethylic alcohols produce those tremors in the inferior animals which we recognize and specially name from their occurrence in man; while the butylic and the amylic most effectively call them forth. Considering how much of the heavier alcohols is distributed for consumption, especially among the lower orders, I think it is possible that the heavier fluids may also be the cause of *delirium tremens* in the human subject, as they are frequently the cause of that continued coldness, lassitude, and depression which follow the well-known dinner with "bad wine."

Speaking honestly, I cannot, by any argument yet presented to me, admit the alcohols through any gate that might distinguish them as separate from other chemical bodies. I can no more accept them as foods than I can chloroform, or ether, or methylal. That they produce a temporary excitement is true; but as their general action is quickly to reduce animal heat, I cannot see how they can supply animal force. I see clearly how they reduce animal power, and can show a reason for using them in order to stop physical or to stupify mental pain; but that they give strength, *i. e.* that they supply material for construction of fine tissue, or throw force into tissues supplied by other material, must be an error as solemn as it is widespread.

The true place of the alcohols is clear; they are agreeable temporary shrouds. The savage, with the mansions of his soul unfurnished, buries his restless energy under their shadow. The civilized man, overburdened with mental labour, or with engrossing care, seeks the same shade; but it is shade, after all, in which, in exact proportion as he seeks it, the seeker retires from perfect natural life. To search for force in alcohol is, to my mind, equivalent to the act of seeking for the sun in subterranean gloom until all is night.

As yet alcohol, the most commonly summoned of accredited remedies, has never been properly tested to meet human diseases. I mean by this, that it has never been tested as alcohol of a given chemical composition, of a given purity, and in given measures. Wines, beers, spirits, are mixtures—compounds of alcohols, and compounds of alcohols with ethers and other organic substances. It is time, therefore, now for the learned to be precise respecting alcohol, and for the learned to learn the positive meaning of one of their most potent instruments for good or for evil; whereupon I think they will place the alcohol series in the position I have placed it, even though their prejudices in regard to it are, even as mine are, by moderate habit and confessed inconsistency, in its favour.

THE CHLORIDES.

I have in previous Reports brought forward the properties of the chlorides of methyl and ethyl. The first is an admirable anæsthetic, when inhaled in the proportion of 15 per cent.: it ranks in safety next to methylic ether, and a compound made of it with absolute ethylic ether is perfect. The objection to it is that, being a gas, it is not easily manageable.

Chloride of ethyl stands in the same position as chloride of methyl; but the action of it is much more prolonged, and a longer time is required for the production of action. With absolute ether it forms an excellent compound, the objection to which is, simply, its instability.

The chlorides of butyl and amyl have an action so much alike that they may be taken together; both are simple and effective anæsthetics, and both are pleasant to inhale, the butyl chloride being most agreeable.

The peculiarity of their action is that the sleep they induce is extremely prolonged, this being specially the fact with chloride of amyl. Pigeons when put to sleep by breathing ten per cent. of chloride of amyl pass slowly through the three degrees of anæsthetic insensibility easily and without convulsion, but invariably with slight vomiting. From ten to twelve minutes of inhalation are required to produce perfect sleep, and the temperature of the body falls full four degrees. The sleep once produced will continue in the common air at 70° Fahr. for fifteen minutes profoundly. The awakening is quick, and recovery is perfect.

In rabbits the action is much the same; seven minutes are required to produce safe narcotism, and the sleep produced is very profound. The breathing is tranquil, and the eyes, as is the case from amylene, usually remain open. A rabbit will lie five-and-thirty and even forty minutes in this state of insensibility before showing signs of recovery, and the temperature will fall from 3° to 4° Fahr. If the inhalation be carried too far, the profound sleep I have mentioned passes slowly into death, the sleep being prolonged in the common air at 70° Fahr. a full hour and a half prior to death. During this time the respiration for the most part is natural, with occasional double breathing; but the temperature of the body is all the while gradually declining, and is even reduced, while yet the animal is breathing, to 21° Fahr. below its natural standard. Thus in one case the temperature of a rabbit fell from 103° Fahr. to 82° Fahr. This is the lowest reduction I have seen in connexion with symptoms of living action; but from this extreme condition recovery is possible if the respiration be sustained in a warm air.

After death from the chloride of amyl the heart is found charged with blood on both sides, and the action of the auricles and ventricles is long persistent. The blood is very slow to coagulate; but the venous and arterial bloods retain their colour. The lungs are natural. The blood-corpuscles are much changed; they are shrunken, stellate, and elongated, with truncated ends.

The brain is left bloodless and of the purest white.

Note on the Chlorides.

The whole of the substances in the chloride series are simple and pure anæsthetics, and the power of their action obviously increases in proportion as there is increase of carbon. They act most readily and determinately on the cerebrum, and on the centres of volition and common sensibility. They have little action on the organic nervous system, and they interfere, even in full doses, but very gradually with the movements of the heart and respiration. The chlorides of butyl and amyl have yet to take a very important part in medicine; they admit of being applied in many cases where a prolonged sleep is required; for this purpose they may to a considerable extent replace opium.

THE IODIDES.

The action of the iodides of methyl and of amyl have already been reported on: they both produce insensibility; the first causing free elimination from glands, and the second causing tremors resembling those induced by amylic alcohol.

The iodide of ethyl resembles the methyl compound closely in its action, but it produces sleep more quickly and with less irritation. The vomiting produced by it is severe, and its action, if carried to the production of insensibility, is not comfortably safe. It may be administered either by inhalation with ether or by subcutaneous injection; it brings down temperature six degrees in birds. *The iodide of butyl* is very slow in its action, and produces symptoms closely resembling those caused by the amyl iodide, viz. tremors, and, during recovery from the insensibility, motions, partly voluntary, in a circle or semicircle, which continue for a long period. The temperature falls under the influence of this agent from five to six degrees in pigeons, and from two to three degrees in rabbits. The colour of the blood is much heightened, the venous appearing as arterial blood, and the coagulation is very slow. The corpuscles are not injured, and show no disposition to coalesce. Recovery from the insensibility produced by the butyl iodide is good. The iodide may be administered by inhalation with ether or methylic alcohol, or by subcutaneous injection; and it has this advantage, that of all the iodides it shows least disposition to undergo change on accidental exposure to the air.

Note on the Iodides.

The substitution of the element iodine in the organic bodies, marked in our Table, induces evident difference of physiological action. The action of the iodine is throughout on glandular structure, an excitation of glandular action and elimination, the action declining as the quantity of iodine is reduced. The whole of these organic iodides exert an eliminatory as well as an anodyne influence, and for this reason they promise to be of great service in medicine. Iodide of butyl will probably be found to be the best of the series.

To make them applicable as internal remedies, I have studied carefully the best mode of preparing them, and find the form of syrup by far the most effective and convenient. Specimens of syrups are before the Section.

PART II.—MEANS OF RESTORATION.

The second and concluding part of my Report has reference to the all-important question of the best means of meeting what seem to be fatal accidents arising from the administration of those agents which are most commonly in use. In this direction of research I have had unexampled opportunities of study, and I regret only that the length of my Report necessitates an undue brevity on this one particular topic.

The substances which commonly produce dangerous symptoms divide themselves into two classes,—those which produce prolonged intoxication, and those which produce quick insensibility and immediate death. The alcohols are illustrations of the first of these series; the chlorides and ethers, and, indeed, all the very volatile and gaseous narcotics, are illustrations of the second.

Respecting the means of recovery from the intoxication by the slowly acting narcotics, the rules are extremely few and simple: they are two only, and they include all; they are (*a*) exposure of the animal to warm air, and (*b*) in extremity the steady and efficient maintenance of artificial respiration. When these rules are rigorously followed, death from the profoundest intoxication is rare. This remark applies even to those extreme examples where there are tremors of muscles and all the signs of instant dissolution. The temperature of the air should be, as a rule, about ten degrees below that of the natural temperature of the animal. But in intervals of great depression the temperature may be raised to ten and even twenty degrees above the degree of temperature natural to the animal.

In regard to recovery from the extreme and sudden effects of the second class of substances, moderate warmth of air is again an advantage; but sudden extreme warmth is often fatal, from the expansion of gaseous matter in the lungs. From 60° to 65° Fahr. is the best temperature for recovery from the more volatile agents.

In both classes of cases artificial respiration is often all essential; but it may be used to kill as well as to save, unless it always be used with a perfect knowledge of what it is to do.

And this I find to be a rule having no exception, that it is always bad practice to excite artificial respiration so long as there is anything like a natural respiration. If the subject be breathing once in ten or even fifteen seconds, it is best to let well alone. The reason for this rule is simple, and rests on the fact that the balance of circulatory and respiratory power must be sustained. In health there is a nicely adjusted balance of pressure between the blood brought by the action of the right side of the heart to the lungs to be aërated, and the air brought by the muscles of respiration to effect aëration. To resort to any violent means to enforce respiratory movement is to destroy this delicate balance, to cause rupture of the air-vesicle, and infiltration of air into the surrounding tissue—emphysema. In brief, when the current of blood passing from the right to the left side of the heart is reduced, as it is in the cases we are treating of, to the extreme of debility, the point of practice is to bring back the respiration and the circulation together. We must treat the body, in a word, as we would a candle or lamp, the active flame of which is extinguished, but the wick of which is still burning without flame. It is also important, in performing this act, not to disturb the body by any sudden movement, for the least motion, when the circulation is ebbing, is often sufficient to stop the enfeebled and hesitating heart.

To meet these refinements in the method of restoring animation, I have invented the simple pocket-bellows which I place before you; they are made of india-rubber, and the bellows part consists of two round balls, which can be grasped by one hand. When the bellows are compressed, the ball on the right-hand side yields the air it contains to the long exit-tube, while the ball on the left hand yields the air it contains directly to the outer atmosphere. When the bellows are allowed to fill with air, the right ball fills directly from the pure air, the left from the long exit-tube. When, then, the long exit-tube is inserted in the nostril, and the bellows are worked together, one bellows fills the lungs, during compression, with pure air, the other empties the lung, during expansion, of impure air. Thus the natural conditions for breathing are carefully imitated, and the manipulation is simple to the last degree. In using the bellows I commonly leave one nostril quite open, putting the tube of the bellows firmly into the other. Then I commence gentle inflation, and continue until such time as the action of the heart has ceased, and all further attempts are useless, or until there is evidence of natural respiration. But when there is once evidence of natural respiration, I am specially cautious to do no more unless the natural act should of itself cease, when I repeat as before. In all my experiments I have never seen the respiration cease after it has been restored, except in one solitary case, and then the relapse was probaby due to injury due to forcing the artificial respiration too strongly at first. On the other side I have frequently seen the continuance of artificial respiration, after the establishment of natural respiration, from the doing too much, destroy effectually the good which had previously been accomplished.

With this convenient instrument, after cessation of breathing by any of the narcotic vapours not heavier than chloroform, life seems to me to be restorable in a large majority of cases, if the respiration be artificially commenced within three minutes after its cessation.

CONCLUSION.

I have thus, Mr. President, brought my labours this year to a close. Had time been permitted for further research, I should have entered upon the study of one or two new series of bodies; but the labour must be held in reserve.

We cannot pretend in Reports like these to vie with our more fortunate brethren in other departments of science. The physiologist has no ground of pleasant work in common with the astronomer, the geographer, geologist, ethnologist, or chemist. His researches are hard (unrelenting I had almost said), excessively minute, laborious, and at all times, however absorbing, painful; many of them can, in fact, only be carried on under a sense of duty amounting to necessity, and with the sincerest, the most solemn feeling that they are being conducted for the ultimate benefit of all the higher classes of animal existence. In the preparation of this Report I have held on throughout by this sense of duty, and earnest faith that good must come out of the labour.

One object which I had directly in view has been to introduce certain new substances which may be directly applied in our treatment for the cure of disease, or for relief of pain; another object has been to discover the best means of removing danger, from the use or abuse of some of the more potent agents; but the leading idea of the Report is that which I brought forward at the Birmingham Meeting—the idea of studying the action of substances which are to become remedies, not by the old and faulty method of so-called experience, but by proving physiological action and the relation of chemical constitution to physiological action. I am certain the time must soon come when the books we call "Pharmacopœias" will be everywhere reconstructed on this basis of thought, and when the chemist and physician will become one and one. That this huge reform may be commenced by order of the legislative authorities in this country is to me an earnest hope. But whether this shall be the final result or not, I shall always recall, with satisfaction, the remembrance that the idea of the reform and the first working of it began in England, and under the auspices of the British Association for the Advancement of Science.

On the Influence of Form considered in relation to the Strength of Railway Axles and other portions of Machinery subjected to rapid alternations of Strain. By F. J. Bramwell, *C.E.*

[Plates III. & IV.]

Before the days of railways, when not only was there much less machinery on which to found observations, but such machinery as there was was worked under far lighter strains and with far fewer alternations of those strains in a given time than the machinery of the present day is subjected to, the question of the influence of form was not an obtrusive one; and, in fact, so long as the weakest part of any piece of machinery, such as a shaft, had the sectional area due to the efficient resistance of the strains that could be ascertained as coming upon it, little or no attention was paid to the manner in which this smallest sectional area was to be associated with enlargements formed for the purposes, in the case of shafts, of receiving wheels or of acting as collars.

As an instance of this, few engineers in the pre-railway days would have hesitated to make a cast-iron crank-shaft for a steam-engine in the manner shown in fig. 1, Plate III. They would have taken care to give the bearings (or journals as they are called) A A such a diameter as was judged to be sufficient, having regard to the area of the piston, the pressure, and the length of stroke; but they would have made the body part, B, of the shaft and the end, C, in the eye of the crank of a much larger section than that of the bearings A A, would probably have made these parts square, and would without hesitation have formed the junctions of the small parts A A with the large parts B and C abruptly with right angles, as drawn in full lines, and without any attempt to ease off the change in form by a bold curve, as shown by the dotted lines.

The square shoulder would be left, in order to get a good endway bearing against the sides of the supporting brass; and few, if any, engineers in those days would have imagined that if the bearings A A were large enough, the making the shaft at B and C of a greatly increased section, and the making the junctions of these sections with the sections A by right angles, could in any way be prejudicial to the strength of the bearings A A. The opinion was (and, on the face of it, by no means an unreasonable opinion) that if the bearings A A were strong enough, the fact of any neighbouring part being stronger could not in any way detract from the value of A A.

Occasionally, however, there were occurrences which might have aroused attention, but which, it is believed, were allowed to pass by, being accepted as mere workshop accidents, and not thought worthy of inquiry by the skilled engineer of the time; and still less were they treated as problems to be solved by scientific men outside the profession of engineering.

Fig. 2, Plate III., illustrates one of these occurrences. It shows a form of eccentric rod commonly then in use. In such a rod the ends A A were made of long screws to carry nuts to tighten against the lugs of the eccentric band, as shown dotted at B B; these ends (A A) were forged in short lengths, say, from C, and after having been turned at the parts A A and screwed, were welded at C to the body of the rod.

It was by no means a common thing, but occasionally it did happen, that, in the act of making the weld at C, the screwed end snapped off at D close to the enlarged part without any blow whatever having been struck upon the end. It has been said the occurrence was not a common one; but it was

Fig. 1.

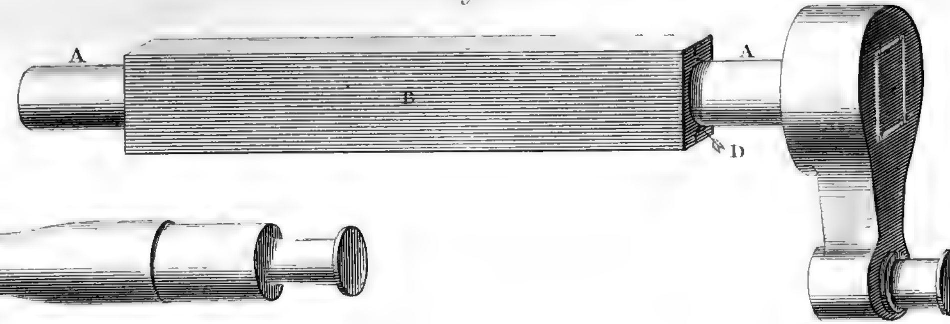


Fig. 4.

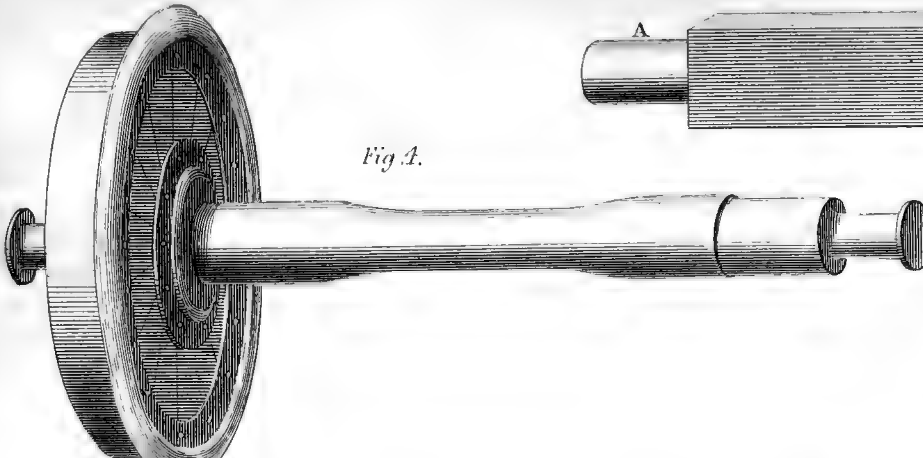


Fig. 3.

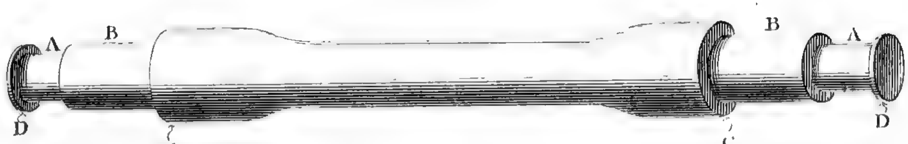


Fig. 3a

Fig. 2.

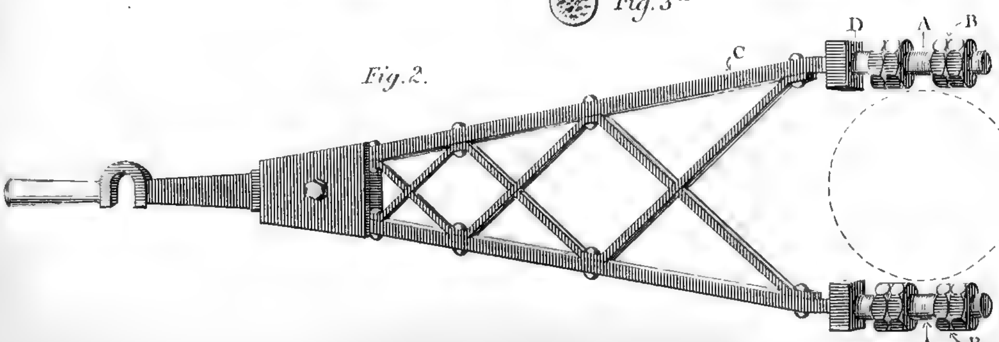


Fig. 5.

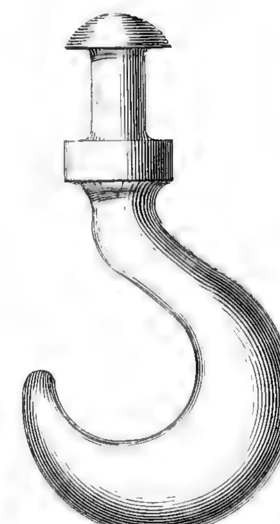
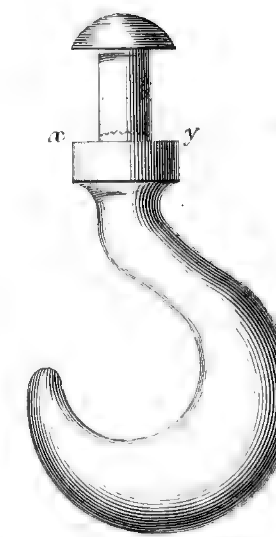
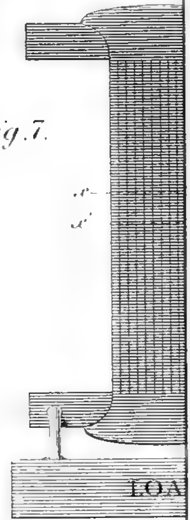


Fig. 6.



J. W. Lowry fc.

Fig. 7.



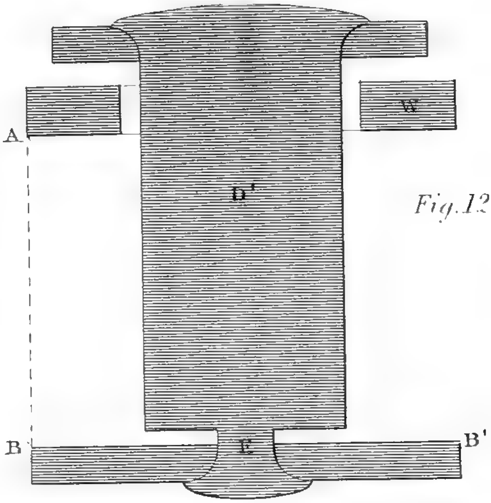
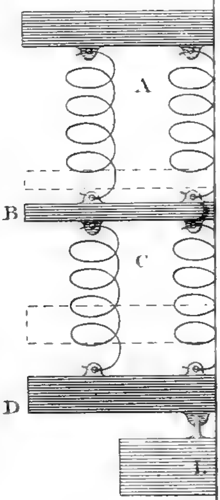


Fig. 12.

Fig. 14.

Fig.



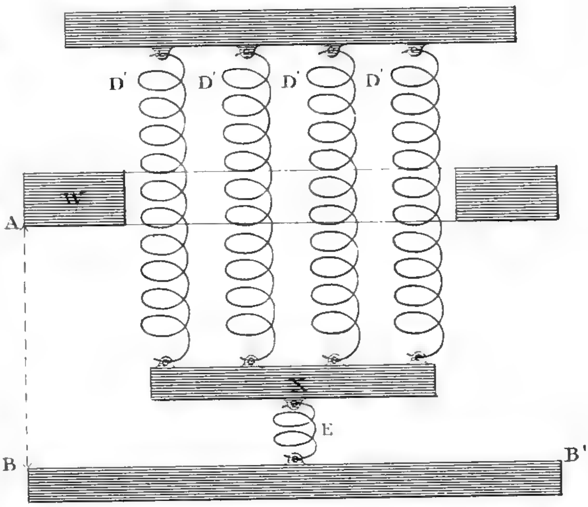


Fig. 15.

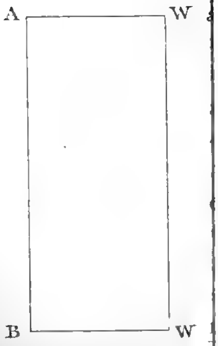
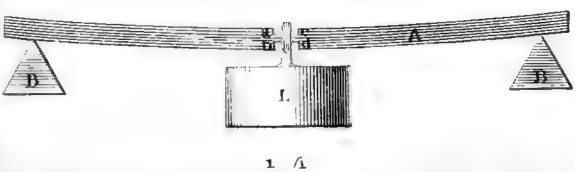


Fig. 19.



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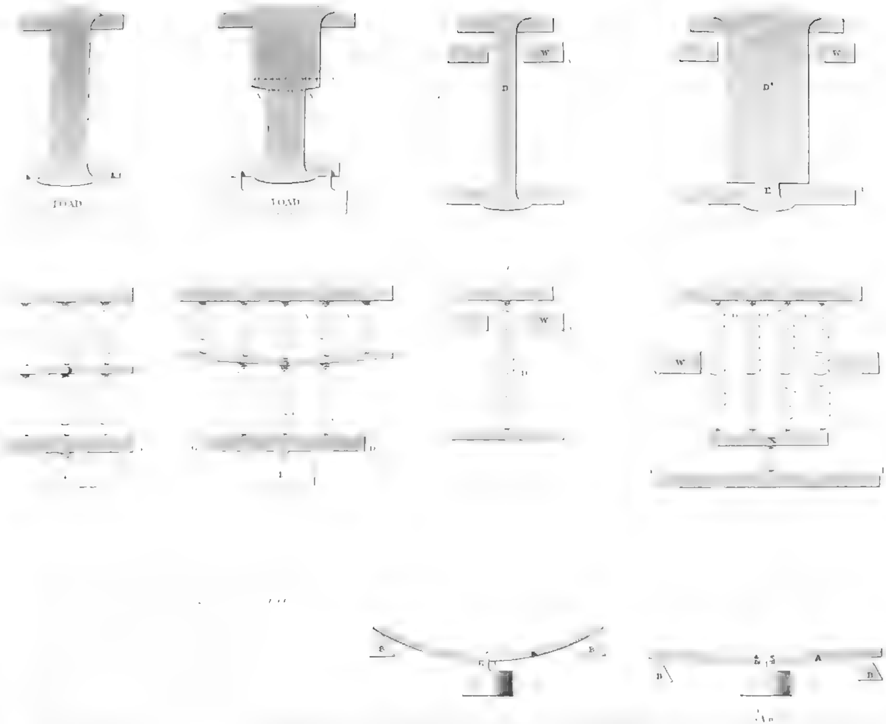
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sufficiently well known to experienced smiths to induce a prudent workman to hold up, by grasping it with his leathern apron, the screw A while the weld was being made at C; and this precaution was generally found sufficient to prevent the fracture.

When, however, the fracture did occur, it was usually attributed to the iron having been originally bad, or to its having been injured by the great amount of local hammering in reducing it from the size of the collar to that of the screw, or to its having been "burnt," or to some other such cause.

Enough has probably been said to give an idea of the state of engineering practice and knowledge on this subject of "form" in the pre-railway times.

The introduction of railways, however, caused machinery to live a very fast life, and now subjects an axle in the course of two or three years' work to the reception of alternating strains and shocks which it would have required half a century to inflict upon the crank-shafts of steady-going old-fashioned engines. On the first establishment of railways the loads were lighter and the pace was slower than the loads and pace of the present day; but more than twenty-five years ago attention was directed to the fact that railway axles, which appeared from their dimensions to be amply strong, were, nevertheless, frequently broken after one or two years' work; and accidents to passengers arose from these breakages, which accidents caused engineers to consider the subject of the fractures.

Fig. 3, Plate III., exhibits, in a somewhat exaggerated manner, the construction of axle then in use on railways, where A A are the bearings or journals, B B enlarged parts to receive the wheels, and at C C there were left projections against which the backs of the wheel-bosses abutted. The journals were made with collars (D D) at their outer ends, and the junctions of these collars and of the enlarged parts B with the journals were made (as in the case of the old form of crank-shaft shown in Plate IV.) by right angles.

It was found that axles thus constructed were liable to fracture at the junctions of the journals A A with the parts B, and also at the terminations of the enlarged parts B up against the shoulders C C.

Such a fracture always exhibited evidence of a crack of long standing round about the axle, which crack had reduced the section of sound metal to but a fraction (three-fourths to one-half) of the original area. (See fig. 3 *a*.)

On one or two occasions instances of these fractures and the consideration of their causes made the subject of papers brought before the Institution of Civil Engineers. In the papers so presented (with the exception of Mr. Rankine's, to be hereafter mentioned), and in the discussions which ensued upon the reading of those papers, many curious causes, including magnetism and electricity, were assigned for the fractures; the prevalent opinion, however, appeared to be that the iron had been deteriorated by the rapid vibration.

In 1843 Mr. Rankine read a paper before the Institution of Civil Engineers, in which he combated the deterioration theory, and attributed the fractures to the fact of the fibres of the iron not following the outline of the axle, they having been stopped short at the square shoulder by the turning down of the journal out of the solid, and to the fact that, on the axle being subjected to impact, the inertia of the particles on the outside of the enlarged parts B caused a greater strain upon the outer part of the journals A. Mr. Rankine recommended that the axle should be forged to the shape so as to ensure the fibre following the outline, and further recommended that the junction between the two different sizes should be made by a curve.

Mr. Rankine gave instances of the beneficial results obtained with certain experimental axles thus constructed. This suggestion of Mr. Rankine is now, so far as regards the curvature, always followed by men of skill.

As a matter of fact, all makers of railway-wheels and axles, and all mechanical engineers of experience, now know that, in order to obtain an enduring axle, it should be made (as shown at Plate III. fig. 4) with bold hollows at the junctions of the journals with the parts on which the wheels fit, and with the least possible projection at the back of the wheel-boss and the formation of a curve at the point of juncture with even this small projection.

The ordinary railway-waggon or -carriage axle has, from its simplicity, been used for an illustration; but it need hardly be said that the cranked axles (those important parts of locomotives) were found to give way under similar conditions of abrupt change of form.

The writer of this paper has the very strongest conviction of the ultimately fatal effects of these abrupt changes. He has known instances where, after many years' work in slow-going engines, large shafts have broken through where changes in the area of section were abruptly made, although these changes of area were but to a very slight extent. The writer is in the habit of introducing into his specifications the following clause:—"Bold hollows are to be formed in the angles of all the bearings and against all collars or other projections, on all shafts or axles, and generally throughout the engine; care is to be taken that every change of dimension is to be made gradually."

Even at the present day, except in the case of those intimately acquainted with the exigencies of railway work, the necessity of attending to these rules is not always appreciated. As an instance, the writer may mention that, having directed the swivel-hook of a large crane to be made with bold hollows, as shown at Plate III. fig. 5, the workman finished it in a manner which he considered "a nice square workman-like job," as shown at Plate III. fig. 6. The materials were all that could be desired; but the writer was compelled to reject this hook, because he has not the slightest doubt that, had it been kept at work, it would very shortly have broken through at the line xy.

Having said thus much in relation to that which may be called the history of the subject, and having brought that history to the point where it is admitted, by all men of skill in railway work, that, to obtain immunity from accident, it is not sufficient the weakest part of an axle should be strong enough, but care must also be taken that no neighbouring part shall be abruptly stronger, the writer will endeavour to show, in a plain, familiar, and, he might say, workshop manner, some only, it may be, among many of the reasons which cause abrupt enlargements to be attended with the disastrous effects we now know to accompany them; and in doing this he will consider four different propositions.

1. That abrupt change of form is detrimental even under a quiescent load.
2. That under impact abrupt change of form is detrimental even if the object suffering the impact be supposed to be made of imponderable matter.
3. That, further, under impact abrupt change is still more detrimental when the weight and inertia of the object are considered.
4. That abrupt change is detrimental when the object is subjected to a vibratory action.

As regards the first of these propositions, viz. that abrupt change of form is detrimental even under a quiescent load, let Plate IV. fig. 7 represent a suspended bar of uniform sectional area in its body part, and let fig. 8 represent another suspended bar of the same sectional area at its lower part as the bar of fig. 7, but having an increased section at its upper part, such increase being *abruptly* made; then, if these two bars be supposed to be subjected to equal loads, there will be more strain at the outside of the smaller part of the bar fig. 8, say at A A, than there is on any part of the uniformly small bar fig. 7.

Assume that the bars are composed of a number of equally elastic parallel columns (and to get rid of any question of what may be called the natural fibre of wrought iron not following the outline of bar fig. 8, let it be supposed that the bars are made of cast iron or cast steel); now if these elastic columns are capable within certain limits of equal increase of extension with equal increments of load, it follows that if the bar fig. 7, when unloaded, were to have a horizontal line drawn across it, as at $x\,y$, and the bar were then to be loaded, the result would be to lower this line to the position $x'\,y'$, the line still being horizontal.

In fig. 8, however, where the wide upper part contains a greater number of such elastic columns than its lower part (or than the bar of fig. 7 contains), then if the horizontal line were in the unloaded state of the bar drawn at $x\,y$ (the part where the dimensions abruptly change), and if the load were afterwards applied, $x\,y$ could not be drawn down so great a distance as in the case of the bar fig. 7, because there are more elastic columns on the upper part of the bar fig. 8 to uphold the load than there are in the bar fig. 7; and, moreover, $x\,y$ could not be drawn down so as to preserve its straightness, unless it could be assumed that the elastic columns at the sides of the wide upper part were equally extended with those in the middle; but it is obvious that these outer upper elastic columns, not having any columns below to pull them, can only be brought down by their lateral connexion with the neighbouring upper elastic columns; but this connexion being in itself elastic, the effect can only be to draw the outer parts partially down, and thus to cause the lowered line $x\,y$ to assume the curved form of $x'\,y'$. Now it will be seen that this curved form of the line $x'\,y'$ involves the outer elastic columns being more extended than the internal columns of the lower part of the bar; but as the strain on the elastic columns may be ascertained by referring to their extension, this proves that the strain is not uniformly distributed, as in the case of the bar fig. 7, and that the outer elastic columns of the lower part of the bar fig. 8 are more strained than the columns of fig. 7, and still more strained than the internal columns of fig. 8.

An endeavour will be made to explain and establish this proposition by the diagrams figs. 9 & 10. In these diagrams the cross bar B B is taken as the equivalent of the lateral connexion which exists among the elastic columns in the bars figs. 7 & 8.

Let fig. 9 represent three spiral springs, A A A, suspended at equal distances apart, and attached at the bottom to the bar B hinged in the middle, and let C C C be three other similar spiral springs attached at their upper ends to the bar B, and at their lower to a perfectly rigid bar D carrying the load L.

Under such an arrangement as this the load would be uniformly distributed, and the result would be simply to stretch the springs equally and to lower the parts B and D from their original positions indicated by the dotted lines. Now let it be assumed that, as in fig. 10, two other springs, A′ A′, each equal to one of the springs A, have been placed alongside of them and have been attached to the outer ends of the hinged bar B, and that the load L has been applied to the bottom bar D as before; the result of such a construction would be to pull down the hinged bar B, no longer in a manner to preserve its horizontality, but to bring it down in a bent form, and thereby to cause less of the load to be carried by the middle lower spring C than its fair share of one-third, as carried by the middle spring of fig. 9, and to throw of necessity this deficiency as an extra burthen upon the two outer springs C C.

The writer trusts he has succeeded in making his meaning clear, and has proved his proposition that, even under a quiescent load, a sudden increase of dimension in a suspended bar carrying such a load is a source of weakness. If the writer has not succeeded in making his meaning clear, he is at a loss how to illustrate it further, unless it be by some such proposition as this. Assume 100 men opposed in line to 100 men also in line, then the conflict would be equal for all; and then assume that one of the contending parties is increased to 102 men by placing one man on each flank; the two men will clearly exert but little influence upon those who are fighting in the centre of the lines, but their presence will be most injuriously felt by the two flank men of their opponents, as these two men will each have to contend with two adversaries in lieu of one. In the same way the internal elastic columns in the lower part of the bar fig. 8 have only similar fibres to deal with up above; but the external fibres of the lower part have not only to deal with their own proper continuations above, but have also to deal with the fibres above them in the parts projecting at the sides.

The second proposition comes now to be considered, namely, the influence of the abrupt change of form when the force of impact has to be resisted by the elasticity of an assumed imponderable bar.

Let D, fig. 11, be a plain bar of uniform section in its body part, but with an enlargement at the top to enable it to be suspended, and with one at the bottom to receive a collar, B, on which the weight, W, is supposed to fall through the distance A B.

The bar D′, fig. 12, is assumed to have in its body part four times the sectional area of D, but to terminate at its bottom end in a short piece E, having a sectional area equal to D, or one quarter that of the upper part, D′. This bar, D′, is also provided with a weight, W, falling through A B on to the collar B′.

Now let the spring arrangements of figs. 13 & 14 be substituted for the bars D and D′.

In fig. 13 there is a single spring D suspended from a support, and carrying a collar B on which the weight W can strike on falling through the distance A B.

In fig. 14 there are four suspended springs, D′ D′ D′ D′, each equal to D of fig. 13. These springs are supposed to be united at their lower ends to an absolutely inflexible bar X, below which is a short single spring E, similar in area and strength, so far as it goes, to either of the springs D, D′.

This spring, E, supports the collar B′, to be struck by the weight W on falling through the distance A B equal to the A B of fig. 13.

Now if, as in any of these figs. 11 to 14, the weight W be suffered to fall through the distance A B, the accumulated work residing in it when it reaches B will equal the weight into the distance.

Let this accumulated work be represented by the parallelogram (fig. 15) A B W W.

This accumulated work it is intended, in the case of fig. 13, to transfer to the spring D, by the extension of that spring; but as the resistance offered by the spring will increase directly as the extension of it, the efficacy of the spring to receive accumulated work may be represented by the triangle fig. 16, where *a b* represents the extension, and the several horizontal lines represent the strains due to the different extensions, the strains increasing from 0 at "*a*" to *b w*; and in order that the accumulated work represented by the parallelogram A B W may be transferred to the spring, its extension must be such that the area of the triangle *a b w* shall equal that of the parallelogram A B W. The maximum strain brought on the spring under these circumstances will clearly be no more than that represented by the length of the horizontal line *b w*.

Now assume that the area of A B W has to be transferred to the four springs D′ of fig. 14, it is clear that only one-fourth of the area will have to be borne by each spring, and the triangle representing the extension and strain of each of the springs will only have one-fourth of the area of that of *a b w*.

Let fig. 17 represent such a triangle, then, in order that its area may be one-fourth, it follows that its sides must each be half of those of the triangle *a b w*, that is, the length of *a l*, the extension, will be half of *a b*, and the length of *l m*, the final strain, will be half that of *b w*; but if this be true of each of the springs D′, the aggregate strain on the four springs must be double that of the strain on D.

But this double strain has, in the case of fig. 14, to be put on to the four springs D′ by means of the short single spring E, therefore this spring, which is equal to D, will be put to a strain twice as much as that put upon D.

It may be well to remark, in passing, that the fact of the ultimate strains put on in arresting the accumulated work being double in the case of fig. 14 to those of fig. 13, although the weight is the same in both cases, is by no means inconsistent with the fact that when the springs are settled to rest and are supporting W as a quiescent load, the sum of the strains of the four springs D′ must exactly equal that of the single spring D.

It has not been thought necessary to take into account the small increase in the fall of the weight W, due to the lowering of the collars B B′ on the extension of the springs.

There now comes to be considered the third proposition, that change of form produces increased strain under impact, when the weight and inertia of the object suffering the impact are taken into account.

It is quite certain that in practice, where a falling weight is arrested by a collar B or B′, the accumulated work of that weight would be partly taken up by the elasticity of the bar D or D′, and would be partly taken up by the setting of the particles of the bar itself into motion, such motion being greatest at the bottom of the bar, and diminishing in the higher parts, until at the top of the bar it would become nothing.

Reverting to figs. 13, 14, 16, & 17, let it be assumed, for the sake of simplicity, and as an illustration only, that all the weight of the apparatus resides in the collars B B′, and that the collar B′ of the four-spring arrangement, fig. 14, is four times as heavy as the collar B of the single-spring arrangement, fig. 13.

Further, reverting to fig. 16, the weight W would be brought to rest in the time during which it would traverse with a decreasing velocity the height *a b*, and in fig. 17 the weight would be brought to rest in the height *a l*, half of that of *a b*; and the time to bring the weight W to rest in this latter case of fig. 17 would be half that required to bring it to rest in fig. 16.

Following this out, if the lines *a b*, *a l* be divided into the same number of equal parts, say ten each, then the time to travel over part 1 in fig. 17

must be half that required to travel over part 1 in fig. 16, and the length of part 1 in fig. 17 must be half that of part 1 in fig. 16.

But the respective collars (B B′) must have their weights put into motion with these velocities, so that the weight B′ has to move through half of the space that B has to move through, and has to do it in half the time; but to move a weight through half the space that another weight is moved through, and in half the time occupied by that other weight, requires double the pressure; therefore it would take double the pressure to move B′ that it would to move B, even if B and B′ were equal in weight; but B′ is four times the weight of B, therefore it will take eight times the pressure to move B′ that it will take to move B, and in this case also the eight times the strain has to be put on by the single spring E, which thus gets eight times as much strain as the spring D.

The fourth proposition has now to be considered, namely, that abrupt change of form is a cause of weakness when vibratory action has to be endured.

As already stated, this cause is the one that has been most recognized by those who have touched upon the question.

The writer will not pretend to investigate what the value of this source of weakness is, as no means suggest themselves to his mind for doing so; it may, however, fairly be assumed that the times of vibration in the large section part of the bar will be different from those in the small, and that at a point where the change of shape occurs there must be a discord in the vibrations, and that thus the metal in this part must be exposed to strains which would not occur were the vibrations on the two sides this point synchronous.

Propositions 2 and 3 have been dealt with as though the increased strains brought upon the small sections by their neighbourhood to the large sections were uniformly distributed over the small sections, which have, for simplicity sake, been assumed to be composed of single springs.

But had these small sections been dealt with as being in themselves composed of several smaller springs, as was done in considering the cases of figs. 9 and 10, then it would have been found that the outer parts of those small sections were doing more than their share of the increased work, and therefore the evils arising from increased section, which have been treated of in propositions 2 and 3, must be multiplied by the evils due to the abrupt change of form considered in proposition 1.

The kind of fracture shown in end view in Plate III. fig. 3 *a*, namely, a fracture which begins all round about the outside and gradually penetrates, is an abundant practical proof that not only are strains arising from impact increased on part of a small section by the neighbourhood of larger sections abruptly joining on to the smaller ones, but that the increase is borne in an undue proportion (as was shown in the case of quiescent weights) by the outer particles of the small section at the part where they abruptly join on to the larger section.

So far this paper has dealt with the evil influence of sudden change of form when it is to be found in a suspended rod or in other positions where the influences act in the direction of the length of the object under consideration. In practice, the bolts which hold on armour-plating are instances to which the foregoing considerations are applicable, as such bolts receive in the direction of their length the quiescent strain, and also that arising from the impact of the recoil of the armour-plating after it has been struck by the shot.

It may be well to allude to the fact that Major Palliser has overcome the difficulty of the fracturing that took place in the ordinary bolts immediately at the junction of the screw parts with the shank, by diminishing the area of the shank, so as to be equal to that at the bottom of the thread, and has thus given in his armour-plate bolts a practical instance that the strength of parts may be added to by reducing that of their larger neighbours.

Besides the armour-plating bolts and other bolts, there are no doubt many cases in which both quiescent strain and the strain of impact are exerted in the direction of the length of the object; but there are probably a still larger number of cases in which the strains are applied transversely, and among them are the important instances of railway axles.

It may be well therefore to glance briefly at the influences exercised by a sudden alteration of form when that alteration occurs in an object exposed to transverse strain.

Let fig. 18 represent an elastic bar (A) of uniform section, placed on supports B B, and subjected to the action of the quiescent load L, the result will be simply to deflect it as sketched.

In this deflection the central parts may be assumed to be extended on the underside, and compressed on the upper, as represented by the converging space *a b c d*.

If, now, the depth of the bar be abruptly increased in the part that lies between these lines *a b c d* and the two ends, as shown in fig. 19, the result will be to aggravate the strains at the parts *a b c d* in a similar way to that which was pointed out in respect of a perpendicularly suspended bar under a quiescent load. But if the bars have to resist impact, then a more serious difference, to the disadvantage of the bar with unequal sections, will be found. It is well known that if one bar be double the depth of another, the first bar will, under a quiescent load, deflect only one-eighth part of that which the second would deflect, the deflections being inversely as the cubes of the depths.

With respect, however, to the resistance offered to the flexure of the bars under impact and not under quiescent loads, the writer believes it can be shown that if there be two elastic imponderable bars alike in all respects except their depth, and if they be exposed within their elastic limits to the impact of equal forces, the result will be that, if the one bar be taken as unity in depth and as deflecting unity under the force, the other bar, having a depth of n, will deflect according to the formula $\frac{1}{n}\sqrt{\frac{1}{n}}$.

Applying this formula to the case of a weight let fall upon a bar which is double the depth of another, the deflection of this bar of double depth will only be $\frac{1}{2}\sqrt{\frac{1}{2}}$, or about ·35 of that which it would have been if of the single depth; but to produce this ·35 of deflection, the strain on the whole section of the bar of the double depth will be 2·828 times as great as it would be upon the bar of single depth.

So that if the bars (figs. 18 and 19) be exposed to the impact of similar forces, the bar fig. 18 would deflect through a space of 2·828 with a strain of ·35 on the central parts, while before the bar fig. 19 could, so far as the greater part of it (namely its enlarged ends) is concerned, be deflected through a space of one, there must be put upon the middle section of it, equal to one only in area, a strain of 2·828. As in the case of the vertical bars, this extra strain would be aggravated by the fact that it would not be uniformly distributed over the area of one, but would be borne in a larger proportion by the outside particles, where they join the increased section.

It will not be necessary to go into the reconsideration, in respect of transverse strains, of the effects of inertia and vibration, which have already been touched on when considering direct strains; but it will be sufficient to say that the strains brought upon railway axles are of a very severe character, and that they are undoubtedly exaggerated by the large difference of dimensions of the neighbouring parts, and that nothing but the greatest circumspection in the designing and manufacture of these parts can insure safety to railway passengers.

On the Penetration of Armour-plates with long Shells of large capacity fired obliquely. By Sir Joseph Whitworth, *Bart., C.E., F.R.S., LL.D., D.C.L.*

At the Meeting of the British Association at Norwich, I contributed a paper to the Mechanical Section "On the Proper Form of Projectiles for Penetration through Water." This paper was illustrated by diagrams, showing the effect produced on an iron plate, immersed in a tank of water, by projectiles with flat, hemispherical, and pointed heads. Copies of those diagrams are now before you. In that paper I claimed for the flat-pointed form of projectile, made of any metal, three points of superiority over the ogival-pointed projectiles adopted in the service:—(1) Its power of penetrating armour-plates, even when striking at extreme angles; (2) its large internal capacity for bursting charges when constructed as a shell; (3) its capability of passing undeflected through water, and of penetrating iron armour below the water line. This latter feature was, I think, satisfactorily proved by the experiments described last year; and I desire to draw the attention of the Section to the experiments I have made for illustrating the penetrative power of long projectiles with the flat front, fired at extreme angles against iron plates.

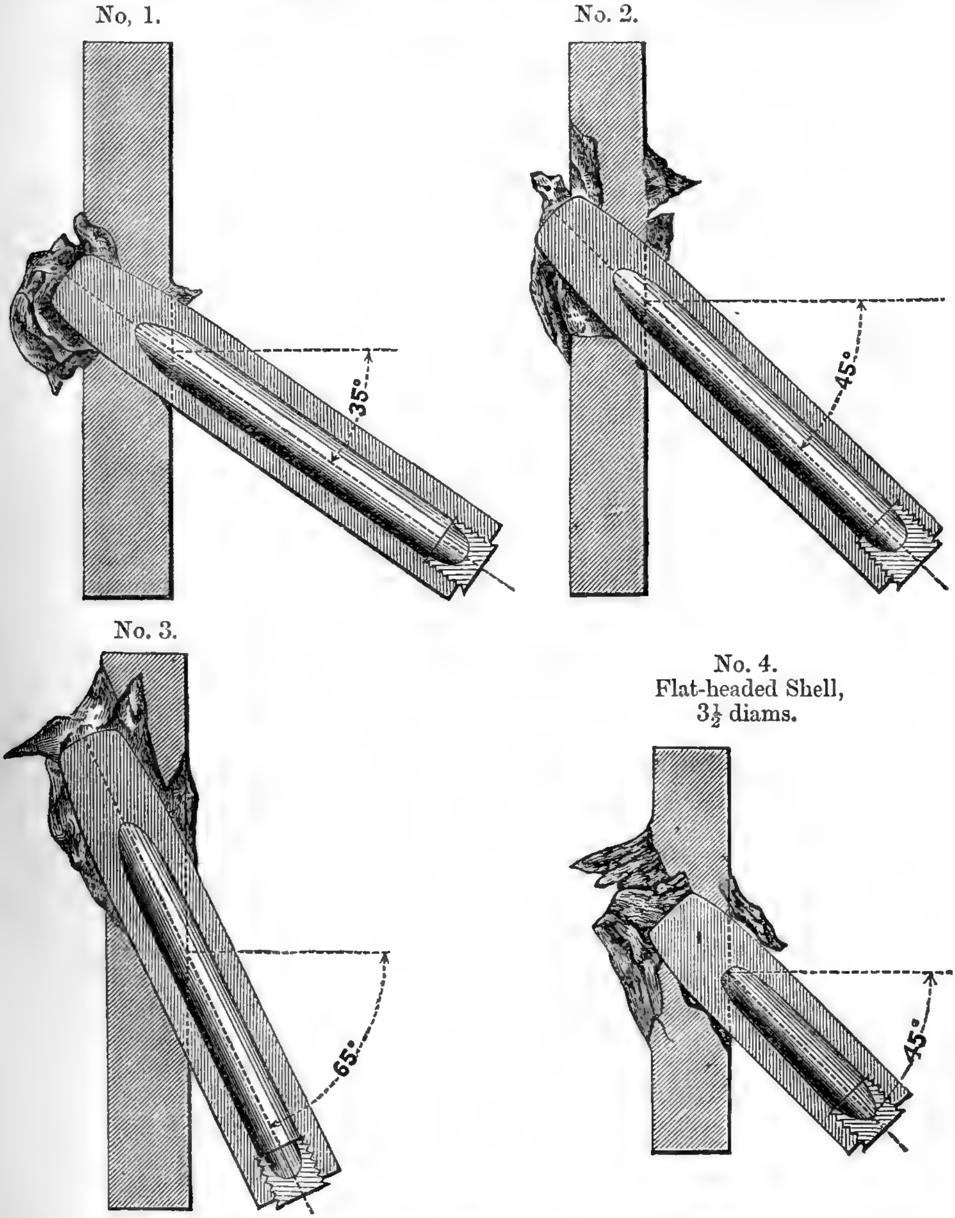
These experiments are illustrated by the projectiles actually fired, and the plates they penetrated, which are laid on the table, and also by the diagrams before you.

The gun from which the projectiles were fired is called a 3-pounder, though capable of firing much heavier projectiles. It weighs 315 lbs., and the maximum diameter of its bore is 1·85 inch. The charge of powder used, in all cases, was 10 ounces, and the weight of the 6-diameter projectile is 6 lbs.

No. 1 is a portion of a plate 2 inches thick, penetrated by the 6-diameter flat-fronted projectile No. 1 at an angle of 35 degrees. No. 2 is a similar piece of plate, 1·7 inch thick, completely traversed at an angle of 45 degrees by the flat-fronted projectile No. 2, which buried itself to a depth of 30 inches in a backing of iron borings. No. 3 is a piece of plate 1·75 inch thick, penetrated at an angle of 65 degrees by the flat-pointed projectile No. 3. No. 4 is a plate 1·7 inch thick, nearly penetrated, at an angle of 45 degrees by the $3\frac{1}{2}$-diameters flat-fronted projectile No. 4. No. 5 is a plate $1\frac{1}{2}$ inch thick, against which the ogival-pointed projectile No. 5 was fired at angle of 45 degrees; the projectile failed to penetrate the plate, being deflected in consequence of the pointed form of the head. The distortion of its shape shows the force with which it struck the plate, and proves the good quality of the material which could resist such a test. No. 6 is a plate also $1\frac{1}{2}$ inch thick, against which an ogival-pointed projectile, of the service proportions, viz. $2\frac{1}{4}$ diameters long, made of Pontypool white iron, has been fired: the projectile has scooped out a furrow 4 inches long and seven-tenths of an inch deep; it broke up into fragments, of which 48 were recovered.

The plates Nos. 1 and 3 were purposely thicker than the projectiles could

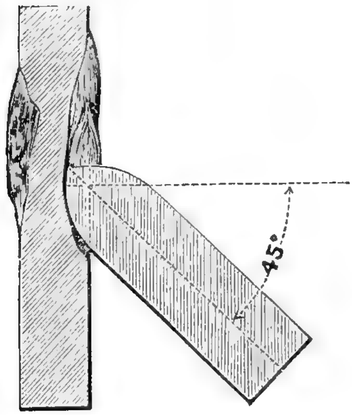
"Whitworth" Flat-headed Shells, 6 diameters long, containing large bursting charges.



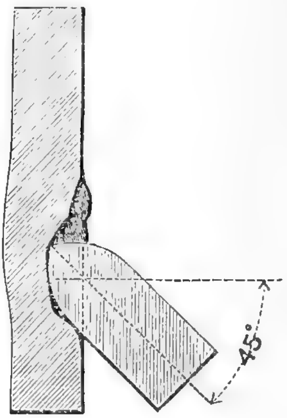
Nos. 1, 2, 3, and 4 were made of "Whitworth" Metal.

quite pass through, in order that the "work" of the projectiles might be as severe as possible: an examination of the projectiles themselves will show how well they have withstood the severe strain to which they have been subjected. The data thus obtained fully establish, I think, the superiority I claimed for the flat-fronted projectiles made of my metal, and satisfactorily prove :—(1) That the flat-fronted form is capable of piercing armour-plates at extreme angles; (2) that the quality of the material of the shells enables

No. 5.
Pointed Solid Shot,
$3\frac{1}{2}$ diams.



No. 6.
Pointed Solid Shot,
$2\frac{1}{2}$ diams.



No. 5 was made of "Whitworth" Metal; No. 6 of Pontypool White Iron.

their length to be increased, without any risk of their breaking up on impact, and materially augments their bursting-charge as shells; (3) that this increase in length, while adding to the efficiency of the projectile as a shell, in no way diminishes, but, on the contrary, proportionally improves its penetrative power; (4) that the amount of rotation I have adopted in my system of rifling is sufficient to ensure the long projectiles striking "end on," and consequently to accumulate the whole effect of the mass on the reduced area of the flat front.

These experiments show, further, that the ogival-pointed projectile has but small power of penetration when striking at an angle, solely on account of the form of the head; a projectile of "Whitworth" metal, with the like ogival-pointed head, as a service projectile, having resisted the shock of impact without breaking up, but being deflected in precisely the same manner as the pointed service projectile, which was shivered into fragments. The objections I made in my paper last year to the ogival-pointed projectile—(1) that its form of head causes it to glance off from plane or convex surfaces when hitting diagonally; and (2) that the brittleness of its material renders it liable to break up on impact—I have now proved to the Section. The facts illustrated by these experiments are not of recent discovery. Ever since 1858 I have constantly been advocating the flat front. I have on the table a small plate $\frac{1}{2}$ inch thick, experimented upon in 1862 with hardened steel bullets fired from my small-bore rifle. No. 39 is the hole made by a flat-fronted bullet, which has penetrated the plate at an angle of 45 degrees. No. 40 is the indent of a hemispherical-headed, and No. 41 of an ordinary round-nosed bullet, both fired at the same angle of 45 degrees. These three rounds were fired in 1862.

Within the last few days I have had an ogival-pointed shaped bullet fired at the same plate at the same angle, in order to confirm the effect with that produced, on a larger scale, on the plate No. 6. It is interesting to observe how closely the results obtained with the small calibre of my rifle agree with those of the 3-pounder gun, which form the subject of this paper. Those experiments recorded in the paper were made with a gun of smaller calibre, from considerations of economy and convenience; but I have always found that what I could do with the smaller calibres of my system, could be reproduced in the larger sizes; and from my past experience I feel warranted in asserting that the effect of penetration now exhibited could be repeated on a proportionate scale with my 9-inch guns at Shoeburyness, or with the 11-inch guns my firm are now engaged in constructing.

A glance at the formidable nature of the projectiles thrown by these guns, and a consideration of the effects they may be expected to produce, will show the importance attaching to the question of penetration of plates by long projectiles. The 9-inch guns to which I have referred weigh 15 tons each, and are capable of firing powder charges of 50 lbs. A 9-inch armour shell, 5 diameters long, weighs 535 lbs., and will contain a bursting-charge of 25 lbs.

I have no hesitation in saying that these projectiles would pierce the side of a ship, plated with heavy armour, at a distance of 2000 yards, and at some depth below the water-line. The 11-inch guns will weigh 27 tons, and will be capable of firing 90 lb. powder-charges. The 11-inch shells, 5 diameters long, will weigh 965 lbs., and will contain bursting-charges of 45 lbs., and would pierce the side of the ship 'Hercules,' plated with 9-inch armour, at a distance of 2000 yards.

Were it not that the increased destructiveness of war must tend to shorten its duration and diminish its frequency (thus saving human life) the invention of such projectiles could hardly be justified; but believing in the really pacific influences of the most powerful means of defence, I call these long projectiles the "anti-war" shell. The principle I have always insisted upon, and laid down for my own guidance in artillery experiments (when either a low trajectory or penetration is required), is, "that every gun should be in strength capable of withstanding the largest charge of powder that can be profitably consumed in its bore." I have drawn up the accompanying Table of the sizes of the bores of my guns, with their proportionate powder-charges, and the guns will all be fully equal to this duty, and I believe the greatest possible effect from the consumption of a given quantity of powder will be obtained. But the guns adopted in our naval service are not equal to such a test; nor, as I believe, are they so proportioned as to realize the best effect from the quantity of powder they consume.

Four guns of 12-inches bore have lately been put on board the 'Monarch.' They weigh 25 tons each, and charges of 50 lbs. and 67 lbs. have been fired from them with projectiles of 600 lbs. weight. I have no doubt that these guns have been made with all possible care, and are as strong as their material and construction admits; but if the weight of these guns was in proportion to the capacity of their bore, and if the material were the best that our metallurgical skill could supply for such a purpose, they ought to fire 117 lbs. of powder, and projectiles of 1250 lbs. weight. They would then be efficient weapons; but at present they are more formidable in name than in reality.

We are often flattered by being told that we have the best guns in the world. That may or may not be the case. But I think that we should not best contented while we are still so far from having attained as much as our present advancement in mechanical and metallurgical science has rendered possible for us.

Particulars of Ammunition for Whitworth Guns, from 5·5-in. to 13-in. bore.

Calibre of bore.	Powder charge.	Common Shells, cast iron, 3·5 diameters long.		Armour Shells, Whitworth metal. 3·5 diameters long.		Armour Shells, Whitworth metal. 5 diameters long.	
		Bursting-charge.	Weight of shell.	Bursting-charge.	Weight of shell.	Bursting-charge.	Weight of shell.
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5·5	11·0	4·0	70	3·5	84·0	6·0	120
7·0	23·0	8·5	150	7·5	180·0	12·0	255
8·0	34·0	13·0	220	10·5	265·0	18·0	375
9·0	50·0	18·0	320	15·0	380·0	25·0	535
10·0	70·0	24·0	440	21·0	525·0	35·0	740
11·0	90·0	32·0	580	28·0	680·0	45·0	965
12·0	117·0	40·0	750	36·0	886·0	58·0	1250
13·0	150·0	51·0	960	47·4	1045·0	75·0	1615

Mr. Whitworth's patent cartridge increases the range from 15 to 20 per cent.

Report of the Committee on Standards of Electrical Resistance.

[Plate VI.]

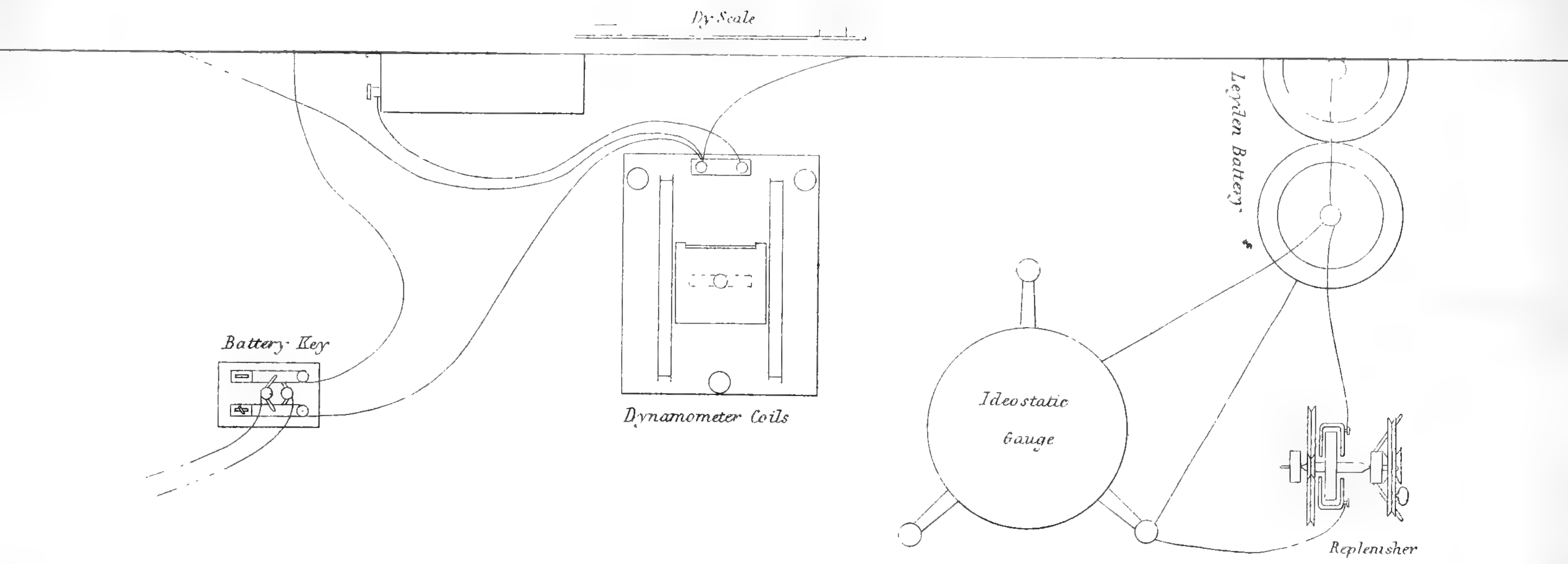
The Committee consists of Professor Williamson, Professor Sir C. Wheatstone, Professor Sir W. Thomson, Professor W. A. Miller, Dr. A. Matthiessen, Mr. Fleeming Jenkin, Sir Charles Bright, Professor Maxwell, Mr. C. W. Siemens, Mr. Balfour Stewart, Mr. C. F. Varley, Professor G. C. Foster, Mr. Latimer Clark, Mr. D. Forbes, Mr. Charles Hockin, and Dr. Joule.

The Electrical Standard Committee have this year had comparatively few meetings, and the results of the experiments made by the individual Members do not call for a Report of any length. It is, however, thought desirable to print at once, as Appendices, the important results obtained by Professor Clerk Maxwell, in determining the ratio of the electromagnetic and electrostatic series of units, and also a description of Sir Wm. Thomson's experiments on the same subject.

Description of Sir Wm. Thomson's Experiments made for the Determination of v, *the Number of Electrostatic Units in the Electromagnetic Unit.* By W. F. King.

The two principal pieces of apparatus used in these experiments were the absolute electrometer and the electrodynamometer. The former of these instruments was described at the last Meeting of the Association, and a description of it is printed in the Report. The annexed Plate illustrates the arrangements described in what follows.

The electrodynamometer consists of two large coils of fine copper wire, and a smaller coil of still finer wire. The two large coils are about 30 centims. diameter, and are placed vertical, in planes parallel to one another; the distance between the large coils is 15 centims. (equal to their radius). The smaller coil is suspended between the large coils by a copper wire of such a



J.W. Lowry sculpt.

thickness as to give the coil a time of vibration such that it completes a period in about thirteen seconds. The upper end of the suspending wire is attached to a milled head, and this head can be turned round by the fingers. The lower end of the wire is firmly fixed to the coil, and is in metallic connexion with one end of it. To the other end of the coil is soldered a spiral of very fine platinum wire which hangs directly below the coil, and its lower end is cemented to the dry woodwork of the instrument. To the fixed end of the spiral coil a copper wire is attached, whose other end is soldered to a binding-screw in an accessible position.

On one side of the small or moveable coil is fixed a plane mirror, and in front of the mirror, at a distance of about 450 centims., the scale is fixed on which the observations are read. A paraffin-lamp wire, to give dark line in image of flame, and lens are used in the ordinary way for finding accurately the angle through which the coil turns. It is never greater than ·05. Its true amount can be determined to within $\frac{1}{10}$ per cent.

The connexions are not very intricate, and are traced thus:—Starting from one pole of the battery (the battery used was sixty sawdust Daniell's in series), the current goes in at one end of large coil No. 1, and from the other end of No. 1 the current goes to either end of the moveable coil, and the end of the moveable coil at which we suppose the current to be coming out is connected with the end of No. 2 large coil, similar to the end of No. 1, to which the battery was first attached, that is to say, the end which will make the current go round in the same direction in both the large coils. When the current leaves the extreme end of No. 2, it passes though a 10,000 B.A. resistance-box; the current is completed by connecting the other end of the resistance-box with the pole of the battery not already engaged.

The absolute electrometer is used in the ordinary way for measuring differences of potential, and its electrodes are connected, one to the end of the dynamometer coil No. 1, which is joined to the battery, and the other electrode is fixed to the end of the resistance-box, which is connected to the other pole of the battery. Thus the greatest difference of potential in the arrangement is measured by the absolute electrometer. An electrometer key is used to reverse these connexions in the course of the experiments.

There is only one other part of the arrangement to be explained, and that is the method of observing the resistance of the dynamometer coils while the experiments are going on. This was done by means of the resistance-box in the circuit and an electrometer. At one time the standard electrometer was used for this purpose, but more lately the quadrant, rendered unsensitive, was employed. Both these instruments are described in the last Report.

To take the resistance of the coils, the electrodes of the electrometer were first placed on the extreme ends of the three coils, and the difference of potential was ascertained. The electrodes were then shifted to the ends of the resistance-box, and the difference of potentials of its two ends was found. This gives at once the resistance of the coils.

There are two things which have to be done before the experiments are commenced. One is the determination of the moment of inertia of the moveable coil. This is done at the beginning and end of a long series of experiments, by comparing it with a ring whose moment of inertia is known. The other is done every day, and it is finding the time of vibration of the small coil after all the connexions have been made, and the coil put into its place. This was done both with the current from the battery flowing through the coils and with no current flowing; but this variation was of very little consequence, as no difference could be detected in the time. When the dynamometer is set up, care is taken to neutralize the effects of the earth's magnetism by a large number of magnets fixed at a great distance from the coils. If the adjustment of the magnets is perfect, there is no alteration of the position of the spot of light when the current is reversed through the coils by the battery-key. Up to the present time (May 1868) various causes have prevented the obtainment of as satisfactory results as the method described above allows us to expect. Eleven sets of experiments, made at various dates, from March 10 to May 8 of the present year, have indicated values for v, of which the greatest was 292×10^8, the smallest $275{\cdot}4 \times 10^8$, and the mean $282{\cdot}5 \times 10^8$ centimetres per second. Sir W. Thomson intends to continue the investigation, hoping to attain much greater accuracy.

[P.S. Nov. 1869.—A new form of absolute electrometer has now been completed and brought into use, with good promise as to accuracy and convenience. A glass jar constituting the "Leyden battery" contains within it the "absolute electrometer" proper, the "idiostatic gauge," and the "replenisher." One observer can use it effectively; although it is more easily worked by two, one maintaining constant potential in the Leyden jar by aid of the idiostatic gauge and the replenisher, and the other attending to the absolute electrometer (main balance and micrometer screw). The main balance, giving electric weighing in known weights, is as steady and as easily used as any of the "attracted disk" electrometers, whether portable or stationary, described in previous Reports.]

Errata in Plate VI.

For Dy Scale *read* Dynamometer Scale.
,, Ideostatic *read* Idiostatic.
Add a connexion between outside of Leyden battery and one terminal of the neighbouring Electrometer key.

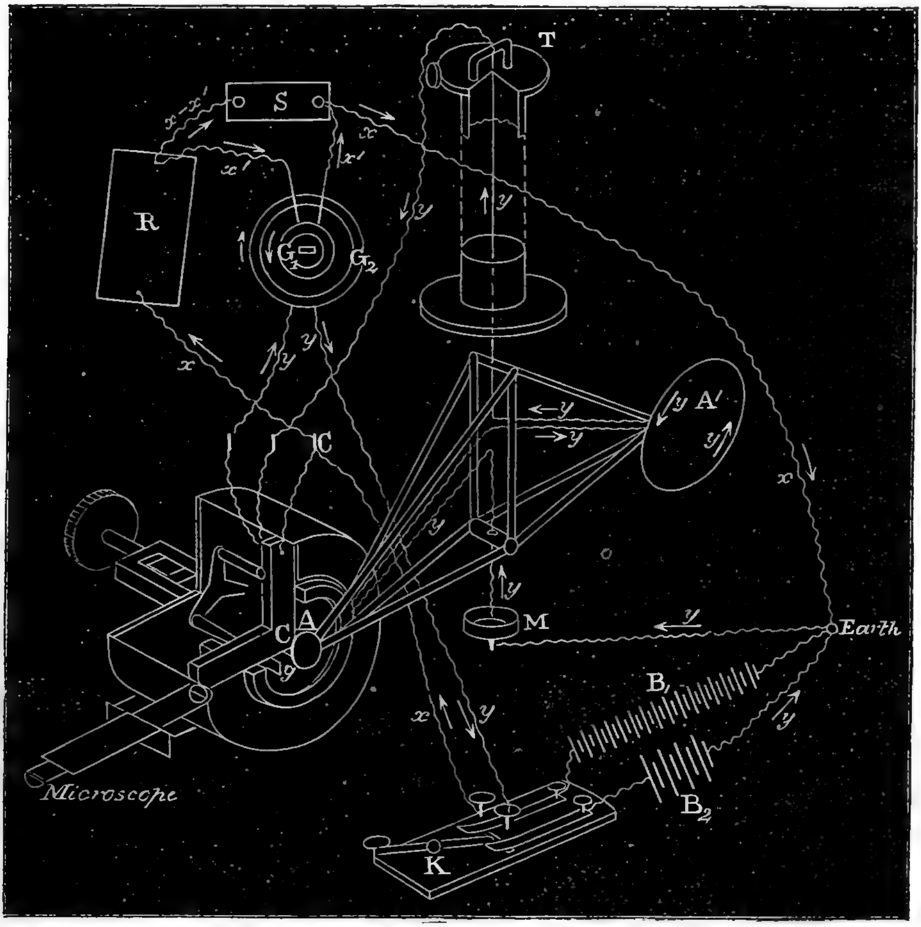
Experiments on the Value of v, *the Ratio of the Electromagnetic to the Electrostatic Unit of Electricity.* By J. Clerk Maxwell.

The experiments consisted in observing the equilibrium between the electrostatic attraction of two disks, at a certain difference of potential, and the electromagnetic repulsion of two coils traversed by a certain current. For this purpose one of the disks, with one of the coils at its back, was attached to one arm of a torsion-balance, while the other, with the other coil at its back, was capable of being moved to various distances from the suspended disk by a micrometer screw. Another coil, traversed by the same current in the opposite direction, was attached to the other arm of the torsion-balance, so as to do away with the effect of terrestrial magnetism.

The fixed disk was larger than the suspended disk, and the latter, when in its zero position, had its surface in the same plane as that of a "guard-ring," as in Sir W. Thomson's electrometers. Its position and motion were observed by means of a microseope, directed to a graduated glass scale, connected with the disk. When the microscope was adjusted so that the image of the zero line on the glass scale coincided with the cross wires of the microscope, the very smallest motion of the scale could be easily detected, so that the observations were very rapid. The disk was brought to zero by the tangent screw at the top of the suspension-wire, and its equilibrium was always observed at zero. The equilibrium, when the electrical forces were applied, was always unstable. This electrical balance was made by Mr.

Becker. The experiments were made in the laboratory of Mr. Gassiot, who kindly gave the use of his great battery for the purpose. Mr. Willoughby Smith lent his resistance-coils, of 1,102,000 Ohms, Messrs. Forde and Fleeming Jenkin lent a galvanometer, a resistance-box, a bridge and a key, and Mr. C. Hockin undertook the observation of the galvanometer, and the testing of the galvanometer, the resistances, and the micrometer-screw.

The difference of potentials of the disks was compared with the current in the coils as follows:—One electrode of the great battery was connected to the fixed disk, and the other to the case of the instrument and the guard-ring



A. Suspended disk and coil.
A′. Counterpoise disk and coil.
C. Fixed disk and coil.
B_1. Great battery. B_2. Small battery.
G_1. Primary coil of galvanometer.
G_2. Secondary coil.
R. Great resistance. S. Shunt.
K. Double key. *g*. Graduated glass scale.

C. Electrode of fixed disk.
x. Current through R.
x'. Current through G_1. $x-x'$. Current through S.
y. Current through the three coils and G_2.
M. Mercury cup. T. Torsion head and tangent screw.

One quarter of the micrometer box, disks, and coils is cut away to show the interior. The case of the instrument is not shown. The galvanometer and shunts were 10 feet from the electric balance.

and the suspended disk. They were also connected through the great resistance R, and the primary coil of the galvanometer G shunted with a resistance S.

A small Grove's battery was employed to send a current through the three coils and the secondary coil of the galvanometer G_2.

Equilibrium of the electric balance was obtained by working the micrometer, and so adjusting the distance of the disks. At the same time equilibrium of the galvanometer was obtained by altering the resistance of the shunt S.

The simultaneous values of the micrometer and the shunt formed the result of each experiment. It was necessary also to ascertain the ratio of the magnetic effects of the two coils of the galvanometer immediately after each set of experiments.

The method of experimenting appeared capable of considerable accuracy; but some difficulties arose from want of constancy in the batteries, from leakage of electricity, &c., so that many of the experiments were known to be faulty. Twelve experiments, however, against which nothing could be proved at the time of making them, in which the distance of the disks ranged from $\frac{1}{4}$ to $\frac{1}{2}$ an inch, and the power of the battery from 1000 to 2600 cells, gave values of v of which the least was 28·4, and the greatest 29·4 Ohms; and in nine of these the values lay between 28·68 and 28·91. The mean of the 12 was—

$$\begin{aligned} v &= 28{\cdot}798 \text{ Ohms.} \\ &= 288{,}000{,}000 \text{ metres per second.} \\ &= 179{,}000 \text{ statute miles per second.} \end{aligned}$$

This result is much lower than that of MM. Weber and Kohlrausch, which was v=310,740,000 metres per second, but agrees, I believe, more nearly with values recently obtained by Sir W. Thomson, whose method, as well as mine, depends on the B.A. unit. Weber's method depends on the measure of capacity. It is to be hoped that this important physical quantity may soon be determined by methods founded on capacity, and disembarrassed from the phenomena of "electric absorption," which occurs in all solid condensers, and which would tend to give too high values of v.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MATHEMATICS AND PHYSICS.

Address by Professor J. J. Sylvester, *LL.D., F.R.S., President of the Section.*

Ladies and Gentlemen,—

A few days ago I noticed in a shop window the photograph of a Royal mother and child, which seemed to me a very beautiful group; on scanning it more closely, I discovered that the faces were ordinary, or, at all events, not much above the average, and that the charm arose entirely from the natural action and expression of the mother stooping over and kissing her child which she held in her lap; and I remarked to myself that the homeliest features would become beautiful when lit up by the rays of the soul—like the sun "gilding pale streams with heavenly alchemy." By analogy, the thought struck me that if a man would speak naturally and as he felt on any subject of his predilection, he might hope to awaken a sympathetic interest in the minds of his hearers; and, in illustration of this, I remembered witnessing how the writer of a well-known article in the 'Quarterly Review' so magnetized his audience at the Royal Institution by his evident enthusiasm that, when the lecture was over and the applause had subsided, some ladies came up to me and implored me to tell them what they should do to get up the Talmud; for that was what the lecture had been about.

Now, as I believe that even Mathematics are not much more repugnant than the Talmud to the common apprehension of mankind, and I really love my subject, I shall not quite despair of rousing and retaining your attention for a short time if I proceed to read (as, for greater assurance against breaking down, I shall beg your permission to do) from the pages I hold in my hand.

It is not without a feeling of surprise and trepidation at my own temerity that I find myself in the position of one about to address this numerous and distinguished assembly. When informed that the Council of the British Association had it in contemplation to recommend me to the General Committee to fill the office of President of the Mathematical and Physical Section, the intimation was accompanied with the tranquilizing assurance that it would rest with myself to deliver or withhold an address as I might think fit, and that I should be only following in the footsteps of many of the most distinguished of my predecessors were I to resolve on the latter course.

Until the last few days I had made up my mind to avail myself of this option, by proceeding at once to the business before us without troubling you to listen to any address, swayed thereto partly by a consciousness of the very limited extent of my oratorical powers, partly by a disinclination, in the midst of various pressing private and official occupations, to undertake a kind of work new to one more used to thinking than to speaking (to making mathematics than to talking about them), and partly and more especially by a feeling of my inadequacy to satisfy the expectations that would be raised in the minds of those who had enjoyed the privilege of hearing or reading the allocution (which fills me with admiration and dismay) of my gifted predecessor, Dr. Tyndall, a man in whom eloquence and philosophy seem to be inborn, whom Science and Poetry woo with an equal spell*, and whose ideas have a faculty of arranging themselves in forms of order and beauty as spontaneously and unfailingly as those crystalline solutions from which, in a striking passage of his address, he drew so vivid and instructive an illustration.

From this lotos-eater's dream of fancied security and repose I was rudely awakened by receiving from the Editor of an old-established journal in this city a note containing a polite but peremptory request that I should, at my earliest convenience, favour him with a "copy of the address I proposed to deliver at the forthcoming Meeting." To this invitation, my first impulse was to respond very much in the same way as did the "Needy knife-grinder" of the 'Antijacobin,' when summoned to recount the story of his wrongs to his republican sympathizer, "Story, God bless you, I have none to tell, Sir!" "Address, Mr. Editor, I have none to deliver."

I have found, however, that increase of appetite still grows with what it feeds on, that those who were present at the opening of the Section last year, and enjoyed my friend Dr. Tyndall's melodious utterances, would consider themselves somewhat ill-treated if they were sent away quite empty on the present occasion, and that, failing an address, the Members would feel very much like the guests at a wedding-breakfast where no one was willing or able to propose the health of the bride and bridegroom.

Yielding, therefore, to these considerations and to the advice of some officially connected with the Association, to whose opinions I feel bound to defer, and unwilling also to countenance by my example the too prevailing opinion that mathematical pursuits unfit a person for the discharge of the common duties of life and cut him off from the exercise of Man's highest prerogative, "discourse of reason and faculty of speech divine,"—rather, I say, than favour the notion that we Algebraists (who regard each other as the flower and salt of the earth) are a set of mere calculating-machines endowed with organs of locomotion, or, at best, a sort of poor visionary dumb creatures only capable of communicating by signs and symbols with the outer world, I have resolved to take heart of grace and to say a few words, which I hope to render, if not interesting, at least intelligible, on a subject to which the larger part of my life has been devoted.

The President of the Association, Prof. Stokes, is so eminent alike as a mathematician and physicist, and so distinguished for accuracy and extent of erudition and research, that I felt assured I might safely assume he would, in his Address to the Association at large, take an exhaustive survey, and render a complete account of the recent progress and present condition and prospects of Mathematical and Physical Science. This consideration narrowed very much and brought almost to a point the ground available for me to occupy in this Section; and as I cannot but be aware that it is as a cultivator of pure mathematics (the subject in which

* So it is said of Jacobi, that he attracted the particular attention and friendship of Böckh, the director of the philological seminary at Berlin, by the zeal and talent he displayed for philology, and only at the end of two years' study at the University, and after a severe mental struggle, was able to make his final choice in favour of mathematics. The relation between these two sciences is not perhaps so remote as may at first sight appears, and indeed it has often struck me that metamorphosis runs like a golden thread through the most diverse branches of modern intellectual culture, and forms a natural link of connexion between subjects in their aims so unlike as Grammar, Ethnology, Rational Mythology, Chemistry, Botany, Comparative Anatomy, Physiology, Physics, Algebra, Music, all of which, under the modern point of view, may be regarded as having morphology for their common centre. Even singing, I have been told, the advanced German theorists regard as being strictly a development of recitative, and infer therefrom that no essentially new melodic themes can be invented until a social cataclysm, or the civilization of some at present barbaric races, shall have created new necessities of expression and called into activity new forms of impassioned declamation.

my own researches have chiefly, though by no means exclusively lain*) that I have been placed in this Chair, I hope the Section will patiently bear with me in the observations I shall venture to make on the nature of that province of the human reason and its title to the esteem and veneration with which through countless ages it has been and, so long as Man respects the intellectual part of his nature, must ever continue to be regarded†.

It is said of a great party leader and orator in the House of Lords that, when lately requested to make a speech at some religious or charitable (at all events a non-political) meeting, he declined to do so on the ground that he could not speak unless he saw an adversary before him—somebody to attack or reply to. In obedience to a somewhat similar combative instinct, I set to myself the task of considering certain recent utterances of a most distinguished member of this Association, one whom I no less respect for his honesty and public spirit than I admire for his genius and eloquence ‡, but from whose opinions on a subject which he has not studied I feel constrained to differ. Göthe has said—

"Verständige Leute kannst du irren sehn
In Sachen nämlich, die sie nicht verstehn."

Understanding people you may see erring—in those things, to wit, which they do not understand.

I have no doubt that had my distinguished friend, the probable President-elect of the next Meeting of the Association, applied his uncommon powers of reasoning, induction, comparison, observation, and invention to the study of mathematical science, he would have become as great a mathematician as he is now a biologist; indeed he has given public evidence of his ability to grapple with the practical side of certain mathematical questions; but he has not made a study of mathematical science as such, and the eminence of his position and the weight justly attaching to his name render it only the more imperative that any assertions proceeding from such a quarter, which may appear to me erroneous, or so expressed as to be conducive to error, should not remain unchallenged or be passed over in silence §.

He says "mathematical training is almost purely deductive. The mathematician starts with a few simple propositions, the proof of which is so obvious that they are called self-evident, and the rest of his work consists of subtle deductions from them. The teaching of languages, at any rate as ordinarily practised, is of the same general nature—authority and tradition furnish the data, and the mental operations are deductive." It would seem from the above somewhat singularly

* My first printed paper was on Fresnel's Optical Theory, published in the 'Philosophical Magazine;' my latest contribution to the 'Philosophical Transactions' is a memoir on the "Rotation of a Free Rigid Body." There is an old adage, "purus mathematicus, purus asinus." On the other hand, I once heard the great Richard Owen say, when we were opposite neighbours in Lincoln's-Inn Fields (doves nestling among hawks), that he would like to see *Homo Mathematicus* constituted into a distinct subclass, thereby suggesting to my mind sensation, perception, reflection, abstraction, as the successive stages or phases of protoplasm on its way to being made perfect in Mathematicised Man. Would it sound too presumptuous to speak of perception as a quintessence of sensation, language (*i.e.* communicable thought) of perception mathematic of language?. We should then have four terms differentiating from inorganic matter and from each other the Vegetable, Animal, Rational, and supersensual modes of existence.

† Mr. Spottiswoode favoured the Section, in his opening address, with a combined history of the progress of Mathematics and Physics; Dr. Tyndall's address was virtually on the limits of Physical Philosophy; the one here in print is an attempted faint adumbration of the nature of Mathematical Science in the abstract. What is wanting (like a fourth sphere resting on three others in contact) to build up the Ideal Pyramid is a discourse on the Relation of the two branches (Mathematic and Physics) to, their action and reaction upon, one another, a magnificent theme with which it is to be hoped some future President of Section A will crown the edifice and make the Tetralogy (symbolizable by $A+A'$, A, A', $A.A'$) complete.

‡ Although no great lecture-goer, I have heard three lectures in my life which have left a lasting impression as masterpieces on my memory—Clifford on Mind, Huxley on Chalk, Dumas on Faraday.

§ In his *éloge* of Daubenton, Cuvier remarks, "Les savants jugent toujours comme vulgaire les ouvrages qui ne sont pas de leur genre."

juxtaposed paragraphs that, according to Prof. Huxley, the business of the mathematical student is from a limited number of propositions (bottled up and labelled ready for future use) to deduce any required result by a process of the same general nature as a student of language employs in declining and conjugating his nouns and verbs—that to make out a mathematical proposition and to construe or parse a sentence are equivalent or identical mental operations. Such an opinion scarcely seems to need serious refutation. The passage is taken from an article in 'Macmillan's Magazine' for June last, entitled "Scientific Education—Notes of an After-dinner Speech," and I cannot but think would have been couched in more guarded terms by my distinguished friend had his speech been made *before* dinner instead of *after*.

The notion that mathematical truth rests on the narrow basis of a limited number of elementary propositions from which all others are to be derived by a process of logical inference and verbal deduction, has been stated still more strongly and explicitly by the same eminent writer in an article of even date with the preceding in the 'Fortnightly Review,' where we are told that "Mathematics is that study which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation." I think no statement could have been made more opposite to the undoubted facts of the case, that mathematical analysis is constantly invoking the aid of new principles, new ideas, and new methods, not capable of being defined by any form of words, but springing direct from the inherent powers and activity of the human mind, and from continually renewed introspection of that inner world of thought of which the phenomena are as varied and require as close attention to discern as those of the outer physical world (to which the inner one in each individual man may, I think, be conceived to stand in somewhat the same general relation of correspondence as a shadow to the object from which it is projected, or as the hollow palm of one hand to the closed fist which it grasps of the other), that it is unceasingly calling forth the faculties of observation and comparison, that one of its principal weapons is induction, that it has frequent recourse to experimental trial and verification, and that it affords a boundless scope for the exercise of the highest efforts of imagination and invention.

Lagrange, than whom no greater authority could be quoted, has expressed emphatically his belief in the importance to the mathematician of the faculty of observation; Gauss has called mathematics a science of the eye, and in conformity with this view always paid the most punctilious attention to preserve his text free from typographical errors; the ever to be lamented Riemann has written a thesis to show that the basis of our conception of space is purely empirical, and our knowledge of its laws the result of observation, that other kinds of space might be conceived to exist subject to laws different from those which govern the actual space in which we are immersed, and that there is no evidence of these laws extending to the ultimate infinitesimal elements of which space is composed. Like his master Gauss, Riemann refuses to accept Kant's doctrine of space and time being forms of intuition, and regards them as possessed of physical and objective reality. I may mention that Baron Sartorius von Waltershausen (a member of this Association) in his biography of Gauss ("Gauss zu gedächtniss"), published shortly after his death, relates that this great man was used to say that he had laid aside several questions which he had treated analytically, and hoped to apply to them geometrical methods in a future state of existence, when his conceptions of space should have become amplified and extended; for as we can conceive beings (like infinitely attenuated book-worms* in an infinitely thin sheet of paper) which possess only the notion of space of two dimensions, so we may imagine beings capable of realizing space of four or a greater number of dimensions†. Our Cayley, the central

* I have read or been told that eye of observer has never lighted on these depredators, living or dead. Nature has gifted me with eyes of exceptional microscopic power, and I can speak with some assurance of having repeatedly seen the creature wriggling on the learned page. On approaching it with breath or finger-nail it stiffens out into the semblance of a streak of dirt, and so eludes detection.

† It is well known to those who have gone into these views that the laws of motion accepted as a fact suffice to prove in a general way that the space we live in is a flat or level space (a "homaloid"), our existence therein being assimilable to the life of the

luminary, the Darwin of the English school of mathematicians, started and elaborated at an early age, and with happy consequences, the same bold hypothesis.

Most, if not all, of the great ideas of modern mathematics have had their origin in observation. Take, for instance, the arithmetical theory of forms, of which the foundation was laid in the diophantine theorems of Fermat, left without proof by their author, which resisted all the efforts of the myriad-minded Euler to reduce to demonstration, and only yielded up their cause of being when turned over in the blowpipe flame of Gauss's transcendent genius; or the doctrine of double periodicity, which resulted from the observation by Jacobi of a purely analytical fact of transformation; or Legendre's law of reciprocity; or Sturm's theorem about the roots of equations, which, as he informed me with his own lips, stared him in the face in the midst of some mechanical investigations connected with the motion of compound pendulums; or Huyghens' method of continued fractions, characterized by Lagrange as one of the principal discoveries of "that great mathematician, and to which he appears to have been led by the construction of his Planetary Automaton;" or the new algebra, speaking of which one of my predecessors (Mr. Spottiswoode) has said, not without just reason and authority, from this Chair, "that it reaches out and indissolubly connects itself each year with fresh branches of mathematics, that the theory of equations has almost become new through it, algebraic geometry transfigured in its light, that the calculus of variations, molecular physics, and mechanics" (he might, if speaking at the present moment, go on to add the theory of elasticity and the highest developments of the integral calculus) "have all felt its influence."

Now this gigantic outcome of modern analytical thought, itself, too, only the precursor and progenitor of a future still more heaven-reaching theory, which will comprise a complete study of the interoperation, the actions and reactions, of algebraic forms (Analytical Morphology in its absolute sense), how did this originate? In the accidental observation by Eisenstein, some score or more years ago, of a single invariant (the Quadrinvariant of a Binary Quartic) which he met with in the course of certain researches just as accidentally and unexpectedly as M. Du Chaillu might meet a Gorilla in the country of the Fantees, or any one of us in London a White Polar Bear escaped from the Zoological Gardens. Fortunately he pounced down upon his prey and preserved it for the contemplation and study of future mathematicians. It occupies only part of a page in his collected posthumous works. This single result of observation (as well entitled to be so called as the discovery of Globigerinæ in chalk or of the Confoco-ellipsoidal structure of the shells of the Foraminifera), which remained unproductive in the hands of its distinguished author, has served to set in motion a train of thought and to propagate an impulse which have led to a complete revolution in the whole aspect of modern analysis, and whose consequences will continue to be felt until Mathematics are forgotten and British Associations meet no more.

I might go on, were it necessary, piling instance upon instance to prove the paramount importance of the faculty of observation to the process of mathematical discovery*. Were it not unbecoming to dilate on one's personal experience, I could tell a story of almost romantic interest about my own latest researches in a field where Geometry, Algebra, and the Theory of Numbers melt in a surprising

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bookworm in an *unrumpled page*: but what if the page should be undergoing a process of gradual bending into a curved form? Mr. W. K. Clifford has indulged in some remarkable speculations as to the possibility of our being able to infer, from certain unexplained phenomena of light and magnetism, the fact of our level space of three dimensions being in the act of undergoing in space of four dimensions (space as inconceivable to us as our space to the supposititious bookworm) a distortion analogous to the rumpling of the page to which that creature's powers of direct perception have been postulated to be limited.

* Newton's Rule was to all appearance, and according to the more received opinion, obtained inductively by its author. My own reduction of Euler's problem of the Virgins (or rather one slightly more general than this) to the form of a question (or, to speak more exactly, a set of questions) in simple partitions was, strange to say, first obtained by myself inductively, the result communicated to Prof. Cayley, and proved subsequently by each of us independently, and by perfectly distinct methods.

manner into one another, like sunset tints or the colours of the dying dolphin, "the last still loveliest" (a sketch of which has just appeared in the Proceedings of the London Mathematical Society*), which would very strikingly illustrate how much observation, divination, induction, experimental trial, and verification, causation, too (if that means, as I suppose it must, mounting from phenomena to their reasons or causes of being), have to do with the work of the mathematician. In the face of these facts, which every analyst in this room or out of it can vouch for out of his own knowledge and personal experience, how can it be maintained, in the words of Professor Huxley, who, in this instance, is speaking of the sciences as they are in themselves and without any reference to scholastic discipline, that Mathematics "is that study which knows nothing of observation, nothing of induction, nothing of experiment, nothing of causation."

I, of course, am not so absurd as to maintain that the habit of observation of external nature will be best or in any degree cultivated by the study of mathematics, at all events as that study is at present conducted; and no one can desire more earnestly than myself to see natural and experimental science introduced into our schools as a primary and indispensable branch of education: I think that that study and mathematical culture should go on hand in hand together, and that they would greatly influence each other for their mutual good. I should rejoice to see mathematics taught with that life and animation which the presence and example of her young and buoyant sister could not fail to impart, short roads preferred to long ones, Euclid honourably shelved or buried "deeper than did ever plummet sound" out of the schoolboy's reach, morphology introduced into the elements of Algebra—projection, correlation, and motion accepted as aids to geometry—the mind of the student quickened and elevated and his faith awakened by early initiation into the ruling ideas of polarity, continuity, infinity, and familiarization with the doctrine of the imaginary and inconceivable.

It is this living interest in the subject which is so wanting in our traditional and mediæval modes of teaching. In France, Germany, and Italy, everywhere where I have been on the Continent, mind acts direct on mind in a manner unknown to the frozen formality of our academic institutions; schools of thought and centres of real intellectual cooperation exist; the relation of master and pupil is acknowledged as a spiritual and a lifelong tie, connecting successive generations of great thinkers with each other in an unbroken chain, just in the same way as we read, in the catalogue of our French Exhibition, or of the Salon at Paris, of this man or that being the pupil of one great painter or sculptor and the master of another. When followed out in this spirit, there is no study in the world which brings into more harmonious action all the faculties of the mind than the one of which I stand here as the humble representative, there is none other which prepares so many agreeable surprises for its followers, more wonderful than the changes in the transformation-scene of a pantomime, or, like this, seems to raise them, by successive steps of initiation, to higher and higher states of conscious intellectual being.

This accounts, I believe, for the extraordinary longevity of all the greatest masters of the Analytical art, the Dii Majores of the mathematical Pantheon. Leibnitz, lived to the age of 70; Euler to 76; Lagrange to 77; Laplace to 78; Gauss to 78; Plato, the supposed inventor of the conic sections, who made mathematics his study and delight, who called them the handles or aids to philosophy, the medicine of the soul, and is said never to have let a day go by without inventing some new theorems, lived to 82; Newton, the crown and glory of his race, to 85; Archimedes, the nearest akin, probably, to Newton in genius, was 75, and might have lived on to be 100, for aught we can guess to the contrary, when he was slain by the impatient and ill-mannered sergeant, sent to bring him before the Roman general, in the full vigour of his faculties, and in the very act of working out a problem; Pythagoras, in whose school, I believe, the word mathematician (used, however, in a somewhat wider than its present sense) originated, the second founder of geometry, the inventor of the matchless theorem which goes by his name, the precognizer of the undoubtedly mis-called Copernican theory, the discoverer of the regular solids and the musical canon, who stands at the very apex of this pyramid of flame (if we may credit the tradition), after spending 22 years

* Under the title of "Outline Trace of the Theory of Reducible Cyclodes."

studying in Egypt, and 12 in Babylon, opened school when 56 or 57 years old in Magna Græcia, married a young wife when past 60, and died, carrying on his work with energy unspent to the last, at the age of 99. The mathematician lives long and lives young; the wings of his soul do not early drop off, nor do its pores become clogged with the earthy particles blown from the dusty highways of vulgar life.

Some people have been found to regard all mathematics, after the 47th proposition of Euclid, as a sort of morbid secretion, to be compared only with the pearl said to be generated in the diseased oyster, or, as I have heard it described, "une excroissance maladive de l'esprit humain." Others find its justification, its "raison d'être," in its being either the torch-bearer leading the way, or the handmaiden holding up the train of Physical Science; and a very clever writer in a recent magazine article, expresses his doubts whether it is, in itself, a more serious pursuit, or more worthy of interesting an intellectual human being, than the study of chess problems or Chinese puzzles. What is it to us, they say, if the three angles of a triangle are equal to two right angles, or if every even number is, or may be, the sum of two primes, or if every equation of an odd degree must have a real root. How dull, stale, flat, and unprofitable are such and such like announcements! Much more interesting to read an account of a marriage in high life, or the details of an international boat-race. But this is like judging of architecture from being shown some of the brick and mortar, or even a quarried stone of a public building, or of painting from the colours mixed on the palette, or of music by listening to the thin and screechy sounds produced by a bow passed haphazard over the strings of a violin. The world of ideas which it discloses or illuminates, the contemplation of divine beauty and order which it induces, the harmonious connexion of its parts, the infinite hierarchy and absolute evidence of the truths with which it is concerned, these, and such like, are the surest grounds of the title of mathematics to human regard, and would remain unimpeached and unimpaired were the plan of the universe unrolled like a map at our feet, and the mind of man qualified to take in the whole scheme of creation at a glance.

In conformity with general usage, I have used the word mathematics in the plural; but I think it would be desirable that this form of word should be reserved for the applications of the science, and that we should use mathematic in the singular number to denote the science itself, in the same way as we speak of logic, rhetoric, or (own sister to algebra *) music. Time was when all the parts of the subject were dissevered, when algebra, geometry, and arithmetic either lived apart or kept up cold relations of acquaintance confined to occasional calls upon one another; but that is now at an end; they are drawn together and are constantly becoming more and more intimately related and connected by a thousand fresh ties, and we may confidently look forward to a time when they shall form but one body with one soul. Geometry formerly was the chief borrower from arithmetic and algebra, but it has since repaid its obligations with abundant usury; and if I were asked to name, in one word, the pole-star round which the mathematical firmanent revolves, the central idea which pervades as a hidden spirit the whole corpus of mathematical doctrine, I should point to Continuity as contained in our notions of space, and say, it is this, it is this! Space is the *Grand Continuum* from which, as from an inexhaustible reservoir, all the fertilizing ideas of modern analysis are derived; and as Brindley, the engineer, once allowed before a parliamentary committee that, in his opinion, rivers were made to feed navigable canals, I feel almost tempted to say that one principal reason for the existence of space, or at least one principal function which it discharges, is that of feeding mathematical invention. Everybody knows what a wonderful influence geometry has exercised in the hands of Cauchy, Puiseux, Riemann, and his followers Clebsch, Gordan, and others, over the very form and presentment of the modern calculus, and how it has come to pass that the tracing of curves, which was once to be regarded as a puerile amuse-

* I have elsewhere (in my Trilogy published in the 'Philosophical Transactions') referred to the close connexion between these two cultures, not merely as having Arithmetic for their common parent, but as similar in their habits and affections. I have called "Music the Algebra of sense, Algebra the Music of the reason; Music the dream, Algebra the waking life,—the soul of each the same!"

ment, or at best useful only to the architect or decorator, is now entitled to take rank as a high philosophical exercise, inasmuch as every new curve or surface, or other circumscription of space is capable of being regarded as the embodiment of some specific organized system of continuity*.

The early study of Euclid made me a hater of geometry, which I hope may plead my excuse if I have shocked the opinions of any in this room (and I know there are some who rank Euclid as second in sacredness to the Bible alone, and as one of the advanced outposts of the British Constitution) by the tone in which I have previously alluded to it as a school-book; and yet, in spite of this repugnance, which had become a second nature in me, whenever I went far enough into any mathematical question, I found I touched, at last, a geometrical bottom: so it was, I may instance, in the purely arithmetical theory of partitions; so, again, in one of my more recent studies, the purely algebraical question of the invariantive criteria of the nature of the roots of an equation of the fifth degree: the first inquiry landed me in a new theory of polyhedra; the latter found its perfect and only possible complete solution in the construction of a surface of the ninth order and the subdivision of its infinite content into three distinct natural regions.

Having thus expressed myself at much greater length than I originally intended on the subject, which, as standing first on the muster-roll of the Association, and as having been so recently and repeatedly arraigned before the bar of public opinion, is entitled to be heard in its defence (if anywhere) in this place,—having endeavoured to show what it is not, what it is, and what it is probably destined to become, I feel that I must enough and more than enough have trespassed on your forbearance, and shall proceed with the regular business of the Meeting.

Before calling upon the authors of the papers contained in the varied bill of intellectual fare which I see before me, I hope to be pardoned if I direct attention to the importance of practising brevity and condensation in the delivery of communications to the Section, not merely as a saving of valuable time, but in order that what is said may be more easily followed and listened to with greater pleasure and advantage. I believe that immense good may be done by the oral interchange and discussion of ideas which takes place in the Sections; but for this to be possible, details and long descriptions should be reserved for printing and reading, and only the general outlines and broad statements of facts, methods, observations, or inventions brought before us here, such as can be easily followed by persons having a fair average acquaintance with the several subjects treated upon. I understand the rule to be that, with the exception of the author of any paper who may answer questions and reply at the end of the discussion, no member is to address the Section more than once on the same subject, or occupy more than a quarter of an hour in speaking.

In order to get through the business set down in each day's paper, it may sometimes be necessary for me to bring a discussion to an earlier close than might otherwise be desirable, and for that purpose to request the authors of papers, and those who speak upon them, to be brief in their addresses. I have known most able investigators at these Meetings, and especially in this Section, gradually part company with their audience, and at last become so involved in digressions as to lose entirely the thread of their discourse, and seem to forget, like men waking out of sleep, where they were or what they were talking about. In such cases I shall venture to give a gentle pull to the string of the kite before it soars right away out of sight into the region of the clouds. I now call upon Dr. Magnus to read his paper and recount to the Section his wondrous story on the Emission, Absorption, and Reflection of Obscure Heat†.

POSTSCRIPT.—The remarks on the use of experimental methods in mathematical

* M. Camille Jordan's application of Dr. Salmon's Eikosi-heptagram to Abelian functions is one of the most recent instances of this reverse action of geometry on analysis. Mr. Crofton's admirable apparatus of a reticulation with infinitely fine meshes rotated successively through indefinitely small angles, which he applies to obtaining whole families of definite integrals, is another equally striking example of the same phenomenon.

† Curiously enough, and as if symptomatic of the genial warmth of the proceedings in which seven sages from distant lands (Jacobi, Magnus, Newton, Janssen, Morren, Lyman,

investigation led to Dr. Jacobi, the eminent physicist of St. Petersburg, who was present at the delivery of the address, favouring me with the annexed anecdote relative to his illustrious brother C. G. J. Jacobi.

"En causant un jour avec mon frère défunt sur la necessité de contrôler par des expériences réitérées toute observation, même si elle confirme l'hypothèse, il me raconta avoir découvert un jour une loi très-remarquable de la théorie des nombres, dont il ne douta guère qu'elle fût générale. Cependant par un excès de précaution ou plutôt pour faire le superflu, il voulut substituer un chiffre quelconque réel aux termes généraux, chiffre qu'il choisit au hasard ou, peut-être, par une espèce de divination, car en effet ce chiffre mit sa formule en défaut; tout autre chiffre qu'il essaya en confirma la généralité. Plus tard il réussit à prouver que le chiffre choisi par lui par hasard, appartenait à un système de chiffres qui faisait la seule exception à la règle.

"Ce fait curieux m'est resté dans la mémoire, mais comme il s'est passé il y a plus d'une trentaine d'années, je ne rappelle plus des détails.

"M. H. Jacobi."

"Exeter, 24. Août, 1869."

Mathematics.

On the Theory of Distance. By W. K. Clifford.

This communication relates to the following two theorems on the foci and asymptotes of curves.

Theorem I.—L, M, N,... are the m tangents from a point a to a curve c_m of the mth class; B is any line through a, meeting the curve in $m(m-1)$ points; $l, m, n,$.. P, Q, R, ... are the $m(m-1)$ asymptotes of the curve, and $p, q, r, \ldots$ are a set of m foci.

$$\frac{\sin^2 \mathrm{LM} \,.\, \sin^2 \mathrm{LN} \,.\, \sin^2 \mathrm{MN}.(\overline{ap}^2 \cdot \overline{aq}^2 \cdot \overline{ar}^2 \,.\,.)^{m-4}}{al \,.\, am \,.\, an \ldots \sin \mathrm{BP} \,.\, \sin \mathrm{BQ} \,.\, \sin \mathrm{BR} \ldots} = \overline{pq}^2 \cdot \overline{qr}^2 \cdot \overline{pr}^2 \ldots.$$

Theorem II.—$l, m, n,$ .. are the n intersections of a line A with a curve C_n of the nth order; b is any point on A from which are drawn the $n(n-1)$ tangents; L, M, N,.. .$p, q, r, \ldots$ are a set of $n(n-1)$ foci, and P, Q, R, ... are the n asymptotes.

$$\frac{\overline{lm}^2 \,.\, \overline{ln}^2 \cdot \overline{mn}^2 \ldots (\sin^2 \mathrm{AP} \,.\, \sin^2 \mathrm{AQ} \,.\, \sin^2 \mathrm{AR} \ldots)^{n-1}}{\sin \mathrm{AL} \,.\, \sin \mathrm{AM} \,.\, \sin \mathrm{AN} \ldots lp \,.\, lq \,.\, lr \ldots} = \sin^2 \mathrm{PQ} \sin^2 \mathrm{QR} \,.\, \sin^2 \mathrm{PR} \ldots$$

The numerator and denominator of the fraction on the left-hand side of the equation in Theorem I. are quantities either of which I call the distance of the point a from the curve C_m. The corresponding quantities in Theorem II. I call the Distance of the line A from the curve C_n. The reason of this is in the similarity of the analytical expressions for the distance of two geometrical forms in all cases, viz. the distance vanishes when the two forms have contact, and is infinite when either of them has contact with the "absolute." The "absolute" in plane geometry (so called by Professor Cayley) is the two circular points at infinity.

I also consider the modifications undergone by these theorems in the case of spherical curves.

The method of investigation employed is an extension of the "geometric analysis" of Grassmann, itself a development of a remark of Leibnitz.

On the Umbilici of Anallagmatic Surfaces. By W. K. Clifford.

On the Common Tangents of Circles. By M. Collins.

Neumayer) took frequent part, the opening and concluding papers (each of surpassing interest, and a letting-out of mighty waters) were on Obscure Heat, by Prof. Magnus, and on Stellar Heat, by Mr. Huggins.

Sketch of a Proof of Lagrange's Equation of Motion referred to Generalized Coordinates. By R. B. Hayward, *M.A.*

Suppose a material system with n degrees of freedom, *i. e.* one for the determination of whose position and configuration n absolutely independent variables or coordinates are necessary and sufficient. Denote one of these coordinates by q, and suppose q to be changed to $q+\delta q$; then a given particle (mass m) of the system receives a displacement definite in intensity and direction, which may be denoted by $k\delta q$, where k may be regarded as a magnitude definite in intensity and direction, which may be called the "variation coefficient" of the particle m with respect to the variable q. It is plain that k is in general a function of all the n coordinates. If v denote the velocity of the particle m in any possible state of motion of the system, T(or $\frac{1}{2}\Sigma mv^2$) the *vis viva* of the system, and q' the rate of change of q or the differential coefficient of q with respect to the time, the author proves that, supposing T expressed in terms of the n coordinates q &c., and their differential coefficients with respect to the time q' &c., and $\frac{d\mathrm{T}}{dq'}$ denoting the partial differential coefficient of T with respect to q',

$$\frac{d\mathrm{T}}{dq'}=\Sigma(mkv\cos\phi),$$

where ϕ is the angle between the directions of k and v, and the summation extends to all the particles of the system. The quantity $\Sigma(mkv\cos\phi)$ may be appropriately termed the *partial momentum* of the system with respect to the coordinate q; and it is easily seen that the n partial momenta with respect to the n coordinates completely determine the motion of the system. It thus appears that each of the well-known equations of motion in the Lagrangean form

$$\frac{d.\frac{d\mathrm{T}}{dq'}}{dt}-\frac{d\mathrm{T}}{dq}=\frac{d\mathrm{U}}{dq}$$

does but express the relation between the rate of change of one of the partial momenta with the time and the forces acting on the system.

This interpretation immediately suggests a direct proof of Lagrange's equations without any reference of the system to fixed rectangular or any other special system of coordinates as in the proofs hitherto given. The direct result of differentiating $\Sigma(mkv\cos\phi)$ with respect to the time t is reduced to the required form by the help of the equation

$$\frac{dv}{dq}=\frac{dk}{dt}\cos\phi-k\sin\phi\,.\,\alpha,$$

where α is the rate of change of the direction of k in the plane of v and k; a relation which it is not difficult to establish.

On Curves of the Third Degree, here called Tertians. *By* F. W. Newman.

The object of this paper was chiefly to suggest *a nomenclature* for those curves of the third degree which are diametral or centric; but to make the argument clear, a concise discussion of the curves was necessary, and a paper was annexed on the roots of a cubic equation.

If $ax^3+3\beta x^2+3\gamma x+\delta=0$ be any cubic equation, and

$$\mathrm{A}=\begin{vmatrix}\alpha & \beta\\ \beta & \gamma\end{vmatrix},\quad \mathrm{B}=\begin{vmatrix}\beta & \gamma\\ \gamma & \delta\end{vmatrix},\quad 2\mathrm{D}=\begin{vmatrix}\alpha & \beta\\ \gamma & \delta\end{vmatrix},$$

it is here shown that if $\mathrm{AB}-\mathrm{D}^2>0$ and also $\mathrm{A}<0$, there are three real unequal roots to the equations. But if $\mathrm{A}<0$ and $\mathrm{A}-\mathrm{BD}^2=0$, there are two equal roots. Lastly, if either $\mathrm{A}>0$ or $\mathrm{B}>0$, or $\mathrm{AB}-\mathrm{D}^2<0$, there is only one real root. Supposing $\mathrm{T}_3+\mathrm{T}_2+\mathrm{T}_1+\mathrm{C}=0$ to be the general equation, where

$$\mathrm{T}_3=\alpha x^3+3\beta x^2y+3\gamma xy^2+\delta y^3,$$

T_3 may be (1) an algebraic cube, (2) may have two equal factors, (3) may have only one real factor, (4) may have three real unequal factors. Accordingly the curves fall under four distinct groups.

The first group, if T_2(or $'Ax^2+2D'xy+B'y^2$) contains in square the *same* factor which in T_3 is in cube, is reducible to the single species $ay^2=x^3$, the Twisted Parabola, here called the Whip-snake. If T_2 contains, once only, the factor which is cubical in T_3, the curve is known as the *Trident,* and is reducible to $ay=x^2-b^3x^{-1}$; but this is neither centric nor diametral, but scalene. If T_2 has no factor common to T_3, then (in this group) the equation is reducible to $y^2=X$, and the curve is here called Calyx. When further reduced to $ay^2=x^3+Cx+D$ the new origin is here called the *Pole.* The curve is of at least six species, here named Lily, when $C=0$, $D=0$; Tulip, especially when C and D are *both* positive; Hyacinth, when $C=0$ and D is *positive*; perhaps Convolvulus when $C=0$ and D is *negative*; Pink, when $C=-3b^2$, $D=2c^3$, if c be positive and $> b$; but if $c=-3b^2$ and $D=2b^3$, it is Fuchsia (or Fucia), the *knotted* Calyx. If $c=-3b^2$, and $D=-2b^3$, it is the *studded* Calyx, or Anti-fucia. If $C=-3b^2$ and $D=2c^3$, and $c < b$, the curve is here called Bulbus; being a calyx with a bulbous poot below it.

The curves of the second group here treated fall into two classes. First, the Palm-stems, $xy^2=a^3$; the Archer's Bow, $xy^2=3b^2(a-x)$; the Twisted Bow, $x(y^2+b^2)=aby$; the Pilaster (?) $x(y^2-b^2)=aby$; the Archway or Tunnel, $x(y^2-b^2)=ab^2$. A second (diametral) class is called *Vas,* $xy^2=X=mx^2+nx+p$, in which m is always positive. The parabola, $y^2=mx+n$, is asymptotic to it, and has elegant geometrical relations with it. When X has no real factor, the curve is called the Urn, if $X=m\{(x+b)^2+c^2\}$; but the Goblet if $X=m\{(x-b)^2+c^2\}$. When $c=0$, the latter becomes the Knotted Goblet; but the case of $X=m(x+b)^2$ is called the Studded Goblet. An outlying conjugate point is in this paper entitled a Stud (clavus), and the curve which has one, Studded (clavatus). But X may have two real factors, under which division there are three species. For $xy^2=a(x+b)(x+c)$ is an Urn with an outlying oval, and is called the Dripping Urn. But $xy^2=a(x-b)(x-c)$ is a Goblet with broken stem; $xy^2=a(x+b)(x-c)$ further has the foot reversed.

The diametral curves of the third group are reducible to the form

$$\mu^2xy^2=D+3Cx+3Bx^2-x^3=X,$$

where D is positive. They naturally fall into four classes, in strict analogy to the four groups of Tertians. When $X=(a-x)^3$, there is but one species, here called Pyramid; but when $\mu^2=1$, it is the Kissoid of Diocles. Pyramid is the analogue of Lily. If $X=(a-x)(b-x)^2$, and $a>b$, we get the Festoon (Cirrus), which is the analogue of Fucia, being knotted. But if $a<b$, it is the Overstudded Hillock; and when $X=(a-x)(x+b)^2$, the curve is in general the Understudded Hillock. Yet if $a>8b$, the head overhangs the sides, and it is called Capito (Great Head); and when $a=8b$, the sides appear at one point perpendicular. The last is called Cassis (Helmet). This makes five species in second class. But in fact four of them are only degenerate forms of third or fourth class.

In the third class, $X=(a-x)\{(x\pm b)^2+c^2\}$. That a curve may be a Conchoid, generally, when X is a function of x of any degree, but essentially positive, we must have $xy^2=(a-x)X$. The simplest case is $X=$constant, which makes the Archer's Bow in our second group. But in the third group, for a Conchoid (here regarded as a hill, whether Tumulus or Mons), $\frac{dy}{dx}=0$ must be impossible within the limits of the curve, $\therefore$ we need $D>B^3$. Thus, if $\mu^2xy^2=(a-x)\{(x+b)^2+c^2\}$ and $r^2=b^2+c^2$, we need $ar^2>\left(\frac{a-2b}{3}\right)^3$. But the *chief* Tertian Conchoid is $xy^2=a^3-x^3$, with polar equation $\rho^3\cos\theta=a^3$. To this $T_3+C=0$ is reducible in this group. But when $D=B^3$, $\frac{dy}{dx}=0$ has two equal roots, and a tangent parallel to x cuts the curve in its point of flexure. This is the Tombstone, Cippus. And when $B^3>D$, $\frac{dy}{dx}=0$ has three real roots, and y has both a maximum and a minimum.

This curve is called the Sphinx. Capito is a studded Sphinx, and Cassis a studded Cippus. In the fourth class X has three real unequal factors, and there is an outlying oval. When $X=(a-x)(b-x)(c-x)$ it is called Mountain and Moon. When $X=(a-x)(b+x)(c+x)$, it is Mountain and Tarn, provided that $D > B^3$. But if $B^3 > D$, we get the Clock and Pendulum, differing from Capito only in having an oval for a stud. If $D=B^3$, you have the Bell and Clapper, which differs similarly from Helmet.

The third group has also a small class of centric curves, $x(m^2x^2+\mu^2y^2)+2(Ex+Fy)=0$; but they are most elegantly treated by the polar equation of their chief variety. Under $\rho^2=a^2 \tan\theta+b^2$ we include three curves, the *third* being obtained by $b=0$. Each is a Twisted Bow; they differ only in the amount of twist. The triple system is here called Cornutus. All centric systems are of the form $T_3+T_1=0$.

Under the fourth group we have an analogous centric system, reducible by a like compact to $\rho^2 \cos 2\theta=a^2 \tan\theta \pm b^2$; but there are five species, as it is now important whether $a > b$ or $a < b$. (We cannot have $a=b$ without degeneracy.) These curves are called the Butterfly. The Twisted Bow appears like two wings. Two hyperbolas are added. There are three rectilinear asymptotes, as *always* in this fourth group.

It is here shown that for a single diameter it is essential *either* that the curve be of the first group, *or else* the general equation must admit the form $(x-ey)U'+C=0$, where the equation $U'=0$ represents a conic curve; and the equation of the diameter whose chords are parallel to $x-ey=0$ is precisely the same in the Tertian as with this conic. But further, when T_3 has three real unequal factors, three diameters become possible. If the diametral equation in this group be expressed by $\mu^2xy^2=x^3-2ax^2+Cx+D$, we find two additional diameters when $C=a^2$, which makes $\mu^2xy^2=x(x-a)^2+D$; such curves are called Trijuga or Triga. There are three species. First, when $a=0$, we have the Starry Triga, $\mu^2xy^2=x^3-b^3$. The other two species are conjugate and expressible by $\mu^2xy^2=x(x-a)^2 \pm b^3$. The chief Starry Triga (when $\mu^2=1$) has a remarkable polar equation.

When the three asymptotes make a triangle, this is called the Cloister. When they all pass through one point, the figure is called Starry. The Cloister is here generally drawn with its vertex upward. (Many drawings accompanied this paper.)

Taking $\mu^2xy^2=x^3-2ax^2+Cx+D=X$, when C is *not* $=a^2$ we may always suppose a positive, except when $a=0$, which makes the system Starry. The height of the Cloister is a. Now, first, if $X=(x-n)^3$, we have an analogue to Pyramid; it is here called the Crane. The height of the Cloister is $\frac{3}{2}n$. Next, if $X=(x-m)^2(x-n)$ and $m > n$, it is Crane and Sack, with some analogy to Festoon. Both are special cases of $X=(x-m)(x-n)(x-p)$, which is called Swing and Chair, the oval being conceived of as a chair. But if $X=(x-m)(x+n)(x+p)$, the curve is called Trophy, as it seems to show a Bow, with Shields and Spears. If in the last $n=p$, the curves cross, and we have the Knotted Flower-pot. In fact if X has only one real factor, say, $\mu^2xy^2=(x-m)\{(x+b)^2+c^2\}$ and $r^2=b^2+c^2$. If $r^2=(\frac{1}{2}m+b)^2$, we get Triga. But if $r^2 > (\frac{1}{2}m+b)^2$, the curve is the Swing without the Chair. But if $(\frac{1}{2}m+b)^2 > r^2$, the curve is the Flower-pot, if we conceive of the upper hyperbola as a calyx. The two lower hyperbolas are so twisted as to exhibit a kind of urn. And when $c=0$, we regain the Knotted Flower-pot. This completes the enumeration.

It is observed that in certain cases the asymptotes have quadratic approach to the curve; and the paper contains various other details.

Postscript.

It is possible for the Swing and Chair to become a Triga. For this, in $\mu^2xy^2=(x-m)(x-n)(x-p)$ we need as a condition $(m+n+p)^2=4(mn+mp+np)$, or $(m-n-p)^2=4np$, which can evidently be fulfilled. Indeed *either* side may be the greater. Conversely, a Triga of the form $\mu^2y^2=(x-a)^2-b^3x^{-1}$ (where a and b^3 have the same sign) may at the same time belong to the species Swing and Chair; *that is*, have an outlying oval within the Cloister. The condition is that $x(x-a)^2-b^3$ shall be resolvable into three real unequal factors; so then must $(\xi+a)\xi^2-b^3$; which requires that $\left(\frac{a}{b}\right)^3$ be $> \frac{27}{4}$. In particular, examine

$$\mu^2y^2=(x-3)^2-x^{-1}=(3-x)^2-x^{-1}.$$

You find μ^2y^2 positive while $x=\frac{1}{8}$, and still positive when $x=2\frac{1}{3}$; but negative when $x=2\frac{1}{2}$, or when $x=\frac{1}{9}$. Thus the interior oval has limits somewhat short of $x=\frac{1}{9}$, $x=2\frac{1}{2}$; while the height of the cloister is 3.

On the Curvature of Surfaces of the Second Degree. By F. W. NEWMAN.

Writing for the equation

$$Ax^2+By^2+Cz^2+2Dxy+2Exz+2Fyz+2\alpha x+2\beta y+2\gamma z+G=0;$$

taking also $V=\begin{vmatrix} A & D & E \\ D & B & F \\ E & F & C \end{vmatrix}$ and $W=\begin{vmatrix} A & D & E & \alpha \\ D & B & F & \beta \\ E & F & C & \gamma \\ \alpha & \beta & \gamma & G \end{vmatrix}$;

we know that in ellipsoids and hyperboloids both V and W are finite; in the Cone V is finite and W=0; in Paraboloids V is zero and W finite; in Cylinders both V and W are zero.

This paper shows by a direct process, (1) that if the axes move parallel to themselves without change of A B C, W remains unchanged; (2) that if the axis turn about a fixed origin while C remains unchanged, the change in the value of W is easy to estimate. In fact if W_1 be the value when the axes are *rectangular* and W belong to the same surface estimated from another system of axes in which

$$D_0=\cos(x,y),\quad E_0=\cos(x,z),\quad F_0=\cos(y,z),$$

it is here proved that

$$W=W_1\begin{vmatrix} 1 & D_0 & E_0 \\ D_0 & 1 & F_0 \\ E_0 & F_0 & 1 \end{vmatrix}.$$

If then we take lengths $Ox=Oy=Oz=1$ along the axes, W is constant, while the *volume* of the parallelepipedon, whose edges are Ox, Oy, Oz, is constant.

The relation of the function W to the curvature is cardinal; W cannot change sign in a given surface; and when W is positive, the curvature is concavo-convex.

On Conic Osculation. By F. W. NEWMAN.

The topic was treated from the general equation

$$Ax^2+By^2+C+2Dxy+2Ex+2Fy=0.$$

First. Taking the origin on the curve, C=0. It then is shown that two curves which have a common tangent at a common point may be denoted by

$$\begin{cases} Ax^2+By^2+2Dxy+2Ex=0, \\ A_0x^2+By^2+2D_0xy+2E_0x=0, \end{cases}$$

and consequently that the two osculate if $E_0=E$.

It immediately follows that (if δ is the obliquity of the axes)

$$B(x^2+y^2+2xy\cos\delta)+2Ex=0$$

is the osculating circle. From this the results of the common treatises are deduced very simply.

Secondly. If the origin be still in the curve, but neither axis be a tangent, put

$$V=\begin{vmatrix} A & D & E \\ D & B & F \\ E & F & C \end{vmatrix},\quad V_0=\begin{vmatrix} A_0 & D_0 & E \\ D_0 & B_0 & F \\ E & F & C \end{vmatrix}$$

(though *here* $C=0$); the two curves

$$\begin{cases} A\,x^2+B\,y^2+2D\,xy+2Ex+2Fy=0, \\ A_0x^2+B_0y^2+2D_0xy+2Ex+2Fy=0, \end{cases}$$

are shown to osculate when $V=V_0$, and *only* then. Also if V_0 become v, when we take $A_0=1=B_0$ and $D_0=\cos\delta$,

$$\text{radius of curvature to former} = \frac{(-v)^{\frac{3}{2}}}{\pm V \sin\delta}.$$

Thirdly. When two curves have a common point $x'y'$, the condition that they may osculate there is expressed by an equation, $U^3V=T^3V_0$, where U and T are known integer functions of the coefficients of the equations which are supposed quite general.

Summary of the Thermodynamic Theory of Waves of Finite Longitudinal Disturbance. By W. J. Macquorn Rankine, *C.E., LL.D., F.R.S.*

This paper contains a summary account of the results of a mathematical investigation, the details of which have been communicated to the Royal Society. It relates to the laws of the propagation of finite longitudinal disturbances along a cylindrical or prismatic mass of an elastic substance of any kind, solid, liquid, or gaseous. The investigation is facilitated by the use of a quantity called the *mass-velocity* or *somatic velocity* of propagation; that is, the mass of matter through which the disturbance is propagated in unity of time along a tube of the transverse area unity; also by expressing the relative positions of transverse planes in such a tube by means of the masses of matter contained between them, instead of by their distances apart. The first part of the investigation relates to the conditions under which the propagation of a wave of longitudinal disturbance of permanent type is possible; and it is shown that the principal dynamical condition of permanence of type is the following:

$$-\frac{dp}{ds}=m^2 \text{ (a constant)};$$

in which p denotes the intensity of the longitudinal elastic pressure in absolute units of force per unit of area, s the bulkiness of the substance (that is, the volume of unity of mass), and the constant m is the mass-velocity already mentioned. (That proposition had been previously demonstrated in a less elementary manner by Mr. Earnshaw.) Then, by the aid of the *thermodynamic function*, it is shown what conditions as to the transfer of heat between the vibrating particles must be fulfilled in order that the above relation between pressure and bulkiness may subsist. Those conditions are the more nearly realized, the more abrupt the changes of density which constitute the disturbance; but they cannot be absolutely realized in any actual substance; whence it is concluded that absolute permanence of type for an indefinite time in waves of longitudinal disturbance is impossible, and that it is most nearly approximated to when the disturbance is abrupt.

The latter part of the investigation relates to *adiabatic waves*; that is, waves in which there is no transfer of heat from particle to particle, and the thermodynamic function is constant. In this part of the investigation, the results are to a great extent identical with those previously arrived at by Poisson, Stokes, Airy, and especially Earnshaw; but are obtained by methods that are comparatively of an elementary kind. It is shown that in adiabatic waves there must be a change of type as the wave advances; that during that change of type the greatest compression and greatest rarefaction remain constant; that the compressed parts of the wave gain upon the rarefied parts of the wave, and at length overtake them, converting a wave which was originally one of gradual disturbance into one of sudden disturbance; and finally, that the compressed and rarefied parts of the wave by their mutual interference cause the dissipation of its energy in molecular agitation. It is conjectured that this phenomenon may be the cause of the non-existence of longitudinal vibrations in rays of light. It is analogous to what takes place in the motion of rolling waves in shallow water, when the crests overtake the troughs and at length break into them.

The linear velocity of advance of a wave is expressed by mS, in which S denotes the undisturbed value of the bulkiness. In all the various cases investigated the limit towards which that linear velocity approximates when the disturbance diminishes indefinitely is the well-known value of the velocity of sound.

On the Mechanical Tracing of Curves. By W. H. L. Russell, *F.R.S.*

In this paper the author gave an account of a machine which he has invented for tracing the general equation of the nth order by continued motion.

On Professor Christian Wiener's Stereoscopic Representation of the Cubic Eikosi-heptagram. By Professor Sylvester, *F.R.S.*

The author produced stereographic drawings sent over to him by Professor Christian Wiener, of Karlsruhe, of the famous complex of 27 right lines lying on a cubic surface discovered by Salmon and rediscovered by Steiner. Dr. Wiener, at the request of Professor Clebsch, of Heidelberg, had actually built up a suitable cubic surface, and marked the lines in colours upon it; from this model the stereograms produced had been photographed.

On the Successive Involutes to a Circle. By Professor Sylvester, *F.R.S.*

The author referred to his communication to the Section at the Meeting held last year at Norwich, "On the General Theory of the Successive Involutes to a Circle now called Cyclodes," and went on to give an account of a particular kind of cyclode which is the simplest of their respective orders, and from the lowering of the degree which takes place in their arco-radial equation are termed reducible cyclodes. He referred to his researches for determining their number and groupings for any order of derivation, and to a new class of theorems in the Partition of Numbers in which these researches have eventuated.

A sketch of his conclusions is contained in a Number recently published of the Proceedings of the London Mathematical Society, copies of which were distributed among the Members of the Section present.

Astronomy.

On Secular Variations of Lunar Tints and Spots and Shadows on Plato. By R. W. Birt, *F.R.A.S.*

One of the most promising lines of research having reference to the physical aspect of the moon's surface consists in an examination from time to time of the tints which characterize every portion of the visible disk. To take this in its entirety would be a most enormous labour; the only way to deal with a subject of this kind is to select a few of the most prominent objects which differ in brightness and colour, and regularly observe them at stated intervals; if even half a dozen such objects were selected and observed on every occasion when the moon appeared above the horizon, as the observations proceeded it would be found that not only a large amount of labour must be expended before any valuable results could be obtained, but the observations must be continued over a long period of years to eliminate the effects of those agencies which produce merely apparent changes. That changes of tint and brilliancy occur on the moon's surface is very evident; no lunar observer is ignorant of the fact that many portions of the surface vary in tint during the course of the luni-solar day; the variation of brilliancy in many of the brighter spots is still more marked during the same period, and these variations have been referred, probably with great truth, to the change of angle at which the sun's light falls upon the objects, but up to this time we are really destitute of the "proof" of this being actually the case. The scales of tint and brilliancy adopted by the three leading selenographers of the present century differ from each other, and the observations which have been referred to solar altitudes and azimuths are so exceedingly few, that *legitimately* to connect variations of brilliancy with change of illuminating angle is quite out of the question; still the presumption is strong that the most striking changes of tint and brilliancy are connected with variations of illuminating angle. It is not, however, light alone that affects the objects in the way observed; the nature of the materials of which they are composed plays an important part, some reflecting more, some less light than others.

When we enter upon a comparison of tints, either observed directly by means of the telescope or recorded on photograms, with those given on our maps or recorded in the works of selenographers, we are often struck with the differences thus detected; but as we fail to connect by ordinary inductive processes apparent variation of brightness with change of illuminating angle, simply on account of the absence, on the one hand, of a suitable scale of brightness, and on the other, of a discussion of the observations with respect to solar altitudes and azimuths, so with regard to the differences just alluded to, we fail to refer them to change of a physical character, just because we are destitute of the necessary evidence that the spots were really darker or lighter than they are at present.

While the scales of Schröter, Lohrmann, and Beer and Mädler differ among themselves, the tints or brilliancy ascribed by each selenographer to the objects recorded by him are comparable one with the other upon his particular scale, and thus a means exists of ascertaining at the epoch of each whether one of any two spots was brighter or darker than the other at the phase at which the brilliancy was determined. It is obvious that now, observations of the brightness of the same two spots may be obtained at about the same phase, provided the suitable opportunities be embraced, and thus a change of brilliancy or tint may be detected of a different character to that dependent on change of illuminating angle; for if the observations be made at precisely the same phase as when the brightness was recorded, it is clear that the illuminating angle must be nearly if not quite the same, consequently the variation of tint or brightness in one or both of the two spots must be referred to some agency different from illumination.

Last year I solicited the attention of the Section to the difference of tint which characterized a somewhat large shallow crater near Alpetragius, as compared with the drawings of Lohrmann, Beer and Mädler, and Schmidt. The floor of this crater was seen to be *darker* in 1868 than the surrounding surface, and therefore darker than delineated by the selenographers just named. The same dark tint, under every phase at which it has been examined, has been observed without exception since August 1868. The legitimate conclusion is, that during the period of the observations in 1868 and in 1869, the surface of this crater was permanently the *darkest* in the neighbourhood. If Lohrmann, Beer and Mädler, and Schmidt were correct in their comparative delineation of the tint of this crater (and it is difficult to conceive that three experienced selenographers could have fallen into the same error), we have presumptive evidence of a phenomenon which may be termed "a secular variation of tint." What it arises from is altogether another question; it, however, does not stand alone on the surface of the moon.

To enter into any speculation as to the cause of such variations, whether from bright to dark, or the reverse, is manifestly premature; there is, however, a class of phenomena which bears much on the same point; the surfaces of many of the larger smooth-walled plains are greatly diversified with spots, streaks, and in some cases spreading fans of light; the rays issuing from Proclus and spreading over the Mare Crisium may be cited as examples of the latter. The walled plain Plato has been the subject of numerous observations, both as regards its very interesting mountain border and still more interesting floor. No two drawings of this floor that I have seen precisely agree, a result to be expected when we consider that the differences of illuminating and visual angle tend materially to influence its aspect as seen from the earth, added to which, we have the different impressions produced at different times on artists and observers; still the differences dependent upon illumination &c. will have a limit; certain well-known features will always be recognized, although somewhat altered in appearance at different times; it is after a lapse of years that a well-conducted series of observations will determine if there be secular change in these stripes and tints. Should some disappear, and others not observed before become visible, the presumptive evidence is that a secular change has taken place. This appears to be the case with several spots on Plato. The earliest record that I have been able to find of any well-defined small spots on the floor is that of Gruithuisen, who observed eight; later records furnish evidence of eighteen additional spots having been observed. Of these, nine have been added so recently as last February and since. Of the twenty-six recorded, six of the earliest observed are still visible, and of the nine seen since January last five have been more or less constantly seen by two observers, leaving fifteen which have either become invisible or are very rarely seen.

When the sun is rising upon Plato the shadows of the peaks on the western wall are admirably calculated to identify certain of these spots, and probably of deciding between craters opened on the floor of Plato and those small white spots to which Herr Tempel solicits attention as indicative of a *warm chemical activity*, and which appear under a high solar illumination, there being no indication whatever of craters existing on their sites as the terminator passes them.

Beer and Mädler measured the three peaks on the western wall, viz. γ, δ, and ϵ, the heights being as under:—

$$\gamma = 7258 \text{ Eng. feet}, \quad \delta = 6369 \text{ Eng. feet}, \quad \epsilon = 5128 \text{ Eng. feet}.$$

Challis measured the shadows on May 16, 1853. The measures were made parallel and perpendicular to a line coincident with the longest diameter of Plato. At the time Challis observed Plato nine spots had been recorded as having been seen on the floor, four of which were delineated by Challis, numbered 1, 3, 4, and 5. They have since been observed by Rosse, Dobie, Dawes, and Pratt, and some of them by Knott and other observers.

Rosse in 1862, Dawes in 1863, and Birmingham in 1869, observed the shadow of the peak γ in close proximity with No. 5 (?). Rosse and Birmingham have drawn No. 1 with the shadow of δ just receding from it, and Birmingham gives No. 3 at the extremity of the shadow of the northern peak ϵ. As matter of observation these are important; for by the variations of the seasons at the moon the shadows will fall somewhat differently in summer than in winter; the extreme range is, however, but small, the azimuthal angle with the same altitude not exceeding 3°; and as solar azimuths at the moon are easily calculated, no real difficulty exists in identifying these spots as lying near the shadows of the peaks. The peaks themselves merit attention; Challis's shadow of δ terminates by a straight line; he measured the two extremities of this line. Rosse delineates the termination of the shadow as from two pinnacles upon the summit, with the crater No. 1 between them. Birmingham gives the south pinnacle only, with the crater No. 1 just beyond it. In Dawes's drawing No. 1 lies between the shadows of γ and δ. There are other peculiarities about the shadows which require the solar azimuths to be calculated for illustrating them. It is to be hoped that good drawings, accompanied by descriptions of the shadows of the west wall and craters visible on the floor, will be *multiplied*, as in referring such drawings and descriptions to the respective periods at which they were made in the luni-solar year, we may become better acquainted with the nature of the summit of the wall, and by means of large apertures, small craters on the floor, hitherto overlooked, may be detected.

Although this branch of lunar physics is confessedly difficult, it is by no means insurmountable. The greatest drawback consists in the paucity of recorded observations of an earlier date, from which arises the uncertainty of the existence of the more recently observed spots. The way, however, for precise observation and careful discussion is gradually opening, and we may hope that Schmidt's suggestion of "trying by the aid of more powerful telescopes to represent the topography of the yet undelineated details of the surface of the moon," may bear good fruit, although the further we proceed the more unable are we to see the end of the work; "it is," says Schmidt, "as if from the ordinary determination of place of the brighter stars down to the eighth magnitude, one passes on to that of the stars of the Milky Way." So, in like manner, each addition to our knowledge of lunar physics leads us onward to the study of still more minute forms, in which perhaps lurk the germs of future interesting and important discoveries.

*On the Heat of the Stars**. *By* WILLIAM HUGGINS, *F.R.S.*

On the Longitude of the Radcliffe Observatory, Oxford, as deduced from Meridional Observations of the Moon, made at Greenwich and Oxford, in the years 1864–68. *By the* Rev. R. MAIN, *M.A., F.R.S., F.R.A.S.*

As the moon has been observed for several years at the Radcliffe Observatory with the Carrington Transit-circle, Mr. Main has thought it desirable to make, by means of the observations as compared with those made at Greenwich, a determination of the longitude of the Observatory. The whole number of observations employed is 217, and include all that were made on the same day at the two Observatories from the year 1864 to 1868, both inclusive.

The following Table gives the results deduced from the observations of each year, together with the final result of the whole of the observations, and the probable errors:—

Year.	Number of observations.	Resulting longitude west.	Probable error.	Probable error of a single result.	Weight.
		m s	s	s	
1864.	32	5 4·72	0·52	4·28	18
1865.	42	4·03	0·34	3·71	30
1866.	46	3·76	0·31	2·11	37
1867.	43	2·44	0·46	3·03	17
1868.	54	3·14	0·39	2·86	24
Means		5 3·65	0·17		

The longitude of the observatory which has been assumed since the year 1841 $5^m\ 2^s{\cdot}6$, which is less than that given above by $1^s{\cdot}05$. This assumed longitude was determined by the late Rev. R. Sheepshanks, by chronometers carried backwards and forwards between Greenwich and Oxford, and though, unfortunately, the details have never been published, there is no doubt that the determination was most trustworthy. Assuming its correctness, and considering the difference between it and the lunar determination to be due to error in the observation of the moon's limb, this error would amount very closely to $0^s{\cdot}04$ to be divided between the two observatories.

Now, as it is known that a personal equation peculiar to the moon's limb does occasionally exist, to the amount of two or three-tenths of a second, it is probable that an error much smaller in amount may affect all transits of the limb, and the preceding investigation will show that in the case of the Greenwich and Oxford observers it is very small.

On the Discordance usually observed between the results of Direct and Reflexion Observations of North Polar Distance. *By the* Rev. R. MAIN, *M.A., F.R.S., F.R.A.S.*

In this paper the author attempts to put in a clear light the origin of the singular difference which has been generally observed, in the use of the mural or the transit-circle, between the results of direct and reflexion observations. After attributing to the present Astronomer Royal the merit of originally organizing the system of reflexion observations as now practised, and of keeping his attention steadily fixed upon the discordance in question, Mr. Main remarks that the Greenwich observations are, both from the frequency and goodness of the observations, best calculated for exhibiting the nature of the errors. He takes then for examination the star-observations of 1865 and 1866, which are peculiarly suitable for the investi-

* *Vide* Proceedings of the Royal Society, vol. xvii. p. 309.

gation, because the error changes its sign between these two years; and his first process is to examine, for all the zenith-point groups having a sufficient number of star-observations, the results given by north stars, by south stars, and by observation of the reflected image of the wire. If the means of these separate results were exhibited in the Greenwich observations, it would be easy to see at a glance that the zenith-points given by north stars frequently differ considerably from those given by south stars, though the mean of these always agrees well with the nadir result. This would show that the circle-readings require a variable correction depending on the sine of the zenith-distance, but none depending on the cosine, or that the error has for its cause either an erroneously assigned flexure of telescope, or something that produces a similar error in the circle-readings. Now, in any one of these cases, as the assumed zenith-point is the mean of all the results (north stars, south stars, and nadir), it is plain that, while it is applied back again to the circle-readings for direct and reflexion observations of north and south stars, the zenith-distances deduced from the direct and reflexion observations will be different, and that the difference will change signs at the zenith, or that the R D will have different signs for north and south stars. Pursuing this investigation through all the groups, Mr. Main succeeds in reproducing the mean results given in what is usually called the R D Table, which appears in each Greenwich volume. This discordance then is plainly traced to changes (much more frequent than is usually supposed) in the state of the instrument, which render the corrections depending on the sine of zenith-distance variable, and which we may therefore presume to be of the nature of flexure.

Remarks on the British Association Catalogue of Stars. *By the* Rev. R. Main, *M.A., F.R.S., F.R.A.S.*

The object of this paper was to show the necessity which exists for the construction of a new general compiled catalogue of stars to replace that which was published in the year 1845, under the direction and at the expense of the British Association. The author would not have ventured in his own person to bring this matter before the Association, if his attention had not been directed to it by the circumstance of his having nearly completed the reobservation of all the stars contained in it which are visible at Oxford, and which require observation.

By this means a rather singular class of errors was brought to light, which, it was thought, might be interesting to astronomers, and to which it is desirable to give publicity.

The principal modern catalogues which were used by Mr. Baily for comparison with the more ancient catalogues of Bradley, Lacaille, and Piazzi, were those of Taylor and Brisbane, the places of the stars in both of the last-mentioned catalogues being, from causes which it is not necessary now to mention, very faulty.

Now, unfortunately, the differences of the right ascensions and declinations given by the ancient and modern catalogues, when reduced to the same epoch, have been attributed not to errors of the observations, but to proper motion, and the resulting proper motion is not only set down in the column appropriated to it, but is used in bringing up the star's place to the epoch 1850. The results of the observations of Bradley and Piazzi, which of themselves would have been very reliable, are thus seriously vitiated; and any one interested in the inquiry may convince himself of the truth of the above statement by consulting the notes appended to the catalogues of stars in the Radcliffe Observations, commencing with 1862.

In addition to this, the author observes that the utility of the catalogue of the British Association is greatly diminished, not only on account of the badness of the star-places, but on account of the interval which has elapsed since the epoch for which the star-constants are calculated, namely 1850. For results of the utmost exactness it is now unsafe to use these constants; and, on the whole, it appears desirable that the Association should shortly consider the propriety of undertaking a new catalogue, which shall embody the plentiful and accurate results of star-observations during the past quarter of a century.

On the recent fall of an Aërolite at Krähenburg in the Palatinate. *By* Dr. A. Neumayer.

On the 5th of May last, at 6.32 p.m., the inhabitants of this village were startled by a terrible noise like the discharge of heavy ordnance from some point high up in the air, which at the time was perfectly clear. It lasted about two minutes, and was followed with a rolling sound like thunder, which ended with a sort of whirring, whistling sound. The people were greatly frightened, and nobody could explain the cause; they saw at length the trees moved by some unaccountable agency, though not a breath of wind was stirring. Two men working in the fields near the village, however, were not at a loss for an explanation, for they saw a mass of stone fall to the ground, shaking it for a considerable distance. It was found the stone had penetrated the ground to a depth of two feet, which they soon unearthed. It was still warm but not dangerous to touch. The walls of the hole were perfectly perpendicular. The sound was heard over a district whose radius was thirty miles. The meteorite (for such it was soon recognized to be) was carefully removed, and its weight ascertained to be 31½ lbs. Several pieces had been knocked off. It was of a grey colour, small specks of a metallic nature being everywhere visible, and likewise small discoloured particles of a globular form. Subsequent analysis gave the specific gravity 3·446. It was composed of chrome-iron 0·94, magnetic pyrites 5·72, silica 43·29, alumina 0·63, magnesia 2·01, protoxide of iron 21·06, soda 1·03. It is of the class of meteors termed chondrites. This fiery rushing body, though broad daylight, was seen flying through the zenith of a place thirty-five miles south-east of the locality where it fell. The author gave other trigonometrical and astronomical particulars showing the height at which it was seen. When passing through the atmosphere it showed a bluish light, leaving a bright stripe of light long after the body had disappeared. What made the fall of this aërolite specially interesting is the fact that it was possible to determine the radiant-point of the shower of meteors to which it evidently belonged. The author said the radiant-point of this system was described in the Tables of the British Association Committee on Luminous Meteors as being "well defined." He hoped that some day "we should succeed in finding the comet whose orbit will exhibit elements identical with that of the meteors, placing us in the proud position of being able to state that we have already a portion of that comet in our possession."

On the Appearance of the Nebula in Argo as seen in the Great Melbourne Telescope. *By the* Rev. Dr. Robinson, *F.R.S.*

Owing to various circumstances this instrument was not available for work till 20th June last, when Mr. Albert Lesueur, the astronomer to whom it is entrusted, turned it on the nebula in Argo, and communicated to Dr. Robinson the results of his observations, with a pencil drawing laid down by comparison with adjacent stars by means which, though not of the highest precision, are yet so exact that future measures are not likely to make any material change. On comparing this sketch with the admirable map of this nebula given by Sir J. Herschel (Cape Observations, p. ix.), it is evident that great changes have occurred in the last thirty-four years. The most remarkable feature in the nebula is a black opening in the brightest part of it, forming a kind of lemniscate. As Sir J. Herschel saw it, this figure had two constrictions, was closed below by a barrier of less bright nebula, and had two small stars *exactly* on its edges. ζ Argus, then larger then Sirius, was south of the upper constriction and on a bright ground. Now the lemniscate has only one constriction; its southern part is of a totally different shape, and there is but a bare suspicion of any nebulous bar there, even with the great light of this telescope. The two stars referred to are now completely in the nebula and on the parallel of the constriction. ζ Argus, now only 6½ mag., is on a faint ground and remote from the bright nebula, and is nearly in the parallel of the north termination of the lemniscate. These changes are not in the stars; for Mr. Ellery has found that down to 9½ mag. they are in very close accordance with Sir J. Herschel's places; there is also south preceding the top of the lemniscate, a V-like bay very nearly as black, and with edges as bright, which could not possibly have been overlooked in the 20-feet reflector had it existed. The amount of change thus indicated implies such prodigious movements in this nebula, as to make it probable that its distance from us is less than was supposed by astronomers, and point it out as deserving most careful watching, with circumstances as litte varied as possible. It may even be hoped that the spectroscope will give some such evidence of its motion as Mr. Huggins has obtained with Sirius.

On Comets.* *By* Prof. P. G. Tait, *F.R.S.E.*

The principal object of this paper was to investigate how far the singular phenomena exhibited by the tails of comets and by the envelopes of their nuclei, the shrinking of their nuclei as they approach the sun, and *vice versâ,* as well as the diminution of period presented by some of them, can be explained on the probable supposition that a comet is a mere cloud of small masses, such as stones and fragments of meteoric iron, shining by reflected light alone, except where these masses impinge on one another, or on other matter circulating round the sun, and thus produce luminous gases along with considerable modifications of their relative motion. Thus the gaseous spectrum of the nucleus is assigned to the same impacts which throw out from the ranks those masses which form the tail. Some of the most wonderful of the singular phenomena presented by comets, such as the almost sudden development of tails of many millions of miles in length, the occurrence of comets with many tails, and the observed fact that there is no definite relation of direction between a comet's tail and its solar radius-vector, were here looked upon as due to the differences of motion of these discrete fragments relatively to the earth in a manner somewhat analogous to the appearances presented by a distant flock of seabirds flying in nearly one plane, and only becoming visible as a long streak when the plane of the flock passes approximately through the spectator's eye. The so-called envelopes are compared with the curious phenomena presented by tobacco-smoke (which seem, however, to be emitted in a form apparently resembling thin continuous films of small particles of carbon), and the so-called "gaseous jets" which appear to be projected from the nucleus and to be repelled from the sun, are not difficult of explanation, the author considered, from the general points of view here taken. Investigation, mainly conducted by quaternions, show how a group of discrete masses, so small that their mutual perturbations are not of great moment except in the case of actual impact, gradually changes its form, as it revolves about the sun, independently of any hypothesis as to the cause, planetary attraction or otherwise, by which it was first introduced into the solar system. The ideas here brought forward occurred to the author more than two years ago, on his being made aware of the identity of the orbits of the August meteorites and of Comet II., 1862; but they seemed so obviously to follow from that identity that it was only on reading Dr. Tyndall's recent speculations, and on being informed by Prof. Newton that the question of tails, envelopes, and "gaseous jets" had been treated by Schiaparelli, as proving the existence of a repulsive force, that he ventured to produce an explanation so apparently simple and yet so inconsistent with what appears to be held by the majority of astronomers.

Optics.

On the Influence of Annealing on Crystalline Structure. *By* Charles Brooke, *M.A., F.R.S.*

The author having been recently engaged in the construction of a rock-salt spectroscope for observations on the heat-spectrum, met with an unexpected difficulty in the construction of the prisms. In some of the optically best specimens of rock-salt in his possession, it was found that, in forming equilateral prisms one side of which was cut parallel to a cleavage plane, the opposite angle intended to be the working angle of the prism was repeatedly traversed by spontaneous clea-

* *Vide* Proceedings of the Royal Society of Edinburgh, 1868–69, p. 553.

vage fissures, and the prism consequently became incapable of being worked. As this was probably due to internal strains analogous to those in unannealed glass, which were further rendered evident by a considerable action on the polarized ray, inconsistent with the normal character of the crystal, it occurred to the author that this inconvenience might probably be remedied by some process of annealing; and the result proved to be completely successful. Owing to the low heat-conductibility of rock-salt, and its great liability to fissure on change of temperature, it was obviously necessary that that change should be effected very slowly. With this view the rock-salt was deeply imbedded in sand in a tin box, and gradually during twelve hours heated up to about 250° C. by a flame of gas placed beneath; it was then allowed to cool gradually, and was subsequently worked without any difficulty. It further appeared that the previously observed action on polarized light was very sensibly diminished, as was shown by comparing two sketches make by Mr. Browning before and after the process of annealing.

On the Relation between the Specific Refractive Energies and the Combining Proportions of Metals. By J. H. Gladstone, *Ph.D., F.R.S.*

The specific refractive energies of thirty metals had been determined by the author mainly from aqueous solutions of their salts. These metals were arranged in the order of their energies, and against them were placed their combining proportions,—that is, the actual amount of the metal which forms a stable salt, when combined with an equivalent of some other body, such as 35·5 of chlorine.

Element.	Specific Refractive Energy.	Combining proportion.
Hydrogen	1300	1
Lithium	540	7
Aluminium	307	9
Chromium	305	17
Magnesium	292	12
Calcium	260	20
Zirconium	234	22
Rhodium	232	35
Manganese	222	27
Iron	214	28
Palladium	210	27
Sodium	209	23
Potassium	207	39
Cobalt	184	29
Copper	183	32
Nickel	177	29
Rubidium	164	43
Zinc	156	33
Strontium	155	44
Cerium	148	46
Silver	145	108
Didymium	133	48
Platinum	132	49
Gold	122	66
Cadmium	121	56
Lead	120	103
Barium	115	68
Thallium	106	204
Cæsium	103	133
Mercury	101	100

It will be seen that while the numbers of the first column decrease, those of the second increase. There are a few evident exceptions, the most notable being silver, lead, and thallium, the combining proportions of which would have to be halved to bring them nearly into their right places in the list.

Though the relation between these numbers has not the exactness of a physical law, it shows some connexion between the power of a metallic element to refract the rays of light, and its power to saturate the affinities of other bodies. The same relation does not hold good with reference to the non-metallic elements.

Méthode pour obtenir les Images Monochromatiques des Corps Lumineux. Par le Dr. Janssen.

A la suite de l'eclipse du 18 Août, 1868, j'ai proposé une méthode pour obtenir les images monochromatiques des corps lumineux (voir les Comptes Rendus de l'Académie des Sciences de Paris, 11 Janvier 1869, et 22 Mars 1869).

J'ai l'honneur de donner à l'Association Britannique, quelques détails sur cette méthode.

Imaginons qu'on fasse tomber l'image d'une flamme (pour prendre un exemple) sur la fente d'un spectroscope; la spectre formé résultera, dans le sens de sa hauteur, de la *juxtaposition* de tous les spectres linéaires fournis par les rayons lumineux qui pénètrent par divers points de la fente.

Supposons maintenant qu'on place au point où le spectre se forme dans la lunette oculaire (tournée vers l'œil), une seconde fente parallèle à la première. Cette fente isolera dans le spectre, une ligne lumineuse d'une couleur determinée suivant le point du spectre où elle aura été placée. La hauteur de cette ligne et ses divers degrés d'intensité lumineuse seront en rapport avec celles de l'image de la flamme au point où elle est coupée par la fente du spectroscope.

Si l'on imagine maintenant que le spectroscope tourne autour d'un arc passant par les deux fentes, alors les diverses parties de l'image lumineuse viendront successivement produire leur ligne monochromatique dans la lunette d'exploration, et si le mouvement rotatif est assez rapide, la succession de toutes ces lignes produira une impression totale qui sera l'image de la flamme formée avec les rayons d'une seule réfrangibilité.

En déplaçant la fente oculaire, on pourra obtenir la série des images monochromatiques de cette flamme.

Pour avoir plus d'égalité dans l'intensité des diverses parties d'une même image, on pourrait donner à la fente une ouverture plus grande vers les points les plus éloignés de l'axe de rotation.

Appliquée au soleil, cette méthode pourrait fournir les images de l'ensemble des protubérances.

Pour la vision d'une protubérance isolée, la méthode de M. Huggins appliquée par M. Zoellner peut avoir certains avantages. Mais le moyen actuel permettrait d'obtenir l'ensemble du phénomène, et d'ailleurs, c'est surtout comme méthode pour obtenir la série des images monochromatiques des corps lumineux, que je la considère comme intéressante.

On a Method by which the Formation of certain definite Chemical Compounds may be Optically established. By the Rev. Professor Jellett, *M.A.*

It is known that several of the vegetable alkaloids, when in solution, possess the power of rotating the plane of polarization of a transmitted ray. It is also known that the addition of an acid, by which the base is converted (wholly or in part) into a salt, modifies, sometimes very largely, the power; generally diminishing it, as in the case of strychnia, brucia, morphia, and codeia; sometimes increasing it, as in the case of quinia and cinchonia; and sometimes reversing it, as in the case of nicotine and narcotine.

Suppose, now, that an acid be capable of forming more than one definite combination with any one of these bases, and let an amount of acid *less* than that required to convert the whole of the base into the lowest, or least, acid salt, be added to a given bulk of the solution. Let the amount so added be denoted by x, and let α, β be the atomic weights of the acid and base respectively. Then, if the least acid salt be formed by the combination of m atoms of acid with n atoms of base, the quantity of base which is so converted will be

$$\frac{n\beta x}{m\alpha},$$

and the quantity of base remaining in its natural state will be

$$b_0-\frac{n\beta x}{m\alpha},$$

where b_0 denotes the original quantity of the base present in the given bulk of solution.

Now let r_0 be the *rotatory power* of the base, or, in other words, the actual rotation produced by a unit of length of solution containing in a unit of bulk a unit of base, and let r_1 be the rotatory power of the salt, the unit of salt being the amount of salt produced from the unit of base. Then if the length of the column of solution through which the light is transmitted be still unity, the rotation which would be produced by that part of the base which is converted into salt, if it existed alone in the solution, would be

$$\frac{n\beta x}{m\alpha}r_1,$$

and the rotation which would be similarly produced by the unconverted base would be

$$\left(b_0-\frac{n\beta x}{m\alpha}\right)r_0.$$

Hence, assuming that these effects are produced independently of each other, we have as the value of the total rotation produced by the acidulated solution,

$$\frac{n\beta x}{m\alpha}r_1+\left(b_0-\frac{n\beta x}{m\alpha}\right)r_0.$$

Now, since $b_0\,r_0$ is evidently the rotation produced by the unacidulated liquid, the change in rotation caused by acidulation is

$$\frac{n\beta}{m\alpha}(r_1-r_0)x.$$

Hence, if we measure along the axis of abscissæ distances representing the values of x in a series of experiments, and raise ordinates proportional to the change in rotation caused by the addition of the acid, the locus of the extremities of these ordinates will be a right line, provided that the quantity of acid be not greater than that required to convert the whole of the base into the lowest or least acid salt.

Suppose, now, that this limit has been attained, and that we continue the addition of the acid. By this continued addition we shall commence the formation of a new salt from the first salt, just as before we formed the first salt from the base. And if we continue the former construction, we shall still have as the locus of the extremities of the ordinates a right line, but not in general the same right line. The completion of the first salt is indicated by the transition from the one line to the other. The same reasoning applies to every subsequent salt, the completion of each definite compound being in general indicated by a *break* in the locus.

The author illustrated this reasoning by a diagram, exhibiting the action of arsenic acid upon brucia.

On the Chemical Action of Light discovered by Professor Tyndall. By Professor AUG. MORREN.

[Printed *in extenso* among the Reports, see p. 66.]

On the Numerical Relations between the Wave-Lengths of the Hydrogen Rays. By G. JOHNSTONE STONEY, *M.A., F.R.S.*

Heat.

On the Absorption, Emission, and Reflection of Heat. By Professor Gustav Magnus.

[Printed *in extenso* among the Reports, see page 214.]

Meteorology.

On the Determination of the Real Amount of Evaporation from the Surface of Water. By Rogers Field, *B.A., and* G. J. Symons.

The authors begin by pointing out the extremely discordant results arrived at hitherto by the highest authorities as to the amount of evaporation from a water-surface; one observer, for instance, giving the amount as 44 inches, and another giving it as 11 inches for the same year. Some difference in the results might be expected, in consequence of difference of locality, but such startling differences can, it is believed, only be explained by the very faulty nature of the evaporators in common use. After giving a quotation from Professor Daniell's *Meteorological Essays*, strongly condemning the ordinary evaporators, the authors proceed to criticize the mode of calculating the evaporation from hygrometric observations, proposed by Professor Daniell as a substitute for quantitative measurements, and come to the conclusion that this method is practically useless.

The great objection to ordinary evaporators is their diminutive size, in consequence of which the water becomes unduly heated, and evaporation unduly increased. The only published experiments on a large scale of which the authors are aware are those made at Dijon, and other places on the Burgundy Canal, with tanks eight feet square, and these gave an evaporation of only about half that generally adopted for the district. Moreover, a small tank one foot square placed by the side of one of the large tanks, gave an evaporation 50 per cent. greater than that from the large tank. Some experiments on a smaller scale at St. Helena also show the way in which undue heating increases the evaporation. In these a small evaporator, fully exposed, gave 50 per cent. more evaporation than a similar evaporator placed in a tub of water.

Large tanks, like those at Dijon, can, however, only be used in exceptional cases, and it therefore becomes important to devise some simple arrangements which should give approximately correct results. The authors have recently commenced some experiments on the subject, and desire to place upon record some of the facts arrived at.

In these experiments the depth of water evaporated was ascertained by direct measurement, without emptying the evaporators, as is generally done. This measurement was effected by means of a small instrument, called a "hook-gauge," shown on the accompanying diagram. The point of the hook can be adjusted with great precision to the exact level of the surface of the water, and the depth read off on a vernier to the hundredth of an inch. By resting the clamped bar on the top of the evaporator, the zero can be placed in any convenient position.

The arrangements adopted by the authors are shown on the diagram. Fig. 1 is perhaps one of the best forms of ordinary evaporators, consisting of a copper vessel fully exposed; fig. 2 is an arrangement designed by Mr. Symons, wherein the vessel, still of metal, is sunk almost wholly in the ground; fig. 3 is a modification of the St. Helena plan, consisting of a glass cylinder placed in the centre of a much larger vessel of water.

A detailed Table is given of the observations for three weeks, ending August 12, 1869. The chief results are—

(1) The total evaporation from fig. 1 was 4·37 inches, from fig. 2, 3·13 inches, and from fig. 3, 2·46 inches, numbers which are to each other in the

ratio of 1·78, 1·27, and 1·00. Fig. 1 therefore lost 78 per cent. more water by evaporation than fig. 3.

HOOK GAUGE

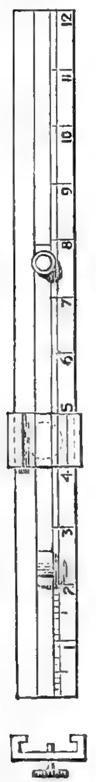


FIG. 1.

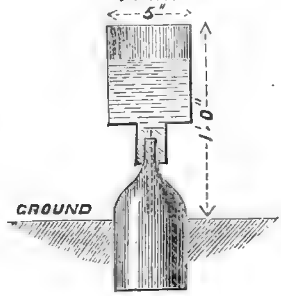


FIG. 2.

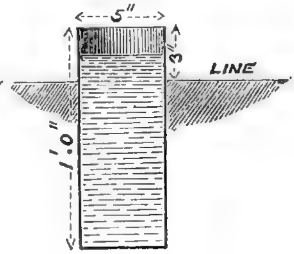
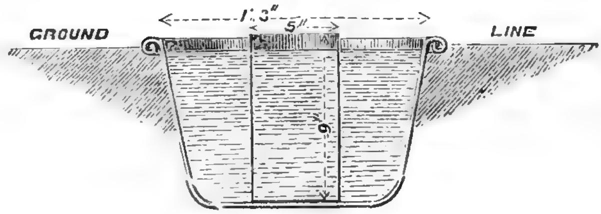


FIG. 3.



(2) During the daytime the sunshine heats figs. 1 and 2 to such an extent that the ratios of evaporation become about 2·50, 1·50, and 1·00.

(3) During the night there are indications of a slight addition to fig. 3 from condensed vapour.

(4) The evaporation, as computed from the hygrometer, bears no regular relation to any of the others, being sometimes greater than any of them, and sometimes less. The total computed evaporation is 3·39 inches.

As already stated, the authors consider that the accuracy of an evaporator is largely dependent on its capability of retaining the temperature of the water at as nearly as possible that of large volumes of water, such as reservoirs. In the few comparisons they have been able to make, they have found that the temperature of the water in fig. 3 has been nearly identical with that of a rather shallow reservoir one acre in extent. The average temperature of the water about 2 P.M. was in fig. 1, 80°·7; in fig. 2, 75°·8; and in fig. 3, 73°·8, showing an average excess of 7° in the temperature of fig. 1 over that of fig. 3. In sunshine there is an excess of twice that amount; in fact, at times the metal becomes so hot as to scorch the hand.

The authors conclude with a strong plea for further investigation, by quoting the words of M. Valles, the French engineer, who first called attention to the great inconsistency of existing experiments. "We do not understand how, in a country like ours, and with reference to one of the most important hydraulic data, we can rest content with only knowing that the numerical value to be attributed to this datum lies between two limits, one of which is double the other."

On the Changes of Temperature and Humidity of the Air up to 1000 feet, from observations made in the Car of M. Giffard's Captive Balloon. By James Glaisher, *F.R.S., F.R.A.S., &c.*

[A communication ordered to be printed *in extenso* in the Proceedings.]

The necessity which existed in all the free balloon ascents I made in connexion with the British Association of leaving the earth with a great ascending power to avoid striking adjacent buildings, caused the first few hundred feet to be passed through too quickly to enable me to determine satisfactorily the temperature and humidity of the air at the lower elevations; at the higher elevations the observations were repeated at will, as I could descend by allowing an escape of gas, or ascend by discharging sand as frequently as I thought desirable. The want of the power of repetition of observation within 1000 feet of the earth has caused our knowledge of the temperature and humidity of the air within this distance to be more limited and less accurate than at higher elevations. The theory of the decline of 1° of temperature in every increase of 300 ft. of elevation was proved to be erroneous in every ascent; in some a decrease of 1° and more than 1° was experienced within the first 100 ft. (see ascents, July 30th, Report 1862; July 11th, Report 1863; and August 31st, Report 1863 and 1864), notwithstanding the rapidity of motion; and there is no doubt that if the balloon could have been kept stationary at the height of 100 ft. on those occasions the decline would have been much greater, whilst in others there has been no decrease of temperature within this space (see April 6th, Report 1864; and Dec. 1st, 1864, Report 1865).

In some of the ascents a decline of 8° or 10° was met with within 1000 ft. of the earth (see ascents of July 30th, 1862; August 18th, 1862; July 11th, 1863; August 31st, 1863, &c.), whilst in others but little or no difference was found within 1000 ft. of the earth. This was very remarkably shown in the descent on June 13th, 1864, which was made at about sunset; after this ascent it was noticed that whenever ascents had been made in the afternoon hours the changes of temperature near the earth were smaller at the time of descent than at the time of ascent; but this was not found to be the case with the ascents which had been made in the morning hours. Two ascents only were made after sunset, the one on October 2nd, 1865, with a clear sky, and the other on December 2nd, 1865, with a cloudy sky; in the former, with a clear sky, the temperature increased on leaving the earth, and continued to increase with elevation, began to decrease on descending and continued to decrease till the earth was reached, the change of temperature during the ascent being somewhat smaller than during the descent. The second night-ascent on December 2nd, 1865, was made with a cloudy sky; the temperature at first decreased, then became stationary, then increased when between 1400 and 1800 ft. high; at greater heights the temperature decreased; thus towards the end of the series of experiments, which were made for the British Association, it was found that the observations indicated that the change of temperature near the earth varied greatly, followed no constant law, in fact, appearing to differ at the different hours of the day; but the ascents were too few in number and too disconnected (having been made in every month of the year, at different times of the day and under different states of the sky) to be able to say positively that such was the case.

These experiments, however, unsettled our previous views, and caused a suspicion to rest on the amounts applied for correction of refraction in astronomical observations.

The great captive balloon, recently located at Ashburnham Park, Chelsea, and kept constantly inflated with 420,000 cubic feet of hydrogen gas, in connexion with a powerful steam-engine, was admirably adapted to settle all these points, and M. Giffard, its proprietor, most kindly placed it at my disposal for any series of experiments to which I could apply it.

This balloon could ascend on a calm day to the height of 2000 ft.; its rate of ascension could be regulated, and the balloon could be kept all but stationary at any point, for any length of time.

The instruments were fixed on a stand attached to the outside ring of the circular car, so that the instruments were out of all influence of persons in the car, and shielded from the sun and radiation in the manner described in the preceding volumes of the British Association.

The ascents and descents were usually even and moderately slow, the balloon remaining at its highest point till the temperature and hygrometrical state of the air at that point were assured. The readings of the several instruments were taken on the ground just before an ascent and again just after its completion; the mean of these two readings was considered to be the temperature on the ground; in like manner the readings were taken at every 100 ft., as near as possible, both ascending and descending, and their means taken to represent the temperatures at these elevations. In this way the numbers in the following Table were formed:—

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubit ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
May 5...	5 36 P.M. to 6 4 P.M.	ground.	54·9	50·8	46·9	3·7	74	(1)
		100	54·1	50·2	46·4	3·6	75	
		200	53·6	50·2	46·9	3·6	78	
		300	52·9	49·5	46·2	3·6	79	
		400	52·1	49·0	44·8	3·5	80	
		500	51·4	48·4	45·3	3·4	80	
		600	51·3	48·1	44·8	3·4	79	
		700	51·0	48·6	46·1	3·5	84	
		800	50·0	47·9	45·7	3·5	85	
		900	49·4	47·2	44·8	3·4	85	
		1000	49·2	47·5	45·7	3·5	88	
		1100	49·1	47·7	46·2	3·6	90	
		1200	47·6	46·5	45·3	3·4	92	
		1300	47·3	46·5	45·7	3·5	94	
July 12.	6 12 P.M. to 6 33 P.M.	ground	81·7	70·2	62·5	6·0	52	(2)
		100	80·9	68·8	60·7	5·6	50	
		200	80·3	68·1	59·8	5·5	49	
		300	80·0	68·0	59·8	5·5	50	
		400	79·6	67·6	59·3	5·4	50	
		500	79·1	67·1	58·8	5·3	50	
		600	78·6	67·1	59·2	5·5	52	
		700	(77·9	66·6)	58·8	5·4	52	
		800	77·1	65·9	58·1	5·3	53	
		900	76·7	65·6	57·8	5·2	52	
		1000	76·7	65·7	58·0	5·1	52	
July 17.	4 22 P.M. to 5 0 P.M.	ground.	83·7	69·7	60·4	5·6	46	(3)
		100	82·0	68·0	58·6	5·2	45	
		200	81·2	67·5	58·2	5·2	45	
		300	80·7	67·3	58·2	5·2	47	
		400	80·6	67·1	57·9	5·2	46	
		500	80·2	66·6	57·3	5·1	45	
		600	79·6	66·9	58·0	5·2	49	
		700	79·2	66·7	58·0	5·2	49	

(1) The sky was nearly free from cloud; the atmosphere was misty; the wind from E.N.E., and its strength was found to be much greater at the height of 1000 ft. than on the ground.

(2) The sky was principally cloudy; the wind was from S.W.

(3) The sky was cloudy; the wind from the E.; the strength of the wind much greater than on the ground.

TABLE (*continued.*)

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Evaporation.	Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 17.	4 22 P.M. to 5 0 P.M.	800	78·8	66·4	57·9	5·2	50	
		900	78·6	65·8	57·8	5·1	47	
		1000	77·7	64·3	55·0	4·6	46	
		1100	77·8	65·6	57·1	5·1	50	
		1200	77·0	65·3	57·1	5·0	51	
		1300	76·2	64·9	56·9	5·1	51	
July 17.	5 5 P.M. to 5 23 P.M.	ground.	81·0	70·8	63·9	6·3	55	
		100	80·4	70·1	63·2	6·1	55	
		200	79·8	69·4	62·3	6·0	55	
		300	79·1	69·0	62·0	6·0	56	
		400	78·7	68·7	61·8	5·9	56	
		500	78·3	68·1	61·1	5·8	55	
		600	78·0	67·9	60·9	5·8	56	
		700	77·2	68·1	61·7	5·9	58	
		800	76·7	68·1	62·1	6·1	61	
		900	76·1	67·3	61·0	5·8	60	
		1000	75·6	67·2	61·4	5·8	61	
July 23.	3 10 P.M. to 3 41 P.M.	ground.	73·6	63·1	55·4	4·8	53	(1)
		100	71·8	61·6	53·9	4·5	53	
		200	71·1	61·0	53·3	4·4	53	
		300	70·0	60·3	52·8	4·4	54	
		400	69·9	60·2	52·8	4·4	54	
		500	69·4	60·0	52·8	4·4	55	
		600	68·8	59·9	52·8	4·4	56	
		700	68·0	59·3	52·4	4·3	57	
		800	67·5	58·6	52·2	4·3	58	
		900	67·0	58·7	52·1	4·3	59	
		1000	66·8	58·5	51·8	4·3	58	
		1100	66·6	58·1	51·3	4·2	58	
		1200	66·3	57·9	51·1	4·1	59	
		1300	65·8	57·8	51·0	4·1	59	
		1400	65·5	57·5	51·0	4·1	59	
July 23.	3 42 P.M. to 4 12 P.M.	ground.	72·3	62·4	55·0	4·8	54	
		100	71·8	61·6	53·9	4·5	54	
		200	70·9	61·1	53·6	4·5	55	
		300	69·7	60·1	52·7	4·4	55	
		400	69·2	59·9	52·7	4·4	55	
		500	68·8	59·7	52·6	4·4	56	
		600	68·6	59·4	52·3	4·3	56	
		700	68·3	59·4	52·1	4·2	56	
		800	68·0	59·0	51·9	4·2	56	
		900	67·5	58·7	51·9	4·2	57	
		1000	66·9	58·5	51·8	4·2	59	
		1100	66·4	58·2	51·7	4.2	59	
		1200	65·7	58·0	51·7	4·2	60	
		1300	65·3	57·7	51·5	4·2	61	
		1400	65·0	57·5	51·4	4·2	61	
		1500	64·7	57·2	51·0	4·1	61	
		1600	64·5	56·9	50·6	4·1	61	

(1) The sky was overcast; wind S.S.W.; very misty; scarcely any pressure of the wind on the ground, but of considerable strength on leaving the earth; air very misty below 700ft.

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the			Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
			Air.	Evaporation.	Dew-point.			
1869.	h m h m	feet.	°	°	°	grs.		
July 23.	4 15 P.M. to 4 34 P.M.	ground.	71·8	62·0	54·6	4·6	55	
		100	71·1	61·3	53·9	4·5	54	
		200	70·6	60·8	53·2	4·5	54	
		300	70·1	60·4	52·9	4·4	54	
		400	69·6	60·0	52·6	4·3	54	
		500	69·3	59·9	52·6	4·3	55	
		600	68·5	59·2	52·1	4·2	55	
		700	68·0	59·0	51·9	4·2	56	
		800	67·8	58·7	51·5	4·2	56	
		900	67·4	58·2	50·9	4·1	55	
		1000	67·1	58·1	50·9	4·1	56	
		1100	66·6	57·9	50·9	4·1	58	
		1200	66·5	57·8	50·8	4·1	58	
		1300	66·0	57·5	50·6	4·0	58	
		1400	65·6	57·2	50·4	4·0	57	
July 23.	4 39 P.M. to 5 4 P.M.	ground.	71·8	61·8	54·3	4·6	54	
		100	70·4	60·8	53·4	4·5	55	
		200	70·3	60·6	53·1	4·5	55	
		300	69·6	60·1	52·8	4·4	55	
		400	69·2	59·8	52·5	4·3	55	
		500	69·1	59·8	52·6	4·3	55	
		600	68·3	59·3	52·2	4·3	56	
		700	67·9	59·1	52·2	4·3	57	
		800	67·4	58·8	52·0	4·3	58	
		900	67·0	58·6	51·9	4·3	58	
		1000	66·3	58·1	51·5	4·2	60	
		1100	66·1	58·0	51·4	4·2	60	
		1200	65·9	58·0	51·6	4·2	59	
		1300	65·6	57·8	51·5	4·2	60	
		1400	65·3	57·7	51·5	4·2	61	
		1500	64·9	57·0	50·5	4·0	59	
July 23.	5 41 P.M. to 6 4 P.M.	ground.	69·9	62·7	57·1	5·1	63	
		100	69·4	62·0	56·2	5·0	62	
		200	68·3	61·6	56·4	5·0	65	
		300	67·9	61·5	56·5	5·0	66	
		400	67·4	61·0	56·2	5·0	66	
		500	67·0	60·5	55·3	4·9	66	
		600	67·0	60·2	54·8	4·8	65	
		700	66·3	60·1	54·8	4·8	67	
		800	65·7	59·6	54·8	4·7	68	
		900	65·4	59·5	54·8	4·7	69	
		1000	64·9	59·4	54·8	4·7	70	
		1100	64·5	59·1	54·8	4·7	72	
		1200	63·9	59·0	54·9	4·8	73	
Ju3	6 6 P.M. to 6 27 P.M.	ground.	69·9	62·8	57·3	5·2	64	
		100	69·1	62·5	57·5	5·2	65	
		200	68·0	62·2	57·7	5·3	68	
		300	67·9	61·7	57·2	5·2	68	
		400	67·5	61·6	56·8	5·1	68	
		500	67·1	61·1	56·3	5·0	68	
		600	66·6	60·8	56·1	5·0	69	
		700	66·3	60·5	56·0	5·0	69	

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 23.	6 6 P.M. to 6 27 P.M.	800	66·0	60·2	55·9	4·9	70	
		900	65·7	60·0	55·7	4·9	71	
		1000	65·1	59·8	55·5	4·8	72	
		1100	64·5	59·2	55·2	4·8	72	
		1200	64·2	59·2	55·0	4·8	72	
July 23.	6 31 P.M. to 6 50 P.M.	ground.	70·0	63·3	58·1	5·3	66	
		100	69·3	62·3	56·9	5·3	64	
		200	68·7	62·1	56·9	5·2	65	
		300	68·3	62·0	57·1	5·2	67	
		400	67·7	61·7	57·0	5·2	68	
		500	67·2	61·4	56·8	5·1	69	
		600	66·5	60·7	55·8	5·1	70	
		700	66·0	60·5	54·8	5·1	70	
		800	65·7	60·3	55·9	5·0	71	
		900	65·1	59·8	55·7	4·9	71	
		1000	64·9	59·6	55·2	4·8	71	
July 23.	6 56 P.M. to 7 12 P.M.	ground.	69·8	62·7	57·2	5·1	64	
		100	69·3	62·4	56·9	5·1	64	
		200	68·8	62·0	56·7	5·1	64	
		300	68·1	61·5	56·3	5·0	65	
		400	67·7	61·1	55·9	4·9	65	
		500	67·3	60·8	55·9	4·9	66	
		600	66·6	60·6	55·8	4·9	69	
		700	66·2	60·4	55·8	4·9	69	
		800	65·4	60·1	55·8	4·9	71	
		900	65·3	59·7	55·3	4·8	70	
		1000	65·0	59·4	55·8	4·7	70	
		1100	64·3	59·0	54·6	4·7	71	
		1200	63·9	58·6	54·7	4·8	71	
		1300	63·9	58·5	54·7	4·8	71	
July 23.	7 20 P.M. to 7 30 P.M.	ground.	68·6	61·8	56·5	5·1	65	
		100	68·1	61·4	56·2	5·0	65	
		200	67·7	60·7	55·2	4·8	64	
		300	67·2	60·4	55·0	4·8	64	
		400	67·2	60·3	54·8	4·8	64	
July 24.	3 23 P.M. to 3 51 P.M.	ground.	76·2	60·5	49·4	3·8	39	(1)
		100	74·3	58·7	47·4	3·5	39	
		200	73·8	58·5	47·5	3·5	39	
		300	73·0	57·8	46·6	3·5	39	
		400	72·3	57·4	46·2	3·4	40	
		500	72·1	57·1	45·8	3·3	39	
		600	71·3	56·7	45·7	3·3	40	
		700	70·8	57·0	46·5	3·4	42	
		800	69·9	55·7	44·9	3·2	40	
		900	69·5	55·5	44·7	3·3	41	
		1000	68·8	54·9	44·0	3·2	40	
		1100	68·3	54·5	43·6	3·1	41	

(1) The sky was free from cloud, the air was misty. It was calm on the earth, but blew with a pressure of fully 1 lb. on the square foot at the height of 1000 ft. At this time smoke was seen passing in all directions on the earth, whilst a strong W. wind blew at this height.

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 24.	3 53 P.M. to 4 12 P.M.	ground.	75·3	59·3	47·8	3·6	38	
		100	73·8					
		200	73·2					
		300	72·7					
		400	72·3	59·3	49·5	3·9	45	
		500	71·7	58·4	48·4	3·7	44	
		600	71·7	57·9	47·5	3·6	42	
		700	71·2	56·8	45·9	3·3	40	
		800	70·3	56·1	45·2	3·3	41	
		900	69·8	56·1	45·6	3·4	42	
July 24.	4 12 P.M. to 4 30 P.M.	ground.	75·5	60·2	49·2	3·8	40	
		100	74·2	59·1	48·1	3·6	40	
		200	73·4	58·9	48·2	3·6	41	
		300	72·8	57·6	46·3	3·5	39	
		400	72·6	57·1	45·5	3·3	38	
		500	72·1	56·6	44·9	3·3	38	
		600	71·7	56·4	44·9	3·2	39	
		700	71·5	56·4	45·0	3·2	38	
		800	71·0	56·5	45·5	3·3	40	
		900	70·7	56·6	45·9	3·3	41	
		1000	69·5	55·9	45·4	3·3	43	
		1100	69·1	55·5	44·9	3·3	42	
July 24.	4 47 P.M. to 5 8 P.M.	ground.	75·5	60·3	49·4	3·8	40	
		100	74·8	59·4	48·3	3·6	40	
		200	73·8	58·6	47·4	3·5	40	
		300	73·1	57·9	46·1	3·5	40	
		400	72·8	57·8	46·6	3·5	40	
		500	72·0	57·6	46·8	3·5	41	
		600	71·7	57·3	46·1	3·4	40	
		700	71·4	57·0	45·9	3·4	41	
		800	70·8	56·5	45·6	3·3	41	
		900	70·5	56·3	45·5	3·3	41	
		1000	70·6	56·8	46.2	3·4	42	
		1100	70·9	57·0	46·5	3·4	42	
July 24.	5 23 P.M. to 5 47 P.M.	ground.	74·2	60·1	49·9	3·9	43	
		100	73·1	59·0	48·6	3·7	42	
		200	72·6	58·4	47·8	3·6	42	
		300	72·5	57·5	46·3	3·5	39	
		400	71·5	57·1	46·3	3·4	40	
		500	71·0	56·7	45·9	3·4	41	
		600	70·5	56·4	45·6	3·3	41	
		700	70·2	56·2	45·3	3·3	41	
		800	70·2	56·0	45·1	3·3	41	
		900	69·7	56·2	45·2	3·3	41	
		1000	69·2	55·7	45·3	3·3	43	
		1100	69·1	55·5	45·3	3·3	43	
		1200	68·1	55·5	45·5	3·4	44	
July 24.	6 0 P.M. to 6 18 P.M.	ground.	74·4	59·0	49·6	3·9	43	
		100	73·3	59·1	48·6	3·7	42	
		200	73·2	59·0	48·5	3·7	42	
		300	72·9	58·6	48·1	3·6	42	

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 24.	6 0 P.M. to 6 18 P.M.	400	72·3	58·0	47·3	3·5	41	
		500	71·7	57·8	47·4	3·5	43	
		600	70·9	57·1	46·7	3·4	43	
		700	70·2	56·5	46·0	3·4	43	
		800	70·0	56·5	46·1	3·4	43	
		900	69·8	56·3	45·9	3·4	43	
		1000	69·2	55·8	45·4	3·3	43	
		1100	68·4	55·1	44·7	3·2	43	
		1200	67·6	54·8	44·6	3·2	43	
		1300	66·9	54·4	44·4	3·2	44	
July 24.	6 21 P.M. to 6 43 P.M.	ground.	73·8	60·4	50·6	4·0	45	
		100	73·4	59·2	48·6	3·7	42	
		200	72·8	58·7	48·2	3·7	43	
		300	72·3	58·3	47·9	3·7	42	
		400	72·3	58·1	47·5	3·6	42	
		500	72·2	58·1	47·5	3·6	42	
		600	71·6	57·8	47·3	3·5	42	
		700	71·0	57·5	47·4	3·6	43	
		800	70·6	57·5	47·5	3·6	44	
		900	70·1	57·4	47·5	3·6	44	
		1000	70·0	57·2	47·4	3·6	45	
		1100	69·8	57·0	47·1	3·5	45	
		1200	69·2	56·8	46·0	3·5	45	
		1300	69·1	56·0	45·8	3·4	44	
		1400	68·5	55·7	45·6	3·3	44	
		1500	68·2	55·3	45·1	3·2	43	
		1600	67·5	54·8	44·7	3·2	44	
July 24.	6 48 P.M. to 7 8 P.M.	ground.	72·7	60·4	51·3	4·2	47	
		100	72·0	58·6	48·6	3·7	44	
		200	71·6	58·0	47·7	3·6	43	
		300	71·0	57·5	47·3	3·6	43	
		400	70·6	57·2	47·0	3·5	44	
		500	70·0	56·9	46·8	3·5	44	
		600	69·5	56·6	46·6	3·4	44	
		700	69·0	56·1	46·1	3·4	44	
		800	68·7	55·8	45·7	3·4	43	
		900	68·1	55·5	45·5	3·4	44	
		1000	67·9	55·4	45·5	3·3	45	
		1100	67·6	55·2	45·2	3·3	45	
		1200	67·3	54·9	45·0	3·3	45	
		1300	67·0	54·5	44·5	3·1	45	
		1400	66·6	54·3	44·4	3·2	44	
		1500	66·4	54·4	44·7	3·2	45	
		1600	66·4	54·6	44·8	3·2	45	
		1700	65·6	54·2	44·9	3·3	47	
July 24.	7 19 P.M. to 7 42 P.M.	ground.	70·9	58·7	49·4	3·9	46	
		100	70·9	58·3	48·7	3·8	46	
		200	70·8	58·0	48·2	3·7	45	
		300	70·5	57·5	47·6	3·7	45	
		400	70·2	57·2	47·3	3·6	44	
		500	69·8	56·8	47·2	3·6	44	
		600	69·5	56·8	47·0	3·5	45	

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 24.	7 19 P.M. to 7 42 P.M.	700	69·1	56·6	47·0	3·5	44	
		800	68·9	56·1	46·1	3·4	44	
		900	68·5	56·0	46·2	3·5	44	
		1000	67·9	55·5	45·7	3·4	45	
		1100	67·4	55·3	45·6	3·3	45	
		1200	66·9	55·0	45·5	3·3	45	
		1300	66·5	54·8	45·4	3·3	46	
		1400	66·0	54·5	45·2	3·3	47	
		1500	65·9	54·6	45·2	3·3	47	
		1600	65·8	54·5	45·2	3·3	47	
		1700	65·5	54·3	45·2	3·3	47	
July 28.	5 30 P.M. to 6 5 P.M.	ground.	61·5	57·1	52·9	4·5	75	(1)
		100	60·9	56·4	52·6	4·5	74	
		200	60·6	56·2	52·4	4·4	74	
		300	59·9	55·7	52·2	4·4	75	
		400	59·3	55·5	52·1	4·4	78	
		500	59·1	55·0	51·9	4·3	77	
		600	58·8	55·0	51·6	4·2	77	
		700	58·3	54·5	51·4	4·2	78	
		800	57·7	54·3	51·2	4·2	79	
		900	57·1	53·9	51·0	4·2	79	
		1000	56·7	53·6	50·7	4·1	80	
		1100	56·2	53·7	50·8	4·1	81	
		1200	56·2	53·5	51 0	4·2	83	
		1300	56·2	53·0	50·0	4·1	81	
		1400	56·0	52·7	49·6	4·0	79	
		1500	55·6	52·1	48·7	3·9	78	
		1600	55·7	52·1	48·7	3·9	78	
July 28.	6 17 P.M. to 6 43 P.M.	ground.	61·2	56·6	52·6	4·4	74	
		100	61·0	56·3	52·2	4·4	74	
		200	60·5	55·8	51·9	4·4	74	
		300	60·0	55·5	51·6	4·3	74	
		400	59·5	55·1	51·5	4·3	75	
		500	59·1	55·0	51·3	4·3	76	
		600	58·6	54·8	51·2	4·2	77	
		700	58·2	54·4	51·0	4·2	77	
		800	57·7	53·9	50·5	4·1	76	
		900	57·3	53·4	49·9	4·0	75	
		1000	56·8	53·3	50·1	4·0	78	
		1100	56·3	52·8	49·9	4·0	79	
		1200	55·8	52·7	49·7	4·0	80	
		1300	55·3	52·4	49·6	4·0	81	
		1400	54·9	52·1	49·5	4·0	81	
		1500	54·6	52·2	49·5	4·0	82	
		1600	54·5	51·9	49·4	4·0	82	

(1) The sky was overcast, and rain had fallen heavily, but had ceased. The wind was from E.N.E. At the height of 700 feet the mist was so thick that the earth was scarcely visible. At 1000 ft. high we rose out of the mist and looked down on the cloud. At 1200 ft. and higher the sun shone on the upper surface of the cloud, gilding a sea of cloud for some distance; then like plains of bright yellow sand, and far away like seas of snow of sparkling and dazzling whiteness, the whole being broken up with hillocks and mounds of the same colour as the plains on which they seemed to be placed. The scene was very rich.

TABLE (*continued*).

Year and day.	Between what times.	Heights above the ground.	Temperature of the Air.	Temperature of the Evaporation.	Temperature of the Dew-point.	Weight of water in a cubic ft. of air.	Degree of humidity.	Reference to notes.
1869.	h m h m	feet.	°	°	°	grs.		
July 28.	6 46 P.M. to 6 57 P.M.	ground.	61·0	57·1	53·7	4·6	78	
		100	60·8	56·5	52·9	4·5	75	
		200	60·5					
		300	60·0	56·1	52·2	4·4	74	
		400	59·5	55·4	51·8	4·4	76	
		500	59·1					
		600	58·8	55·1	51·8	4·3	78	
Aug. 4.	10 32 A.M. to 11 20 A.M.	ground.	69·1	62·0	56·4	5·0	64	(1)
		100	68·1	61·2	55·8	4·8	64	
		200	67·2	60·5	55·2	4·8	65	
		300	66·2	60·1	55·2	4·8	68	
		400	65·2	59·5	54·9	4·7	68	
		500	64·8	59·1	54·5	4·6	68	
		600	64·0	58·6	54·1	4·4	69	
		700	63·2	58·3	54·1	4·5	72	
		800	62·1	57·5	53·7	4·4	69	
		900	62·0	57·4	53·7	4·4	70	
		1000	61·3	57·2	53·7	4·5	77	
		1100	61·0	57·1	53·7	4·6	77	
Aug. 7.	5 59 P.M. to 6 15 P.M.	ground.	63·5	56·7	51·0	4·2	64	
		100	63·3	56·1	50·2	4·0	63	
		200	62·6	55·6	49·6	4·0	62	
		300	62·1	54·8	48·5	3·9	62	
		400	61·7	54·7	48·7	3·8	62	
		500	61·3	54·3	48·5	3·8	62	
		600	60·6	54·2	49·0	3·8	65	
		700	60·4	54·1	48·6	3·8	65	

(1) Overcast; wind W.S.W., with light pressure on the ground, but very strong on leaving the earth, and caused a great strain on the rope, so great indeed that the observations were not repeated.

On July 23rd, 1869, with a cloudy sky, nine successive series of experiments were made between the hours of 3 P.M. and 7.30 P.M.

The temperature of the air on the ground at the first series was 73°·6, and at the last 69°·8, showing a decrease of 3°·8.

The temperature of the air at 1000 ft. high at the first series was 66°·8, and at the last 65°.

The temperature of the air at 1000 ft. was therefore 6°·5 and 4°·8 lower than on the ground respectively at these two times.

On the ground the temperature declined 3°·8, whilst at the height of 1000 ft. the decline was 1°·8, or less than one-half that on the ground.

On July 24th, 1869, with a clear sky, a similar set of experiments were made within the same hours, viz., 3 P.M. to 7.30 P.M.

The temperature of the air on the ground at the first series was 76°·2, and at the last was 70°·9.

The temperature of the air at the height of 1000 ft. was 68°·8 at the first, and 67°·9 at the last series; it was therefore lower by 7°·4 at the first, and by 3° at the last series, than on the ground; the decline of temperature on the ground was 5°·3, whilst that at 1000 ft. high was 0°·9.

Of the 3° less temperature at 1000 ft. high at the last experiment, 1° took place between 200 and 500 ft., and the remaining 2° between 500 and 1000 ft. Of the 7°·4 less temperature at 1000 ft. high at the first experiment about one-fourth part, or 1°·9, took place in the first 100 ft.; at the last experiment there was no decrease between this space, the temperature being sensibly the same as on the ground up to 200 ft.

In both states of the sky the temperature at the height of 1000 ft. underwent less change than on the earth, and therefore the rates at which the temperature changes with the height, is not independent of the time of day. The next Table but one (see p. 37) contains the decrease of temperature for every 100 ft. as found from the preceding Tables in every series of experiments.

On July 17th, 23rd, 24th, and 28th more than one series of experiments were taken during the afternoon hours, and in every case the changes are smaller at the later than at the earlier experiments. On July 23rd and 24th nine sets of experiments were made on each day, between the hours of 3 P.M. and 7.30 P.M.; on the former under a cloudy, and on the latter under a clear sky. In both series the largest changes are those in the first set of experiments; and the smallest those in the last set, so that experiments made at the same hours must be grouped together and distinct from those at other times. Comparing the changes in the first 100 ft., it will be seen they are larger with a clear than a with cloudy sky. By comparing the general results with the two states of the sky together, it will be seen that the changes from hour to hour are less with the cloudy than with the clear sky, and consequently the experiments in the two states of the sky must be treated separately. The following Table has been formed by taking the means of observations between the same hours in the two different states of clear and cloudy skies.

Table showing the mean decrease of Temperature for every increase of 100 ft. of Height depending on the hour of the day and the state of the sky.

Height above the ground.	10 to 11 A.M.	3 to 4 P.M.		4 to 5 P.M.		5 to 6 P.M.		6 to 7 P.M.		7 to 7.30 P.M.	
	Clear sky.	Clear sky.	Cloudy sky.	Clear sky.	Cloudy sky.	Clear sky	Cloudy sky.	Clear sky.	Cloudy sky.	Clear sky.	Cloudy sky.
ft. ft.	°	°	°	°	°	°	°	°	°	°	°
0 to 100	1·0	1·7	1·2	1·2	1·3	1·0	0·6	0·6	0·5	0·0	0·5
100 to 200	0·9	0·6	0·8	0·7	0·5	0·5	·7	·4	·6	·1	·5
200 to 300	1·0	·7	1·2	·6	·6	·4	·6	·5	·4	·3	·6
300 to 400	1·0	·6	0·3	·3	·3	·9	·5	·4	·5	·3	·2
400 to 500	0·4	·4	·5	·6	·3	·6	·3	·4	·5	·4	·4
500 to 600	·8	·4	·4	·4	·7	·3	·2	·7	·5	·3	·7
600 to 700	0·8	·5	·5	·3	·4	·3	·7	·5	·5	·4	·4
700 to 800	1·1	·9	·4	·6	·4	·5	·6	·3	·5	·2	·8
800 to 900	0·1	·5	·5	·3	·3	·6	·5	·4	·4	·4	·1
900 to 1000	·7	·7	·4	·6	·6	·4	·5	·3	·3	·6	·3
1000 to 1100	0·3	0·5	·4	0·0	·2	0·1	·4	·4	·5	·5	·7
1100 to 1200	...	...	·5	...	·4	1·3	·3	·6	·4	·5	·4
1200 to 1300	...	...	·5	...	·5	0·3	·0	·4	·5	·4	0·0
1300 to 1400	...	...	·3	...	·3	...	·2	·5	·4	·5	...
1400 to 1500	...	...	·3	...	·4	...	·4	·2	·3	·1	...
1500 to 1600	...	...	0·2	...	...	...	0·1	·3	0·1	·1	...
1600 to 1700	...	...	...	...	...	...	...	0·8	...	0·3	...

These numbers were then laid down on diagrams, the heights as ordinates and the decrease of temperature as abscissa; these points were joined, and a line was drawn to pass through or near to them giving equal weight to every point.

In all these curves there was a decrease of temperature with increase of eleva-

Table showing the Decrease of Temperature with every increase of 100 ft. of height.

Height above the ground.	May 5, 1869.	July 12, 1869.	July 17, 1869.		July 23, 1869.									July 24, 1869.									July 28, 1869.			Aug. 4, 1869.	Aug. 7, 1869.
	5.36 to 6.4 P.M.	6.12 to 6.33 P.M.	4.22 to 5.0 P.M.	5.5 to 5.23 P.M.	3.10 to 3.41 P.M.	3.42 to 4.12 P.M.	4.15 to 4.34 P.M.	4.39 to 5.4 P.M.	5.41 to 6.4 P.M.	6.6 to 6.27 P.M.	6.31 to 6.50 P.M.	6.56 to 7.12 P.M.	7.20 to 7.30 P.M.	3.23 to 3.51 P.M.	3.53 to 4.12 P.M.	4.12 to 4.30 P.M.	4.47 to 5.8 P.M.	5.23 to 5.47 P.M.	6.0 to 6.18 P.M.	6.21 to 6.43 P.M.	6.48 to 7.8 P.M.	7.19 to 7.42 P.M.	5.30 to 6·5 P.M.	6.17 to 6.43 P.M.	6·46 to 6.57 P.M.	10.32 to 11.20 A.M.	5.59 to 6.15 P.M.
	Clear sky.	Cloudy sky.	Cloudy sky.		Cloudy sky.									Clear sky.									Cloudy sky.			Clear sky.	Clear sky.
ft. ft.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0 to 100	0·8	0·8	1·7	0·6	1·8	0·5	0·7	1·4	0·5	0·8	0·7	0·5	0·5	1·9	1·5	1·3	1·1	1·1	1·1	0·4	0·7	0·0	0·6	0·2	0·2	1·0	0·2
100 to 200	·5	·6	0·8	·6	0·7	0·9	·5	0·1	1·1	1·1	·6	·5	·4	0·5	0·6	0·8	0·6	0·5	0·1	·6	·4	·1	·3	·5	·3	0·9	·7
200 to 300	·7	·3	·5	·7	1·1	1·2	·5	·7	0·4	0·1	·4	·7	·5	·8	·5	·6	·7	0·1	·3	·5	·6	·3	·7	·5	·5	1·0	·5
300 to 400	·8	·4	·1	·4	0·1	0·5	·5	·4	·5	·4	·6	·4	0·0	·7	·4	·2	·3	1·0	·6	·0	·4	·3	·6	·5	·5	1·0	·4
400 to 500	·7	·5	·4	·4	·5	·4	·3	·1	·4	·4	·5	·4	...	·2	·6	·5	·8	0·5	·6	·1	·6	·4	·2	·4	·4	0·4	·4
500 to 600	·1	·5	·6	·3	·6	·2	·8	·8	·0	·5	·7	·7	...	·8	·0	·4	·3	·5	·8	·6	·5	·3	·3	·5	0·3	·8	·7
600 to 700	0·3	·7	·4	·8	·8	·3	·5	·4	·7	·3	·5	·4	...	·5	·5	·2	·3	·3	·7	·6	·5	·4	·5	·4	...	0·8	0·2
700 to 800	1·0	·8	·4	·5	·5	·3	·2	·5	·6	·3	·3	·8	...	·9	·9	·5	·6	·0	·2	·4	·3	·2	·6	·5	...	1·1	...
800 to 900	0·6	·4	·2	·6	·5	·5	·4	·4	·3	·3	·6	·1	...	·4	0·5	0·3	·3	·5	·2	·5	·6	·4	·6	·4	...	0·1	...
900 to 1000	·2	0·0	·9	0·5	·2	·6	·3	·7	·5	·6	0·2	·3	...	·7	...	1·2	—·1	·5	·6	·1	·2	·6	·4	·5	...	·7	...
1000 to 1100	0·1	......	—·1	...	·2	·5	·5	·2	·4	·6	...	·7	...	0·5	...	0·4	—·3	0·1	·8	·2	·3	·5	·5	·5	...	0·3	...
1100 to 1200	1·5	......	·8	...	·3	·7	·1	·2	0·6	0·3	...	·4	...	...	...	...	...	1·0	·8	·6	·3	·5	·0	·5	...	...	...
1200 to 1300	0·3	......	0·8	...	·5	·4	·5	·3	...	...	...	0·0	...	...	...	...	...	...	0·7	·1	·3	·4	·0	·5	...	...	...
1300 to 1400	......	......	...	...	0·3	·3	0·4	·3	...	...	...	...	...	...	...	...	...	...	...	·6	·4	·5	·2	·4	...	...	...
1400 to 1500	......	......	...	...	...	·3	...	0·4	...	...	...	...	...	...	...	...	...	...	...	·3	·2	·1	·4	·3	...	...	...
1500 to 1600	......	......	...	...	...	0·2	...	...	...	...	...	...	...	...	...	...	...	...	...	0·7	·0	·1	—·1	—·1	...	...	...
1600 to 1700	......	......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0·8	0·3	...	...	...	...	...

tion, but of a progressively different form, being the most inclined the furthest from, and the least so, the nearest to, the time of sunset.

By reading the temperatures from these curves at every 100 ft. of elevation up to 1000 ft. the next Table was formed.

Table showing the decrease of Temperature with increasing elevation at every 100 ft. up to 1000 ft.

Height above the ground.	Clear sky.						Cloudy sky.				
	Times of ascent.						Times of ascent.				
	10 to 11 A.M.	3 to 4 P.M.	4 to 5 P.M.	5 to 6 P.M.	6 to 7 P.M.	7 to 7.30 P.M.	3 to 4 P.M.	4 to 5 P.M.	5 to 6 P.M.	6 to 7 P.M.	7 to 7.30 P.M.
ft. ft.	°	°	°	°	°	°	°	°	°	°	°
0 to 100	1·0	1·5	1·1	0·9	0·5	0·0	1·2	1·2	0·6	0·5	0·5
100 to 200	0·9	0·8	0·7	·6	·5	·1	0·9	0·6	·6	·6	·5
200 to 300	·9	·8	·7	·6	·5	·3	·9	·5	·6	·5	·5
300 to 400	·9	·7	·6	·6	·5	·4	·6	·6	·6	·5	·4
400 to 500	·8	·6	·6	·6	·5	·3	·4	·4	·5	·4	·5
500 to 600	·8	·5	·5	·5	·4	·3	·4	·4	·5	·5	·5
600 to 700	·7	·5	·5	·4	·4	·4	·4	·4	·5	·4	·4
700 to 800	·7	·5	·4	·4	·4	·4	·5	·4	·5	·5	·5
800 to 900	·6	·5	·4	·4	·4	·3	·4	·4	·5	·5	·5
900 to 1000	0·5	0·4	0·4	0·3	0·3	0·2	0·5	0·4	0·4	0·4	0·5

The numbers in these Tables prove that which was indicated by the several free ascents, viz. that the decrease of temperature with increase of elevation has a diurnal range, and different at different hours of the day; the changes being the greatest at midday and the early part of the afternoon, decreasing to (at or about) sunset, when with a clear sky there is little or no change of temperature through several hundred feet from the earth; whilst with a cloudy sky it decreases from the midday hours at a less rapid rate to (at or about) sunset, when the decrease is nearly uniform at the rate of 1° in 200 ft. I was not able to take any observations after sunset; but such observations are greatly needed, as there seems to be a very great probability that the temperature at the height of 1000 ft. may not undergo a greater range of temperature during the night-hours than during the day-hours; and if this be the case, then the temperature at night must increase from the ground with elevation: this inference seems to be confirmed by the after-sunset observations of Oct. 2nd, 1865, but it is desirable and very important that the facts should be determined by direct experiments. The law with a clear sky may be thus represented:—Take the heights as ordinates of a curve of which the corresponding changes of temperature are the corresponding abscissæ (considered positive when the temperature decreases, *i. e.* so that a decrease of 10° at 1000 ft. would correspond to a point on the curve whose positive abscissa is 10 and ordinate 1000, then the curve thus formed will be somewhat hyperbolic, for the changes are greatest near the earth), the concavity being turned towards an ordinate through the origin or axis. The concavity will be greatest when the curve represents the decline of temperature at a time soon after midday; but as the afternoon advances the curve gradually closes up to and coincides with the axis at or about sunset, becoming then rectilinear; after passing this critical position, in which the temperature is uniform and equal to that on the earth for the first 1000 ft., the curve probably becomes hyperbolic again, its concavity still being turned towards the axis, so that an increase of temperature corresponds to an increase of height, and the extreme position is reached probably at or soon after midnight, when the curve returns as before, the motion being probably nearly symmetrical on both sides of the axis, and the time of a complete oscillation twenty-four hours. If this be so, the numbers in Table VI. in each of my Reports in the years 1862–66, under the head of means up to 1000 ft. high, both in the clear and cloudy states of the sky, must not be considered as of general application, as supposed when the Reports were written, but the individual results from which the means were deduced must be grouped together according to the hour of observation.

On the Formation of Dew, and its Effects. By HENRY HUDSON, *M.D.*

The author contends that the condensation of atmospheric moisture tends necessarily to produce an "inversion of the normal law of its temperature." From a full analysis of all Mr. Glaisher's balloon ascents, he shows that, *in every instance*, there is an increase of temperature "above the clouds," *i. e.* where vapour is condensed. The night ascents are peculiarly interesting. That on the 2nd of October 1865 distinctly proves an *increase* of temperature as we ascend *in clear calm weather*, "when condensation takes place;" and the ascent on the 31st of March 1863 is equally conclusive in proving that, "with a blue and almost cloudless sky," no such inversion of the normal atmospheric temperature may occur, simply because "the dew-point, just before reaching the earth, was on this occasion 12½ degrees below the atmospheric temperature, and was even much further removed at the higher elevations." Hence there was *no* condensation of vapour during this ascent, and consequently the law of "diminution of temperature with increase of elevation" was never subverted.

The author asserts that Dr. Wells, from not attaching its due weight to this source of atmospheric heat, was led to adopt an erroneous theory, all his ingenious experiments clearly showing that the phenomenon which required explanation in "dewy nights" is "increase of temperature in ascending from the earth," and not *merely* a chilled surface in reference to the air generally.

If we assume terrestrial radiation as a cause, it is evident that the *maximum* absorption of heat must occur in the *lowest* stratum of the atmosphere, and this could not therefore in any way contribute to "greater heat" at higher elevations. Many of Dr. Wells's assumptions are plainly inadmissible; for instance, "that dense clouds near the earth must possess the same heat as the lower atmosphere;" and again, "that terrestrial radiation *must have* a ready transit through an atmosphere which *transmits solar heat* copiously." Also (as if to explain the *inversion* of the normal atmospheric temperature) he assumes "that the superficial stratum of air proceeds to radiate back to the earth its excess of heat" (acquired by radiation FROM the earth), "and that it is thereby more chilled than the superior strata," apparently forgetting that if it radiated to the earth it must do so also to the upper strata, which (in like manner) must be considered to radiate both upwards and downwards, and his hypothesis is therefore utterly worthless for explaining the phenomena. The chilling effect of air descending from the higher regions appears to be altogether ignored by Dr. Wells, and he assumes that clouds act as radiators of heat to the earth, instead of merely "screening it" from the extreme chilling etherial influences (in a manner similar to the "raised board" in his own experiments), and yet he admits that "during nights, *generally clear*, if the *zenith* be occupied by a cloud for *only a few minutes*, a thermometer on the grass will rise several degrees." A cloud "in the zenith" may well act as a screen and produce such a result; but its influence cannot be attributed to "radiation of *heat* to the thermometer." It merely *interferes* to diminish the chill from above, and thus enables the heat of the earth to regain its ascendency in warming the surface. The author also adverts to the fact observed in Mr. Glaisher's last recorded ascent (29th May 1866), that "at the height of 6200 feet (the sun having set nearly twenty minutes) the temperature was about 6 degrees warmer than at the same elevation an hour before."

In page 6 (Casella's edition), Dr. Wells writes, "Dew probably *begins* to appear upon grass, in places shaded from the sun, during clear and calm weather, soon after the heat of the atmosphere has declined;" and again, "I have frequently *felt grass moist*, in dry weather, *several hours before sunset*;" on the other hand, "I have *scarcely ever* known dew upon grass to exhibit *visible drops* before the sun was very near the horizon, or to be very copious till some time after sunset." Again (page 27) he writes, "According to a few observations made by me, the greater coldness of grass than that of the air BEGINS to appear, in clear and calm weather, in places sheltered from the sun, soon after the heat of the atmosphere has declined." Hence it is evident that the "dew-process" was in active operation long before he could possibly find any addition to the weight of his wool, and, as regards the amount of heat received by the air, it is sufficient to point out that the latent heat of 20 grains of moisture (which he frequently found in 10 grains of wool) would raise the temperature of 20 cubic feet of air about 8 degrees; hence we see what an enormous amount of heat must have been given out by the vapour deposited on the grass-plot, and wonder how such a "vera causa" has been ignored in the explanation of the phenomena; and yet Dr. Wells only notices the fact in the following terms (page 53):—"The formation of dew, indeed, not only does not produce cold, but, like every other precipitation of water from the atmosphere, produces heat." He knew that heat was eliminated, and that it was not communicated to the surface, and yet failed to see in it the source of atmospheric increase of temperature. In page 72 Dr. Wells admits that "bodies exposed in a clear night to the sky must *radiate* as much heat to it during the prevalence of wind as they would do if the air were altogether still, but in the former *little or no cold* will be observed upon them above that of the atmospheric." That is to say, there was little dew, and therefore the air had received *little or no heat* from this source. If Dr. Wells had given *actual temperatures*, instead of merely "differences," we should have had far more satisfactory data to go upon.

In conclusion the author insists that Prevost's Theory of Exchanges cannot be reconciled to the different "radiation energies" of surfaces. Imagine a thermometer in the focus of a metallic mirror, and a cubic canister (two *adjacent* sides being bright metal and the other two varnished) placed *angularly* in the line of the axis of the mirror; it will be admitted (supposing the temperatures of mirror, thermometer, canister, and air to be identical) that, whether the metallic or varnished sides are "radiating" to the mirror, there will be no effect on the focal ball, and yet the "radiating energy" of the varnished sides is *manifold* greater than that of the metal; why, then (on Prevost's theory), does not the focal thermometer indicate this increased effect, as concentrated by the mirror? It will be understood that the angular position of the canister is to meet any hypothesis of the "metal reflecting the thermometer's radiation back again to it." *A fortiori* (under the above arrangement), if the canister *alone* be reduced below the temperature of the air, why does the varnished surface *chill* the thermometer more than the metal, although the former is so much more potent in radiating heat?

Above thirty-four years ago the author devised what he considered an *experimentum crucis* on this subject. He had a vessel made of zinc, with one side of it a mirror. This was filled with water at 173° F., and one ball of a delicate differential thermometer having been placed in the focus of the mirror, the other ball was moved round until the instrument marked zero. A large tin screen was in front of the mirror, at a distance of about 6 feet. The temperature of the room being 55°, a cubic canister (as described) containing water at 67° was placed just in front of the screen; the focal ball showed increase of temperature, and the rise was greatest with the varnished sides of canister. On moving the canister nearer to the mirror, these effects diminished, and at a certain distance the effect (from both sides) became *nil*. On being moved nearer still the canister began to act *as if it were a cold body*, and the varnished surface produced the greater chilling effect. A paper, containing these results, was read by the author in Section A at the first Dublin Meeting of the British Association (in 1835), and was honoured by having been printed *in extenso*, amongst the Reports. The author did not *then* call attention to the consequences of these experiments, saying that he considered them only explicable on a "Wave Theory."

As Prevost's theory is still received by the first physicists of Europe, the author no longer hesitates to assert that it is not true. The facts adduced appear to him to demonstrate that when any body is of *the same temperature* as the medium, there is no "radiation," but when it is either warmer or colder than the medium, waves (either of *excess* or *deficiency*) are propagated from it through the medium,—a result to which a rude analogy may be found in imagining a bucket of water poured into (or taken out of) one end of a long narrow channel of still water. The previous equilibrium is thereby overthrown, and a wave is propagated either from or towards the site of the disturbance.

Faits divers de Physique Terrestre. *Par* Dr. Janssen.

The Rainfall of Natal, South Africa. *By* Dr. Mann, *F.R.G.S. &c.*

The British colony of Natal, situated on the south-east coast of Africa, 800 miles beyond the Cape of Good Hope, lies between the 27th and 31st parallels of south latitude, and the 29th and 32nd meridians of east longitude, looks out upon the Indian Ocean by a coast-line of 150 miles broad, and slopes down from a height of 6000 feet, where the inland frontier is formed by the rim of the great tableland of the Continent. The general set of the air-current is from the moist spaces over the ocean, up this rapid land slope, and the rainfall of the colony is in the main due to this cause. The result is a very remarkable climate, in which tropical productions grow luxuriantly in the lower districts, and temperate productions thrive in the higher regions. The mean temperature of the year is 64°·7 at a height of 2000 feet, and 69°·2 on the coast.

The year is divided into a wet and dry season, rather than into a summer and winter season. The six months from October to March are cloudy and moist, and the six months from April to September are months of bright and rarely interrupted sunshine. The entire rainfall, for a period of ten years, at an elevation of 2095 feet, and 45 miles inland, was 302 inches, giving a mean yearly fall of 30·22 inches; of this 25·53 inches fall during the six summer months, and 5·09 during the six winter months. The mean monthly fall for the summer period is 4·2 inches; the same for the winter period is 0·87 of an inch. The increase and diminution of the fall is singularly regular, as becomes apparent when the progression is represented in a diagram traced out pictorially upon paper.

The months of April and September are properly intermediate months in regard to rainfall. They have each a mean fall of one inch and a half, while the mean monthly fall for the rigidly dry period from May to August barely exceeds half an inch.

The heaviest rainfall in one year during this period was 37·31 inches; the least rainfall in one year 22·34 inches. Upon eight months out of the 120 comprised in the period of observation, no rain fell on 33 months only. The monthly fall was less than one inch, on one occasion only. There were 107 days in succession without rain. Eight other intervals gave rainless periods of between 40 and 68 days, and 13 intervals of between 20 and 33 days.

There were 19 months on which the monthly fall reached 5 inches, 9 months on which it reached 6 inches, 2 months on which it reached 7 inches, and 1 month when it reached 8·95 inches. There were 49 days on which the daily fall exceeded 1 inch, 13 days on which it reached 1½ inch, only 5 days on which it exceeded 2 inches. The heaviest daily fall was 2½ inches. The heaviest fall at Maritzburg on consecutive rainy days was 10·81 inches.

The rivers in Natal are low, but not dry in the winter season, and are swollen during the six months of heavier rain. The coast district alone is subject to occasional devastating floods. In 1857 there was one in which the river Ungeni, near its mouth in the neighbourhood of the seaport of Durban, rose 28 feet above its ordinary level, and overflowed a considerable space of low ground near the port, carrying down cattle, large deposits of reeds and large trees to the sea. In 1868 another coast-flood took place, in which a fine iron-girder bridge, 900 feet long, and recently erected over the same river at a cost of £19,000, was carried away, and in which damage to the extent of £100,000 was inflicted on public works and private property.

The rainfall on the first occasion was 21 inches on the coast, and 11 inches at

Maritzburg. On the second occasion $16\frac{1}{2}$ inches on the coast, and 10·81 inches at Maritzburg.

The ordinary rains of Natal are caused by the moist sea-air rushing suddenly inland to considerable elevation, and thence becoming rarefied and depositing the moisture suddenly in the midst of violent electrical demonstrations, constituting thunderstorms. The storms occur soon after 2 P.M., and rain continues to fall into the late evening, but this fall is followed by a fine morning. The storms occur three or four successive days, with a low barometer, and there is then a similar rainless interval, with a higher barometer. The devastating coast-floods are, however, due to another class of rains, namely, rains accompanying strong sea-gales from the south or south-west, and going in continuously for two or three days at a stretch. They occur often with a high barometer. During these rains the rainfall is much heavier on the intermediate coast than it is further inland. On the higher hills it diminishes into a thick mist, like that which is often found on the Scotch mountains. In one marked rain of this character, in which the author was caught between swollen coast rivers, the fall on the coast was 8·97 inches, and at Maritzburg, 2095 feet high, 1·23 inch.

Taken altogether, the coast rainfall is heavier than the rainfall at an elevation of 2000 feet. The entire rainfall for the two years 1866 and 1867, on the coast and at Maritzburg, was—

	1866. inches.	1867. inches.
The coast	48·54	33·080
Maritzburg, 2095 feet high, and 45 miles inland	30·26	31·49

The mean average fall at Maritzburg, for the several months of the year, deduced from a period of ten years, extending from 1858 to 1867, was—

January	4·23 inches.
February	5·20 "
March	4·08 "
April	2·33 "
May	0·51 of an inch.
June	0·10 "
July	0·21 "
August	0·70 "
September	1·73 inch.
October	2·59 inches.
November	5·68 "
December	4·48 "

The rainfall for each year of the period of ten years, at Maritzburg, was—

1858	27·42 inches.
1859	28·34 "
1860	30·60 "
1861	22·34 "
1862	29·96 "
1863	34·61 "
1864	37·31 "
1865	31·08 "
1866	29·26 "
1867	31·29 "

The comparative rainfall for Maritzburg, 2090 feet high, and 45 miles inland, and for the Coast district, near the sea-level, for the several months of the two years 1866 and 1867, was—

1866.	Merebank, near Durban. inches.	Maritzburg. inches.
January	1·010	5·965
February	2·670	3·565
March	20·190	4·448

1866 (*continued*).	Merebank, near Durban. inches.	Maritzburg. inches.
April	1·200	1·148
May	2·410	0·000
June	0·000	0·250
July	1·210	0·410
August	2·130	0·590
September	3·980	1·850
October	4·370	1·100
November	5·760	5·790
December	3·610	5·150
	48·540	30·266
1867		
January	1·110	3·400
February	5·410	5·660
March	3·660	3·860
April	6·890	3·140
May	0·070	0·000
June	1·260	0·000
July	0·160	0·000
August	0·430	0·370
September	0·210	2·040
October	4·240	3·080
November	5·490	6·690
December	1·520	3·250
	33·080	31·490

Remarks on Meteorological Reductions, with especial Reference to the Element of Vapour. *By* BALFOUR STEWART, *F.R.S.*

It will be desirable to preface the method of reduction herein proposed by a few remarks on the objects contemplated in such reductions. These objects are twofold. In the first place, meteorological reductions may be pursued with the immediate object of acquiring information as to the climate of a place; or secondly, they may be pursued with the immediate object of extending our knowledge of meteorology, regarded as a physical science.

Thus, for instance, a certain kind of reduction might be imagined to be of immediate practical benefit in determining whether a certain place might suit a certain class of persons or a certain class of plants, but yet it might not materially advance our knowledge of meteorology, regarded as a physical science. But, on the other hand, all observations tending to advance our knowledge of meteorology are of undoubted practical benefit. The amount of vapour present in the air is without doubt a very important element of climate, inasmuch as this affects in a marked manner the skin of the human body and the leaves of plants; but I am not aware that it has yet been determined by the joint action of naturalists and meteorologists what is the precise physical function which expresses proportionally the effect of moisture upon animal and vegetable life. Is it simply relative humidity? or does not a given relative humidity at a high temperature have a different effect from that which it has when the temperature is low?

There is, in fact, an absence of information as to the precise physical formula which is wished by physiologists as expressing the effect of moisture upon organic life. On the other hand, physicists may be presumed to confine themselves to meteorology regarded as a physical science. It is in this latter aspect that I proceed to discuss the question.

Regarding meteorology, therefore, as a physical science, it is one of our objects to ascertain the distribution and laws of motion of the dry and wet components of our atmosphere; and it cannot be denied that we are at the present moment in very great ignorance of these laws.

With respect to the motion of our atmosphere, it cannot be anticipated that we shall ever possess the same sort of knowledge which astronomy gives us regarding the motions of the heavenly bodies; for in the latter case the identity of the object is not lost sight of, while in the former case it is clearly impossible to ascertain the motions of individual particles of air. Our inquiries into the distribution and motion of the elements of our atmosphere must therefore be pursued by that method which enables us to ascertain the distribution and motion of any other substance or product with the individual components of which we find it impracticable to deal.

Suppose, for instance, we wish to ascertain the wealth of our country in grain or in spirits, and the distribution of this commodity over the earth's surface. We should first of all begin by taking the stock of the commodity corresponding to a given date; we should next keep a strict account of all the imports and exports of the material, as well as of its home production and home consumption.

Now, if we have taken stock properly at first, and if our account of the imports, the exports, the production, and the consumption of our material is accurate and properly kept, it will obviously be unnecessary to take stock a second time. But if these accounts are not kept with sufficient accuracy, or if we suspect that our material leaves us by some secret channel which we wish to trace, it will clearly be necessary to take stock frequently; and thus a comparison of our various accounts may enable us to detect the place and circumstances of that secret transit which has hitherto escaped our observation.

Applying these principles to the vapour of our atmosphere, what we wish to know is the amount of the material present at any one station at any moment, and also the laws of its motion. It would appear that the best way of measuring the amount present at any moment is by ascertaining the *mass* of vapour present in a *cubic foot* of air, mass and volume being fundamental physical conceptions.

Next, with regard to the motion of the atmosphere, including its vaporous constituent, the method of coordinates suggested by Dr. Robinson would appear to be the natural way of arriving at this. Let us set up at a station two imaginary apertures, one facing north and south and the other east and west, and gauge the mass of dry air and the mass of moisture that passes each of these openings in one hour; we shall by this means get the nearest attainable approach to the elements of motion of the atmospheric constituents from hour to hour. We shall not, however, obtain by this means a complete account of this motion, for we have at present no means of measuring its vertical component. This vertical component corresponds in fact to the secret channel in the illustration given above, which we must endeavour to detect by some indirect method. Another thing that ought to be determined is the production or consumption of the vaporous element of our atmosphere as it passes from place to place. This might be done could we keep an accurate account of the evaporation and the precipitation, the two processes by which this element is recruited and consumed. This would, however, be a very difficult observation.

Let us now recapitulate what information regarding moisture we can obtain from such meteorological observations as are at present made. We have—

(1) The mass of vapour actually present at a station from hour to hour.
(2) The mass that passes a station in one hour, going east and west.
(3) The mass that passes a station in one hour, going north and south.

There is wanting—

(4) The vertical component of the motion of vapour.
(5) Its production or consumption as it passes from place to place.

These deficiencies may, however, be to some extent overcome by the following considerations:—

First, the atmosphere moves as a whole when it moves, the dry and moist air moving together; *secondly*, dry air is neither capable of production or of consumption, but always remains constant in amount.

To illustrate this part of the subject, let it be supposed we wish to investigate the vertical motion of the atmosphere at a certain station. Make this station the imaginary centre of a circle, the circumference of which may be supposed to be studded with other stations at sufficiently frequent intervals, so that we can tell, hour by hour, how much dry air passes in towards the centre of the circle through its circumference, and also how much passes out.

Let us suppose that more is passing in than is passing out, or that the imports into the area of the circle are greater than the exports out of it. Now, the dry air that passes in is incapable of production or of consumption, and hence the stock of the material at the central station, and in the area generally, ought to be on the increase, since we have imagined the imports to be greater than the exports. If, however, we ascertain from actual observation that the stock of dry air is diminishing instead of increasing, we may be sure that some is carried off by an upward current, which of course carries the moisture with the dry air.

So much for the vertical component; and in the next place, with regard to the production or consumption of aqueous vapour as it passes from place to place. Our consideration has hitherto been confined to *quantity*; let us now define what is meant by the *hygrometric quality* of the air. It may be represented by the following quotient:—

$$\frac{\text{mass of vapour in a cubic foot}}{\text{mass of dry air in a cubic foot}}.$$

Now this quotient can only alter by evaporation, by precipitation, or by mixture. This hygrometric quality of the air may perhaps be considered as a quality sufficiently constant to aid us in tracing the actual motion of air, just as we may make use of the element of saltness to trace the actual path of an oceanic current. But besides this aid, we may make use of it to enable us to tell the precipitation or evaporation. For instance, a very damp air, in passing over a very dry country, may be supposed to emerge less damp, having its hygrometric quality changed; or a very dry air, in passing over a very damp country, may be supposed to emerge less dry, having its quality changed in the opposite direction. Thus, by actual observation of the quality of the air at the time of its reaching some particular tract of land or ocean, and at the time of its leaving it, we may possibly get much better observations of what goes on in the country, as far as this particular research is concerned, than if it were studded with gauges.

I should therefore suggest that meteorological observations should, by a system of reduction, be made to show—

(1) The mass of dry air and moisture in one cubic foot actually present at each station from hour to hour.

(2) The mass of dry air and of moisture that passes each station, hour by hour, in two lines of direction at right angles to each other, namely, north and south and east and west.

When these hourly elements are obtained, they might for seasonal changes be reduced after the method of five-day means, or for the investigation of abrupt changes of weather, such as storms, they might be utilized in some other way.

Retaining the belief that meteorology ought to be treated as much as possible with the view, in the first place, of determining the actual motions of our atmosphere, and, in the next place, of assigning the cause of these, it is no doubt the greater movements of the atmosphere that will be indicated by five-day means. It ought, however, to be remarked that the observations at any station are subject to the influence of locality, none probably more so than those of wind. It would appear that this influence ought to be eliminated before we can make any trustworthy *quantitative* deductions regarding the greater movements of our atmosphere. I should, however, imagine that the *quality* of the air, as herein indicated, may be made of immediate use in the study of storms.

It has been suggested by Mr. Meldrum, who expresses his concurrence with the above remarks, that in addition to the five-day means indicated above, there might be given a brief epitome of the weather. Thus, for instance, "The wind blew from the N.E. at Kew from January 1st, 1 A.M., to January 4th, 3 P.M., in all 86 hours, at the average velocity of 16 miles an hour, with an average pressure of 30 inches, a temperature of 40° F., and an average hygrometric quality represented by ·075." The same remarks had previously occurred to myself, and Mr. Airy also has recently suggested the study of the meteorological phenomena of those periods during which the wind blows in the same direction.

Electricity.

Description of some Lecture-experiments in Electricity.* *By* Professor G. C. Foster, *F.R.S.*

In this communication the author draws attention to the facility with which the transient electric currents accompanying the production and disappearance of electrostatical charge can be detected by the use of Sir William Thomson's reflecting galvanometer; and, in illustration, describes the application of this instrument to the investigation of the action of the electrophorus, and to the comparison of electrostatic capacities and electromotive forces. A description is also given of a simple method of proving the existence of the inverse and direct extra-currents in coiled conductors.

On the Metallic Deposit obtained from the Induction-discharge in Vacuum-tubes. *By* J. P. Gassiot, *V.P.R.S.*

The usual metallic deposit obtained from the discharge of an induction-coil in vacuum-tubes is known to arise from minute particles of the negative electrode, emanating in a lateral direction from the wire; these are thus deposited on the glass with metallic lustre when examined by reflected light. Such particles are very freely deposited from gold, silver, or platinum electrodes; less so from iron, copper, and other metals, but not from aluminium, although the latter becomes red-hot and ultimately fuses.

In one of Geissler's tubes with which I have for some time experimented, I obtained, by using my extended series of the voltaic battery, not only a very dense opake deposit on the glass round the negative electrode, but five or six bands of dark deposit along the tube; in carefully examining their position, I found they exactly coincided with the dark bands between the striæ, that they did not increase in density by continuing the discharge like the deposit round the negative, but remained without any further change.

I have not any record from Geissler as to the nature of the gas with which the tube was originally filled, I therefore requested him to prepare other similar-shaped tubes with the several simple and compound gases he had previously used, but I have not as yet been able to obtain similar results in any of these vacuums. A short time since, when examining some vacuum-tubes at Messrs. Cetti & Co., my attention was directed to one in which I observed a series of brilliant metallic rings deposited inside the glass; on inquiry Mr. Cetti informed me that the tubes had been originally charged with arseniuretted hydrogen and then exhausted in the usual manner; that almost immediately after he had passed the induction-discharge, the stratifications were much reduced, the beauty, as he described it, of the experiment was destroyed, while on the inside of the several uranium glass bulbs through which the discharge passed, a thick metallic coating, apparently the metal arsenium, was deposited.

This result appeared to me to explain that the deposit in Geissler's tube already referred to, did not arise from particles of the negative electrode, but from the gas with which it was originally charged; and if this is the case, their being deposited exactly in the spaces occupied by the dark portions between the luminous disks may lead to a correct explanation of a phenomenon that has hitherto baffled the ingenuity of the experimentalist.

On an Electromagnetic Experiment. *By* The Hon. J. W. Strutt†.

On the Electric Balance. *By* F. H. Varley.

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* This paper is printed *in extenso* in the Philosophical Magazine for September 1869.
† *Vide* Philosophical Magazine, July 1869.

On Electrification. By Thomas T. P. Bruce Warren.

When an insulated wire or cable is connected to a battery, and the deflection noted on a galvanometer, the first rush of current into the cable is due to the electrostatic capacity of the insulator. Battery-contact being still maintained, the deflection falls very rapidly at first, and gradually becomes reduced for some time after. The ratio between the deflections for equal periods of contact is independent of the length, and is greater or less according to the specific resistance of the dielectric. The ratio is unaltered under different electromotive forces, so long as constancy is maintained during the time of observation, and the deflection itself the same at the end of the first period of contact. But when, with different electromotive forces, the deflections at the end of the first period of contact are not the same, we may obtain the deflections which should be given on prolonged contact, if we know the deflection for a corresponding period by any electromotive force, since the deflections for the first period of contact will have to one another the same ratio which the deflections at any other period of contact have; thus, if with a given electromotive force we obtain at the end of the first minute's contact a deflection of 84, which at the end of the second minute is reduced to 76, and with a different electromotive force we have a deflection of 70 at the end of the first minute's contact, the deflection at the end of the second minute will have the same ratio to 76 which 84 has to 70. Under different temperatures the resistances corresponding to one, two, three, &c. minutes' contact follow the same law of variation; thus if $R = r \times$ const. represent the resistance after one minute's contact, then

$$\begin{array}{lllllll} R' & = r' & \times \text{ const.} & = & \text{resistance after} & \text{2nd} & \text{min.} \\ R'' & = r'' & \text{,,} & = & \text{,,} \quad \text{,,} & \text{3rd} & \text{,,} \\ R''' & = r''' & \text{,,} & = & \text{,,} \quad \text{,,} & \text{4th} & \text{,,} \\ R^n & = r^n & \text{,,} & = & \text{,,} \quad \text{,,} & n\text{th} & \text{,,} \end{array}$$

r, r', r'', r''', r^n are the resistances determined after 1, 2, 3, 4, n minutes' contact respectively, and R, R′, R″, R‴, R^n the required resistances for the same differences of temperature t, and at the end of 1, 2, 3, 4, n minutes' contact. If at any temperature T we obtain a deflection G after one minute's contact which at the end of the second minute falls to g, we may calculate what the deflection should be at the end of the second minute for any other temperature by knowing only the deflection after the first minute at this temperature. Let G and g be the deflections after one and two minutes' contact at a given temperature, and G′ the deflection at the end of the first minute at any other temperature, then $G : G' :: g : g'$; g' will be the deflection at the end of the second minute at this temperature. By calculating in this way the value of g and comparing it with the actual reading, much more reliance can be placed on the value of a test than can be done by correcting for temperature in the usual way. We are thus quite independent of temperature for knowing whether a core or cable has received the slightest injury in manufacture. G and g may readily be obtained by testing a core at a fixed temperature, as 75° F., as is now done. Coils having the same dimensions have rarely the same ratio in their resistances on prolonged contact with a battery; but when several coils are joined together the ratio between the deflections for any two successive durations of contact may be obtained from the reciprocals of the deflections of the several coils. In reducing tests of insulation by discharge to measures of resistance, it is impossible to obtain but approximations in the ordinary way of making the tests. The best way is to charge the cable or core for one minute, and leave it free for another minute, and then note the discharge, recharge the core, and take the instantaneous discharge. By this method we know exactly the amount of electrification which has been given to a core, but by taking the instantaneous discharge first, even although contact with a battery is made for one minute, we cannot say how much electrification is retained in the core. When a core is thus connected to a battery for one minute, and afterwards removed, electrification still takes place, but of course not precisely as if connected to a battery; for the insulator, instead of being acted upon by a constant charge, is affected by the variable charge consequent upon leakage; but when the core is held free for one minute it is very easy to ascertain how much effect the electrification has added in reducing the loss. The amount of electrification retained at any given interval is proportional to the quantity of charge remaining at that time. The longer battery-contact is maintained, the slower will a core or cable lose its charge, and conversely. In a cable which has been charged by contact with a battery for one minute, and afterwards held free for one minute, the electrification will be the same as if, instead of being held free, it had been left connected to a battery having the last tension, thus:—If the discharge after one minute's contact and one minute's insulation be 180, and the immediate discharge 200, the duration of contact being also one minute, the total effect for electrification at the end of the minute's insulation will be 95 per cent. of what it would have been if connected to the same battery for two minutes. By taking these considerations into account the formula of Professor Fleeming Jenkin,

$$R=\left(\frac{t}{K\,.\,\log\epsilon\,\frac{C}{c}}\right)\times 10^6,$$

may be rendered strictly applicable for deducing from the loss of static charge in time t, the resistance for the same period of contact in absolute measure, or in terms of that system which makes R and K functions of each other; and we may expect that the capacity K can be eliminated from this formula when R is known, if we can determine the constant for electrification for the interval of time during which the core is held free.

In this formula if the test is performed in the manner here indicated t will be 60, and the value obtained for R will be the resistance at the end of the second minute more nearly as $\frac{C}{c}$ approaches 1. This resistance has then to be divided by a number which expresses the ratio between the first and second minutes' contact. Approximately, and on short lengths of core, this may be obtained as follows:—Recharge the core after being kept to earth for some hours, maintaining contact with the battery for two minutes before noting the loss; then by dividing the percentage of loss in the first experiment by the percentage of loss given in the second experiment, we shall obtain a number by which, if R be divided, the resistance corresponding to one minute's contact may be found.

The following ratio expresses the rate of increase on prolonged contact:—Let D be the deflection at the end of the first period of contact and d the deflection at the end of the nth period, then D : d : : d : deflection at the end of n^2 minutes.

I have to acknowledge my obligation to Mr. Hooper for placing at my disposal the necessary instruments and cores for the subject of this paper.

Instruments.

On a New Anemometer for Measuring the Speed of Air in Flues and Chimneys. *By* A. E. Fletcher, *F.C.S.*

This paper is a continuation of one read at the Dundee Meeting in 1867.

Not able at that time to give a mathematical interpretation of the working of his instrument, the author, resting on experiment, drew up an empirical table of the speed of air indicated by it. Now independent calculations are given, and the results corroborated by experiment.

The problem to be solved may be briefly stated thus:—

The lower end of a vertical straight tube, open at both ends, dips into a liquid. To what height will the liquid be raised in the tube by the action of a current of air passing with a given velocity across its upper end?

On consideration, it will appear probable that the height of the column is but a measure of the impact force of the air in motion; experiment proves this to be the case; it shows that the liquid is drawn up to the same height it would have reached had the stream of air been directed against the surface of the liquid in the cistern. The problem is now exchanged for one easier of solution.

Let v = velocity of the air in feet per second.
g = gravity = 32·18 feet per second.
w = weight of a cubic foot of air at 60° Fahr., and 29·92 inches barometric pressure = 0·076107 lbs.
P = pressure in lbs. per square foot of a flat surface held at right angles to the direction of the current of air.

Then $v^2 w = g\mathrm{P}$.

Let p = the height of the column of liquid driven up the tube, measured in inches.
W = weight in lbs. of $\frac{1}{12}$ cubic foot of this liquid.

Then $\mathrm{P} = p\mathrm{W}$; $v^2 w = gp\mathrm{W}$; $v = \sqrt{p \frac{g\mathrm{W}}{w}}$.

Where the liquid used is water, W = 5·20833, and $v = \sqrt{p} \cdot 46{\cdot}92$, or $p = \frac{v^2}{2202}$.

In the anemometer here described, ether of the specific gravity ·740 is employed, and the instrument is so used that the reading is double the actual column of ether supported. In this case

$$v = \sqrt{\frac{p}{2} \frac{g\mathrm{W}}{w}} = \sqrt{p} \cdot 28{\cdot}55.$$

In order now to see what correction will be necessary when the temperature of the stream of air is different from that of 60° Fahr.,

Let v' = velocity of air at some other temperature, say at the temperature of t degrees Fahr.
w' = weight of a cubic foot of air at that temperature.
vol' = volume of a cubic foot of air at that temperature.

Then

$$\frac{w}{w'} = \frac{vol'}{vol} = \frac{vol \text{ at } 32°\left(1 + \frac{t-32}{491}\right)}{vol \text{ at } 32°\left(1 + \frac{60-32}{491}\right)} = \frac{459+t}{519},$$

or

$$\frac{1}{w'} = \frac{1}{w} \frac{459+t}{519};$$

but

$$v = \sqrt{\frac{p}{2} \frac{g\mathrm{W}}{w}} \text{ or } v' = \sqrt{\frac{p}{2} \frac{g\mathrm{W}}{w'}} = \sqrt{\frac{gp\mathrm{W}}{2} \frac{1}{w} \frac{459+t}{519}}$$

$$= \sqrt{p \frac{459+t}{519}} \times 28{\cdot}55.$$

But it is generally necessary to carry the correction a step further, and to give the velocity in feet of air at 60° temperature.

Now

$$v = v' \frac{vol}{vol'} = v' \frac{519+t}{459}$$

$$= \sqrt{p \frac{459+t}{519}} \times 28{\cdot}55 \times \frac{459+t}{519}.$$

$$= \sqrt{p \frac{519}{459+t}} \times 28{\cdot}55.$$

Further, to correct for variations in barometric pressure,

Let v'' = velocity of air at some other pressure than 29·92 inches, say at a pressure of h inches.
w'' = weight of a cubic foot of air at that pressure.
vol'' = volume of a cubic foot of air at that pressure. Then

$$\frac{w}{w''} = \frac{29{\cdot}92}{p}, \text{ or } \frac{1}{w''} = \frac{1}{w} \frac{29{\cdot}92}{p}.$$

As above,

$$v''=\sqrt{\frac{p}{2}\frac{gW}{w''}}=\sqrt{\frac{p}{2}\frac{gW}{w}\frac{29{\cdot}92}{p}}$$

$$=\sqrt{p\frac{29{\cdot}92}{p}}\,.\,28{\cdot}55.$$

In cases where it is necessary to give the velocity in feet of air at a pressure of 29·92 inches,

$$\frac{v}{v''}=\frac{h}{29{\cdot}92}\qquad v=v''\frac{h}{29{\cdot}92}$$

$$=\sqrt{p\frac{h}{29{\cdot}92}}\times 28{\cdot}55.$$

The complete formula, embodying the formulæ of correction for variations of temperature, and also of barometric pressure, would therefore be

$$v=\sqrt{p\frac{h}{29{\cdot}92}\cdot\frac{519}{459+t}}\times 28{\cdot}55,$$

v being the velocity of air at a temperature of t degrees Fahr., under a pressure of h inches of mercury; but the velocity is measured in feet per second of air at the normal temperature and pressure.

When drawing a sample of air from a chimney or fire-flue in order to examine it, that sample is measured, by the aspirator employed, under the existing barometric pressure; we want, therefore, the velocity to be given in feet of air under the same condition. The following is the formula then to be used:—

$$v=\sqrt{p\frac{29{\cdot}92}{h}\cdot\frac{519}{459+t}}\times 28{\cdot}55.$$

The number 28·55 thus obtained by calculation differs somewhat from the number obtained by the experiments which were made two years ago. These were not carried out with the accuracy that might now be obtained by help of the experience which has been gained in the use of the instrument since that time; they have therefore been repeated.

The same method was adopted as formerly. A regular current of air was established in a long flue or air-channel, one end of which was in connexion with a high chimney, and the other end open. The speed of this current was measured by the anemometer, and at the same time measured by noting the time a puff of smoke took in travelling from one end of the flue to the other. These experiments were made in three separate flues, and many experiments were made in each.

The value of c is found in each case from the formula

$$c=\sqrt{\frac{v^5}{p}\cdot\frac{29{\cdot}92}{h}\cdot\frac{459+t}{519}}.$$

No. of experiment.	Distance.	Time occupied by smoke.	Speed of smoke per second.	Pressure shown by anemometer.	Temperature of air in the flue.	Barometer pressure.	Value of c.
	feet.	seconds.	feet.	inch.	deg. F.	inches.	
1.	55	9	6·111	0·045	54	30·10	28·56
2.	117	12·3	9·513	0·1055	50	30·10	28·92
3.	94	13·5	6·963	0·0575	55	29·65	29·02
4.	94	16·5	5·757	0·038	55	29·65	29·21
5.	145	8	18·12	0·4195	44	30·30	27·38
6.	145	16	9·06	0·101	44	30·30	27·90
Average..................................							28·50

The average value of c in the experiments is 28·50, while the value arrived at by purely mathematical considerations is 28·55. This close correspondence is the more satisfactory when the difficulty of accurately measuring short intervals of time is borne in mind.

The formula $v=\sqrt{p}\times 28{\cdot}55$ may therefore be adopted as correct. The author has constructed a Table by means of it, showing the velocities which correspond to the various readings of the anemometer; also a Table showing the correction to be made for variations in the temperature of the air whose speed is to be measured. The corrections to be made for small variations in barometric pressure are unimportant. When it is necessary to make the correction, recourse must be had to the formula

$$v''=\sqrt{p\frac{29{\cdot}92}{h}}\times 28{\cdot}55, \text{ or } v=\sqrt{p\frac{h}{29{\cdot}92}}\times 28{\cdot}55,$$

according to the circumstances of the case. In the former the velocity is given in feet per second of air measured under the barometric pressure existing in the air-channel, in the latter it is given in feet per second of air measured under a pressure of 29·92 inches of mercury.

It may be asked if allowance should be made for the expansion or contraction which will take place in the ether of the manometer when exposed to varying temperatures. The variations of temperature to which the manometer itself are exposed are not great, being those of the external atmosphere only. It will be found that for a variation of 10 degrees the error introduced is about one per cent. Thus if the manometer has been exposed to a temperature of 50°, and the speed of the air experimented on is by calculation 10 feet per second, the real speed will be 10·1 feet. If the temperature of the ether in the manometer was 70°, then the real speed in place of 10 feet will be 9·9 feet per second.

In order to test by experiment the corrections of the formula for making allowance for variations in the temperature of the air whose velocity is to be measured, the following trial was made:—In a furnace, constructed for an experimental purpose, a current of air entered through a pipe 9 inches diameter at a temperature of 170°; after traversing channels of red-hot brickwork, it passed out through a 6-inch pipe at a temperature of 560°.

The reading of the anemometer at the inlet flue was 0·012 inch. Referring to the Table, the speed given is 3·127 feet per second. The correcting figure for the temperature 170° is 0·9083. Multiplying the two together, we have 2·84 feet per second as the speed of the air measured at 60°. The quantity of air passing was therefore 1·255 cubic feet per second.

At the outlet pipe the anemometer reading was 0·102 inch, showing by the Table a speed of 9·118 feet per second, to be multiplied by 0·7137, the figure of correction for the temperature 560°. This gives 6·508 feet per second for the speed of air measured at 60°; therefore the quantity of air passing was 1·278 cubic feet per second. The error is less than two per cent. Such an approximation is perhaps as close as could be expected in measurements of this kind, and may, it is thought, be taken as a confirmation of the general correctness of the formulæ.

Description of a New Self-recording Aneroid Barometer. *By* F. Martin.

On the Maury Barometer, a new Instrument for Measuring Altitudes. *By* Frederick T. Mott, *F.R.G.S.*

The author said that at present there was no instrument in the hands of the engineer by which he could make a rapid survey across mountainous or hilly country with ease and accuracy. At the suggestion of Captain Maury, Mr. E. T. Loseby, a well-known chronometer maker, had invented a pocket barometer, which promised to supply this desideratum.

The Maury barometer, like the aneroid barometer, measures the atmospheric pressure by the expansion and contraction of a vacuum-box; but this box is of larger size in proportion to the instrument, and of superior construction; and the measuring-machinery consists simply of a fine micrometer-screw attached to the index, and a thin steel drop-piece between the screw and the vacuum-box. All levers, chains, and spiral springs are got rid of, and the vacuum-box has got no work to do in moving the machinery, the required force being supplied by the hand of the observer. In shape and size the Maury is precisely like an old-fashioned watch. The outside diameter is $2\frac{1}{8}$ inches, the thickness about $\frac{5}{8}$ of an inch, the weight from 3 to $3\frac{1}{2}$ oz. On the dial is a scale ingeniously arranged in spiral coils, on which a range of 24 barometric inches, equal to 27,000 feet of elevation, can be engraved, with 50 divisions to the inch; the smallest divisions, equal to about 20 feet, being perfectly legible to the eye, and large enough for readings to be estimated accurately to 5 feet, and with care and practice almost to a single foot. Various experiments were referred to, in which the Maury had been tested against the aneroid, and found to be more regular and accurate.

A plan, suggested by Captain Maury, was also described by which two travellers, each carrying a Maury barometer, and following each other at definite intervals of time and space, could make a very rapid survey over any extent of country, correcting each other for all changes of general atmospheric pressure. In conclusion, the author said that the inventor of the Maury barometer claimed for his instrument a general superiority over the aneroid in the ratio of 4 to 1; and that the experiments and comparisons which had been described not only confirmed that claim, but showed a much larger ratio of advantage.

Dr. Burdon Sanderson, F.R.S., exhibited an instrument for recording respiratory movements, for a description of which see Section D.

On a Self-recording Rain-gauge. By Dr. Balfour Stewart, *F.R.S.*

The instrument described in this paper, and which was exhibited to the Meeting, was invented by Mr. Robert Beckley, of the Kew Observatory, and made and patented by Mr. James Hicks, of Hatton Garden, London.

It is designed to register the fall of rain by means of the varying immersion of a float in a fluid, and consists of a vessel supported on an annular plunger resting on a cistern of mercury, into which the rain collected in a funnel is conducted.

A pencil is fixed to the vessel, and in its descent traces a curve on a cylinder which is moved round regularly by a clock. A siphon of peculiar construction is adapted to the receiver, so as to empty it immediately it becomes filled to a certain height.

In the instrument exhibited the funnel, receiver, and float were so proportioned that a fall of 0·25 inch of rain traced a line 1 inch long on the cylinder.

The recording-cylinder is made of unglazed earthenware, and the whole of the clock-mechanism employed to give rotation to the cylinder is enclosed in an air-tight case, to protect it from the same injury by moisture, the motion being transmitted by mercurial stuffing-boxes.

The whole apparatus is contained compactly in a cast-iron case, 14 inches square and 10 high, and can be placed on the ground or elsewhere without any special arrangements being made for its erection.

On Collimators for adjusting Newtonian Telescopes. *By* G. Johnstone Stoney, *M.A., F.R.S.*

The author of this communication had described in 1856, at the Cheltenham Meeting of the British Association, a collimator for adjusting Newtonian telescopes. The collimator resembles a small refracting telescope, with eyepiece and cross-wires, differing from it only in the position of its object-glass, which is to be pushed somewhat in, so that the light transmitted from the illuminated cross-wires may leave the collimator as a divergent beam. To use this collimator, it is to be substituted for the eyepiece of the telescope; its construction then enables the rays emitted from its illuminated cross-wires to reach the great speculum of the telescope normally, so that, after reflection by the speculum, they return upon their path and form an image, which, if the great telescope be in adjustment, coincides with the cross-wires.

Several years before, Sir John Herschel described a very different collimator for adjusting reflecting telescopes, which consists of a Kater's collimator fastened inside the tube of the telescope, parallel to its axis. In using this collimator the eyepiece is not removed. The collimator emits a parallel beam of light, which, falling on the speculum, enables the cross-wires to be seen as a distant object, simultaneously with the heavenly body under review.

Moreover the adjustments which the two instruments are capable of effecting are also different. For while Sir John Herschel's collimator enables the observer to bring the image of that point of the object towards which the axis of the tube of his telescope is pointed, into the middle of his field of view, which is the adjustment of most importance when the telescope is to be used as a *surveying* instrument, Mr. Stoney's collimator enables the observer, if his mirrors are out of adjustment, to move the small mirror so as in the greatest possible degree to compensate for a faulty position of the great speculum, which is the adjustment of most importance, when the telescope is used as an *optical* instrument.

Thus the collimators themselves, and the adjustments they effect, are entirely different; yet Sir John Herschel, after describing his collimator in the later editions of the 'Outlines of Astronomy,' writes in the following words of Mr. Stoney's communication:—"It is to be presumed that Mr. Stoney, in bringing before the British Association in 1856 this application of the collimating principle as a novelty, has been unaware of this its prior use, since he has not alluded to it. The direct reference of objects to the collimating cross described in the text would seem to have been overlooked by him."—Outlines of Astronomy, 8th edition, page 128.

It is true that Mr. Stoney was not aware in 1856 that Sir John Herschel had suggested and used a different collimator for effecting other adjustments; but it is equally true that many readers have been misled by the foregoing passage into supposing that Mr. Stoney reproduced in 1856 the instrument previously described by Sir John Herschel. Moreover, the direct reference of objects to the collimating cross was not overlooked by Mr. Stoney, as Sir John Herchel supposes, inasmuch as no such reference is possible in Mr. Stoney's collimator.

On a cheap form of Heliostat. By G. JOHNSTONE STONEY, *M.A., F.R.S.*

This heliostat was planned throughout with a view to cheapness. It costs only five guineas, and yet, in the opinion of the author, who has used the first of them for a year and a half, is quite as efficient as the more expensive instruments. It has no second reflection, has the adjustments of the mirror under easy control, and is adapted for use at any station within a range of latitude of five or six degrees. It was made for the author by Messrs. Spencer and Son, of Dublin.

Mr. Stoney expressed the opinion that a heliostat could be made on the same plan at small cost, and yet so large as to be of much use in printing photographs, and especially in enlarging them.

On the best Forms of Numerical Figures for Scientific Instruments, and a proposed Mode of Engraving them. By Lieut.-Colonel A. STRANGE, *F.R.S., F.R.A.S.*

Mr. G. J. SYMON exhibited a Storm Rain-gauge.

On Self-registering Hygrometers. By E. VIVIAN, *M.A., F.M.S.*

Mean results in meteorology are ordinarily deduced from one or more daily observations at specified hours, with corrections for diurnal range; or from curves traced by photography or mechanical apparatus. In the rain-gauge, evaporating-vessel, and certain forms of anemometer, the aggregate amounts, however fluctuating, are obtained by accumulative action.

The latter of these methods is the most certain, and admits of being more readily reduced into a tabular form for the comparison of general averages. At a former Meeting of the British Association the author exhibited self-registering instruments on the cumulative principle for recording the mean values of the difference between the wet- and dry-bulb thermometers, and a self-registering maximum and minimum hygrometer. The author now produced an improved form of the former instrument, and a series of curves showing the comparative results of Leslie's hygrometer, his maximum and minimum differential, and his mean self-registering, which may be regarded as the standard; also the curve of evaporation of water in an open vessel.

It will be seen that these curves differ very widely as regards each period of 24 hours, but their monthly means are sufficiently uniform to show the approximate accuracy of the old methods during a long continuance of observations. This is still more evident from the second table, which extends over the greater portion of two years. The author briefly repeats that the action of the *mean* self-registering hygrometer depends upon the condensation of the vapour of alcohol in the wet bulb, the readings being taken from the fall of the column of spirit in the tube which represents the dry bulb in Leslie's hygrometer. If the temperature of both is alike there will, of course, be no action; if a uniform difference, say of 5°Fahr., that figure will be indicated on the scale; and if there is a fluctuating difference, say of from 0° to 10°, during the period which has elapsed since the last observation, then the record will be 5°, or such other figure as shall be the sum of the differences.

The author has applied this principle to the recording of the aggregate difference of solar heat in sun and shade, and to the duration of rain (the wet bulb being supplied by a funnel into which the rain is received), and to the amount of nocturnal radiation. He also proposes to apply it, in conjunction with an evaporating vessel, to the recording of mean temperature. Also as an anemometer, by deducting the results due both to heat and hygrometrical action.

On Chambered Spirit-levels. *By* T. Warner.

On a Self-setting Type Machine for recording the Hourly Horizontal Motion of Air. *By* C. J. Woodward, *B.Sc.*

The author referred in the first place to the methods in use for recording the horizontal motion of air. With a view of testing the errors incidental to the method adopted in the Birmingham instrument, he had had a series of readings made by two independent observers, and he found that during the fifteen days over which the observations extended, there were eighty-five differences of reading. Errors, too, were liable to creep in when the first results were copied into the log-book. To avoid these errors and with a view of obtaining the results in a neat form, the author proposed a mechanical arangement in connexion with the cups of an ordinary Robinson's instrument, by which a series of type-wheels should be acted upon so as to indicate the hourly horizontal motion of air. From these types the results could be printed off into the log-book. The mechanical details of the contrivance were in a great measure due to Mr. Alfred Cresswell.

A model to indicate the principle of the instrument was exhibited.

CHEMISTRY.

Address by H. Debus, *Ph.D., F.R.S., President of the Section.*

I believe it has been the custom with many of my predecessors in this office to place before the members of the British Association a Report of the progress of Chemistry during the year preceding their election. In attempting to follow their example, I soon found that it would be impossible for me, without making too great a demand upon your time, to give even a bare outline of the more important chemical work done during the year. A science the report of whose yearly advances fills about 1000 large octavo pages cannot by any powers of mine have its progress chronicled in an address of half an hour's duration. The best course open to me under such circumstances is to direct your attention to the ideas which at present guide chemists in their researches, to place in a clear light the objects they are striving to attain, and to indicate the direction of scientific thought of our time. To do this is by no means an easy task; for the more manifold and diversified the objects of a science become, the more numerous and extensive its relations with other branches of knowledge, the more difficult it becomes to draw a picture of its actual condition.

It is always an excellent recommendation of a theory or hypothesis when amongst the cultivators of the science to which it pertains very little difference of opinion exists as regards its admissibility and scientific value. This is in a high degree the case with regard to the atomic theory. The vast majority of chemists, I believe, accept this theory as the most suitable exponent of the fundamental truths of their science; and certainly if the quality of the tree may be judged by its fruit there is no other view which furnishes a clearer image to our minds of the chemical constitution of bodies, and at the same time conducts to the discovery of so many important facts and relations. According to Dalton's profound hypothesis all bodies are supposed to be composed of atoms of infinitely small dimensions. But these atoms are supposed not to be single; two or more of them are held together by certain forces and thus constitute what is called a molecule. One atom of carbon, one atom of calcium, and three atoms of oxygen, joined together by the force called chemical affinity, constitute a molecule of carbonate of lime. Vast numbers of such molecules bound to each other by the force of cohesion form a visible piece of chalk. If a chemist wishes to examine a body, his first endeavour is to ascertain of what sort of atoms the body is formed. This is a mere matter of experiment. He next determines how many of such atoms are contained in each molecule of the body, and finally he ascertains how these atoms are arranged, or, more correctly, combined within the molecule; for it is quite clear that a substance like saltpetre, which contains one atom of nitrogen, one of potassium, and three of oxygen, may have these atoms arranged in very different manners and still have the same composition. We might assume the potassium and nitrogen in more intimate union, nearer to each other than they are to oxygen, or we might consider nitrogen and oxygen more closely packed together, and, so to speak, attached as a whole to the potassium; in both cases, saltpetre would have in each molecule the same number of atoms, and the weight of the molecule would be the same. The three determinations just mentioned are of fundamental importance to the chemist; not that such inquiries are the only ones which interest him, for we shall in the sequel notice others of almost equal importance.

Nor must it be supposed that questions of this nature are of quite a modern date; for Leucippus, 500 B.C., appears to have sought to explain the nature of things by the assumption that they are formed by the union of small particles, which latter received the name of atoms from Epicurus. It is true the notion of atoms as conceived by the Grecian philosophers is not quite the same as ours, but their speculations contain our notions pretty much in the same way as the acorn contains the oak tree.

The determination of the quality of the atoms in a molecule, or the analysis of the latter, has not undergone many changes during the last few years, and the same may be said about the finding of the relative weight of a molecule, or the determination of the number of atoms which are contained in it. With regard to the latter point, however, it may be mentioned that Avogadro's hypothesis, according to which equal volumes of gaseous substances, measured at the same temperature and pressure, contain the same number of molecules, guides us chiefly in assigning to each molecule its relative weight and its number of atoms; this hypothesis has won more and more the confidence of chemists, and it is now admitted to hold good in nearly all well-examined cases.

Our views relative to the combinations of atoms in molecules, and our methods of ascertaining this arrangement, have, however, undergone great alterations and received great additions during the last ten or fifteen years. To a consideration of these changes I will now, for a short time, invite your attention. Since our modern views, however, originated in a great measure from the study of organic bodies, and since the majority of chemists now devote their time and labour thereto, I shall confine my remarks principally to the organic branch of the subject.

Eighteen years ago Professor Williamson read before the members of this Association a remarkable paper which contained the germ of our modern chemical views, and was the cause of many important discoveries. He proposed to regard three large classes of bodies, acids, bases, and salts from the same point of view, and to compare their chemical properties with those of a single selected substance. For this term of comparison he chose water. Now water is composed of three atoms, two of hydrogen and one of oxygen. Williamson showed that all oxygen acids, all oxygen bases, and the salts resulting from a combination of the two can, like water, be considered to be composed of three parts or radicals, two of the radicals playing the part of the hydrogen atoms in water, and the third that of the atom of oxygen; thus:—

$\left.\begin{matrix}H\\H\end{matrix}\right\}O$	$\left.\begin{matrix}K\\H\end{matrix}\right\}O$	$\left.\begin{matrix}NO\\H\end{matrix}\right\}O$	$\left.\begin{matrix}NO\\K\end{matrix}\right\}O$
Water.	Potassic hydrate.	Hydric nitrite.	Potassic nitrite.

Potassic hydrate is water which has one of its atoms of hydrogen replaced by an atom of potassium, hydric nitrite is water which has one atom of hydrogen replaced by nitric oxide, and potassic nitrite is water with one of its hydrogen atoms replaced by nitric oxide and the other by potassium. This speculation, as every chemist knows, is well supported by experiments; it embraces three large classes of bodies which till then had been considered as distinct. M. Gerhardt, in 1853, extended Williamson's views by distinguishing two other types of molecular structure, represented respectively by hydrogen and ammonia, and succeeded, by help of the radical theory, in arranging the majority of the then known substances under one or the other of the three types already mentioned.

Like every theory which is in harmony with experience, the above considerations led to results of unexpected importance; for it soon became apparent that the radicals which thus replace hydrogen in water are not all of the same chemical value. If we place together the formulæ of hydric nitrite and carbonic acid

$\left.\begin{matrix}NO\\H\end{matrix}\right\}O$	$CO\}O$
Hydric nitrite.	Carbonic acid.

we perceive at once that the atomic group N O has replaced one atom of hydrogen in one molecule of water, and carbonic oxide, C O, two atoms of hydrogen in one molecule of water. Nitric oxide (N O) is therefore said to be equivalent to one atom of hydrogen, and carbonic oxide (C O) equivalent to two atoms of hydrogen. The radical of phosphoric acid [P O] is found to be equivalent to three atoms of hydrogen. Professor Odling was one of the first to observe this difference in the equivalence of atoms and groups of atoms, or compound radicals, as they are termed, a difference which he marks as shown in the following examples:—

Radicals.

Equivalent to one atom of hydrogen.		Equivalent to two atoms of hydrogen.	
Nitric oxide	$(NO)'$	Carbonic oxide	$[CO]''$
Methyl	$(CH_3)'$	Methylene	$[CH_2]''$
Ethyl	$(C_2H_5)'$	Ethylene	$[C_2H_4]''$

The notion of equivalence enabled Professor Kekulé to form most interesting speculations on the constitution of organic bodies, and to explain the relation between composition and equivalence of such radicals as methyl, CH_3, ethyl, C_2H_5, methylene, CH_2, ethylene, C_2H_4, and acetylene, C_2H_2.

If from one molecule of marsh-gas, CH_4, one atom of hydrogen is abstracted, the residue, CH_3, called methyl, can combine with an atom of hydrogen again, and produce the original marsh-gas molecule. But methyl, instead of combining with an atom of hydrogen, can unite with an atom of chlorine, or an atom of bromine, that is to say, the place of the atom of hydrogen can be taken by an atom of chlorine or bromine. Methyl being thus equivalent to an atom of hydrogen is said to be monovalent. If from a molecule of marsh-gas two atoms of hydrogen are removed, the residue, CH_2, called methylene, can again unite with two atoms of hydrogen, or instead of hydrogen two atoms of chlorine or bromine, and form the compounds CH_4, CH_2Cl_2, CH_2Br_2, respectively. Methylene, therefore, being equivalent to two atoms of hydrogen, is termed divalent. The radical CH, left after the abstraction of three atoms of hydrogen from marsh-gas, is able to reproduce with three atoms of hydrogen one molecule of marsh-gas, or to combine with three atoms of chlorine, and form chloroform, $CHCl_3$. The residue, CH, is thus trivalent, or equivalent to three atoms of hydrogen. In the same manner carbon is found to be tetravalent or equivalent to four atoms of hydrogen; but carbon, formen [CH], methylene, CH_2, methyl, CH_3, not only combine with hydrogen, chlorine, or other elements according to their equivalence, but also amongst themselves, and thus produce the so-called hydrocarbons, native as well as artificial. Methyl combines with methyl and produces dimethyl, or better known as ethylic hydride, $CH_3+CH_3=C_2H_6$; methylene combines with methylene and forms ethylene, $CH_2+CH_2=C_2H_4$. Methylene is divalent and methyl monovalent; therefore methylene combines with two equivalents of methyl and forms propylic hydride, C_3H_8, $CH_2+2CH_3=C_3H_8$. Six equivalents of formen are supposed to be contained in benzol [C_6H_6], $6CH=C_6H_6$.

What has been said of marsh-gas also applies to ammonia and water. Ammonia, NH_3, minus one atom of hydrogen, forms the monovalent radical, NH_2, minus two atoms of hydrogen, the divalent radical, NH, and nitrogen itself is trivalent, that is to say, it can replace three atoms of hydrogen in compounds, or can combine with three atoms of hydrogen. Water minus one atom of hydrogen produces the monovalent radical hydroxyl, HO, and water without both atoms of hydrogen gives us divalent oxygen. These radicals, NH_2, NH, N, HO, and O, can combine with each other, and with methyl, methylene, formen, and carbon respectively, in different proportions. Thus methyl, methylene, and hydroxyl are contained in common alcohol. The union of methyl, carbon, oxygen, and hydroxyl gives acetic acid, $C_2H_4O_2$,

$$CH_3+C+O+HO=C_2H_4O_2.$$

Glycocoll is considered as a combination of methylene, amidogen [NH_2], carbon, oxygen, and hydroxyl:

$$CH_2+NH_2+C+O+HO=C_2H_5NO_2=\text{glycocoll}.$$

The radicals C, CH, CH_2, CH_3, HO, O, N, NH, NH_2, and CO are considered to form the proximate constituents of the most important organic compounds. It often happens that, from the union of the same radicals, two or more bodies of the same composition, but differing from one another in properties, result. Glycocoll as well as glycolamide contain the radicals methylene, hydroxyl, carbonic oxide, and amidogen, NH_2. In such cases the nature of the compound depends on the arrangement of the radicals, as may be seen by the following formulæ:—

$$CH_2.NH_2.CO.HO=C_2H_5NO_2=\text{glycocoll},$$
$$CH_2.HO.CO.NH_2=C_2H_5NO_2=\text{glycolamide}.$$

Now the great problem with whose solutions scientific chemists are occupied is—*To determine, first, what sort of radicals of the above nature are contained in a given organic body, and, second, how these radicals are grouped amongst each other.*

There are several ways of solving this problem. The molecule may be built up by placing the radicals which are supposed to exist in it under suitable conditions in contact. Two molecules of iodopropionic acid placed together with metallic silver will lose their iodine, and the residues of the two molecules remain united. A new acid, called adipic acid, is thus formed.

$$\left.\begin{array}{l}\text{Iodopropionic acid}\left\{\begin{array}{l}CO.HO\\CH\\CH_2I\end{array}\right.\\ \\ \text{Iodopropionic acid}\left\{\begin{array}{l}CH_2I\\CH_2\\COHO\end{array}\right.\end{array}\right. +Ag_2=2AgI+\left\{\begin{array}{l}COHO\\CH_2\\CH_2\\CH_2\\CH_2\\COHO\end{array}\right. \text{adipic acid.}$$

We know, therefore, the radicals of adipic acid and their arrangement if we possess the same knowledge with regard to iodopropionic acid.

The above elegant synthesis has lately been performed by Professor Wislicenus of Zürich. M. Berthelot has now succeeded in producing representatives of the principal classes of hydrocarbons from the elements of carbon and hydrogen, and Messrs. Bauer and Verson of Vienna have prepared from amylene, $C_5 H_{10}$, a compound, $C_{10} H_{16}$, which appears to be identical with terebene, a body closely allied to turpentine.

Another way to determine the proximate constituents of molecules, is to take the little structures to pieces, and to form a judgment of their constitution from the radicals which thus can be extracted. This plan has been adopted by Mr. Chapman, and described by him at one of our former Meetings.

The more common and more reliable method for the determination of the grouping of atoms in molecules is, however, the replacement of one or more of them by atoms of another kind, and the careful examination of the properties of the bodies thus formed. M. Gautier has recently obtained a new substance of the same composition as acetonitrile, which he calls methcarbylamine. According to their formation, acetonitrile, as well as methcarbylamine, can be considered as combinations of cyanogen and methyl$=CH_3 CN$. The two bodies, however, do not possess the same properties; if they are heated with potassic hydrate and water, methcarbylamine produces formic acid and methylia, whereas the same reagents cause acetonitrile to form acetic acid and ammonia. Thus

$$\underbrace{C_2 H_3 N}_{\text{Acetonitrile.}} + \underbrace{2 H_2 O}_{\text{Water.}} = \underbrace{C_2 H_4 O_2}_{\text{Acetic acid.}} + N H_3$$

$$\underbrace{C_2 H_3 N}_{\text{Methcarbylamine.}} + 2 H_2 O = \underbrace{C H_2 O_2}_{\text{Formic acid.}} + \underbrace{N \begin{cases} C H_3 \\ H_2 \end{cases}}_{\text{Methylia.}}$$

In the first case, the radical methyl remains after the decomposition in union with carbon, and in the second case in combination with nitrogen. Accordingly it is supposed that the same arrangement prevails in the undecomposed molecules, and with this supposition all the other properties of methcarbylamine and acetonitrile agree. In symbols these relations are expressed as follows:—

$$N \begin{cases} C'' \\ C H_3 \end{cases} = \text{methcarbylamine.}$$

$$\{ C_2 H_3 = \text{acetonitrile.}$$

This case of isomerism is most interesting, inasmuch as it furnishes a most instructive lesson on the grouping of atoms. The homologous bodies of methcarbylamine in the ethyl and propyl series have also been obtained.

Isomerism, indeed, has received much attention during the last year, and a great many interesting discoveries have resulted; of these one more example may be mentioned. We know two compounds of the formula $CN_2 H_4 O$, the one is ammonic cyanate, and the other urea. Until recently, only one corresponding sulphur-compound, ammonic sulphocyanate, was known. Professor Reynolds has succeeded in obtaining the true sulphur-urea, a body isomeric to ammonic sulphocyanate.

Thus every year produces results which improve our conceptions of the atomic and molecular constitution of bodies; and as our knowledge improves new questions suggest themselves, and our power over the elements increases. It has already become possible to prepare in the laboratory bodies of a very complex character, such as a few years ago were only found in the bodies of animals or plants.

Alizarin, the beautiful compound of the madder root, has been obtained by artificial means in the course of the year by Messrs. Liebermann and Græbe. Results of such a nature render it highly probable that, at no distant period, it will be in our power to prepare artificially nearly all, if not all, the substances found in plants and animals. Here I must not be misunderstood. Organic structures, such as muscular fibre or the leaves of a tree, the science of chemistry is incapable of producing, but molecules like those found in a leaf or in the stem of a tree will no doubt one day be manufactured from their elements.

I must not conclude this address without reference to two or three papers of great importance.

Professor Bunsen, of Heidelberg, has published a paper on the washing of precipitates. Every one acquainted with practical chemistry knows how much time is often lost in waiting for a liquid to pass through a filter. Bunsen found the rate of filtration nearly proportional to the difference between the pressures on the upper and lower surfaces of the liquid. If, accordingly, the funnel be fixed air-tight by means of a perforated cork to the neck of a bottle, and the air exhausted in the bottle, the liquid will run faster through the filter in proportion to the diminution of the pressure in the bottle. Comparative experiments, some made according to the old, and others according to the new method, showed that the filtration, washing, and drying of a precipitate which took seven hours by the old plan could be performed by filtration into an exhausted bottle in thirteen minutes. But a saving of time is not the only advantage of the improved method of collecting and washing precipitates. A more perfect washing with less water than is required by the common way of proceeding is by no means the least recommendation of Bunsen's ingenious method.

A very important paper has been published by Professor Liebig on the improvement of the nourishing qualities of bread. Certain quantities of phosphates and other salts form necessary ingredients of wholesome food. Now, it is well known that most of these salts, which are naturally in wheat, remain with the husk. Liebig proposes to add salts, of a nature similar to those remaining in the husk, to the flour, and at the same time to substitute for the carbonic acid developed by fermentation, gas liberated from sodic carbonate. The bread prepared according to Liebig's recommendation is said to be of excellent quality, and to exceed in value bread made by the ordinary method.

Mr. Graham, of Her Majesty's Mint, has continued his researches on the absorption of hydrogen by palladium. Palladium appears to be able to absorb more than 900 times its volume of hydrogen, and to form a combination which consists of nearly equal equivalents of the two elements. Hydrogenium, as Mr. Graham calls the combined hydrogen, acts in this case like a metal, and thus the opinion held by some scientific men, that hydrogen constitutes the vapour of a metal, receives confirmation. The specific gravity of hydrogenium, as contained in the alloy, was found to be 1·95. These experiments are remarkable in more than one respect. The palladium, which absorbs and combines with the hydrogen, does not change its state of aggregation, but remains solid and expands as if it had been heated. The molecules of the palladium have consequently changed their relative positions and combined with hydrogen, whilst the continuity of the metal remained intact.

The last paper to which I have to draw your attention is an excellent one by Professor Tyndall, on a new method of decomposing gaseous substances by means of light. Tyndall's experiments bring us face to face with the motions of atoms in molecules, and the relation of these motions to chemical decomposition. They will no doubt, at some future time, furnish valuable materials to chemical dynamics.

On the Absorption-bands of Bile. By THOMAS ANDREWS, *M.D., F.R.S.*

A solution of bile in water or alcohol exhibits, when examined by the spectroscope, characteristic absorption-bands, which differ from those of the red colouring-matter of blood or its derivatives. The most conspicuous of these bands lies nearly midway between the yellow soidum-line and the green line β calcium. Another band occurs, chiefly in the orange, extending a little beyond the sodium-line. A third band occurs in the green, bounded on its more refrangible side by the magnesium group (*b*, Fraunhofer). These absorption-bands are also found in solutions of biliverdin, but not in solutions of the yellow colouring-matter of bile. They are not affected by reducing agents, but are weakened, and at last effaced by the action of nitric acid.

The absorption-bands furnish a ready test for bile in liquids, such as water or urine, which have no absorption-bands of their own. With a column of liquid $2\frac{1}{2}$ inches long, the presence of bile was in this way discovered, when diluted 100 times, and with a column 8 inches long, when the dilution was carried four times further. An estimate of its amount may also be made, and its fluctuations in disease observed from day to day.

The Water Supplies of Plymouth, Devonport, Exeter, and St. Thomas. *By* Henry K. Bamber, *F.C.S.*

The water supplied to the town of Plymouth is taken near Sheepstor, from the River Meavy, which receives its water from the granite-hills in the neighbourhood, and has a drainage area of about 4000 acres.

The water is conducted from the river by means of an open leat as far as Knackersknowle, a distance of about 12 miles, from thence the water for domestic use is carried through iron pipes of 24 inches and 12 inches diameter, a further distance of about three miles into reservoirs, from whence it is distributed to the different parts of the town.

The surplus water is carried from Knackersknowle by the old leat around a distance of about 10 miles, to supply several mills, and is then delivered into the Great Western Docks at Milbay. The supply of the water is in the hands of the Corporation.

Analyses of samples of the water, taken at the commencement of the leat at Sheepstor, and in Plymouth, gave the following results. It was perfectly clear, transparent, and colourless, and contained in an imperial gallon:—

	At Sheepstor. grains.	In Plymouth. grains.
Inorganic matter	2·38	2·69
Organic and volatile matter	0·57	0·54
Total solid matter	2·95	3·23
Chloride of sodium	1·25	1·29
Ammonia	0·0045	0·01
Nitrates	none.	slight trace.
Hardness before boiling	0°·61	0°·75

The inorganic constituents were principally chloride of sodium and sulphate of calcium.

These samples were taken after a continuance of dry weather, on August 5, 1869. It is very good water, and for manufacturing, cooking, and washing purposes, its extreme softness is a great advantage: but it acts rapidly on the iron pipes, corroding them considerably, thereby diminishing their internal diameter, so that now all the pipes are coated with asphalte before being fixed in their places.

Devonport Supply.—The water supplied to Devonport is taken from streams near the source of the River Dart, on Dartmoor, including one stream which would be much better excluded; for, as its name (Blackwater or Blackabrook) indicates, its water is highly coloured with peat, and colours the water of the Devonport leat.

The water is carried nearly all the way, a distance of 34 miles, in an open leat. Some portion of the water, however, is detained at Knackersknowle, and from thence is delivered through iron pipes into a reservoir at Stoke, to supply the higher levels, but the largest portion is delivered into Devonport from the leat direct.

I took a sample of the water from the leat at Downsland Barn, and also a sample in Devonport, as supplied to the Company's own offices. On analysis the samples gave the following results.

The water was clear and transparent, but had a brown colour of peat, the sample taken at Devonport being the least coloured of the two. It contained in an imperial gallon:—

	At Downsland Barn. grains.	In Devonport. grains.
Inorganic matter	2·59	2·36
Organic and volatile matter	1·46	0·58
Total solid matter	4·05	2·94
Chloride of sodium	1·20	1·55
Ammonia	0·004	0·01
Nitrates	none.	slight trace.
Hardness before boiling	0°·9	1°·0

The inorganic constituents were the same as in the Plymouth water, but the sample taken in Devonport contained a quarter of a grain of oxide of iron per gallon, which had been dissolved as the water lay in the pipes; the action of the water on the pipes also removed, as usual, a considerable quantity of the organic matter.

This water, like the Plymouth water, is exceedingly soft, and on this account is admirably adapted for culinary and manufacturing purposes; but from the presence of the colouring-matter, it is not so agreeable for drinking purposes as the Plymouth water.

These very soft waters always rapidly corrode the iron pipes, not so much by deposition from the water, as by converting the iron of the pipes into *oxide of iron*, pipes of 12 inches diameter becoming, after a few years, reduced to 10 inches in diameter. These waters also act on *freshly cut lead.*

Exeter Supply.—The water used for the supply of Exeter is taken from the river Exe, at Upton Pines, about two miles and a half above Exeter. The water is pumped from there to the reservoirs and filter-beds at the back of the County Prison in Exeter, from whence it is distributed to the town, but the water used to supply the higher levels is frequently pumped directly from the river to the houses, without filtration. I took a sample of the water at the house of H. S. Ellis, Esq., the present Mayor of Exeter, from the tap as it was running from the main into his cistern; the water was red with rust of iron, and deposited a considerable quantity of earthy matter on standing.

I also afterwards obtained a sample of the water of the Exe, above the entrance of the river Culm, from the spot whence the future supply is to be taken.

Analyses of these two samples gave the following results.

After all sedimentary matter had been allowed to deposit, the clear water was poured off, and contained, in an imperial gallon:—

	In Exeter. grains.	Future supply. grains.
Inorganic matter	11·48	6·63
Organic and volatile matter	0·16	1·00
Total solid matter	11·64	7·63
Chloride of sodium	2·15	1·75
Ammonia	0·005	0·006
Nitrates	a trace.	a trace.
Hardness before boiling	7°·60	4°·57
" after "	2·27	2·72

The inorganic constituents were carbonate and sulphate of calcium, carbonate of magnesium, and chloride of sodium

In the case of the sample taken in Exeter, a considerable quantity of the organic matter originally present in the water had been removed by the action of the water on the iron pipes.

This is a good water, and that taken from the Exe, above the entrance of the river Culm, is all that can be desired for a domestic and general supply.

St. Thomas's Supply.—The supply for St. Thomas's is taken chiefly, if not entirely, from a well in the surface-gravel, and is pumped up into a reservoir, from which it is distributed to the houses.

This water was cloudy when drawn, but after the suspended matter had been deposited, the water was poured off, and was then clear, transparent, and colourless, and contained, in an imperial gallon:—

	grains.
Inorganic matter	25·66
Organic and volatile matter	1·82
Total solid matter	27·48
Chloride of sodium	5·55
Ammonia	0·003
Nitric acid	2·00
Hardness before boiling	20·26
" after "	7·73

The inorganic constituents consisted of carbonate of calcium, sulphate of calcium, carbonate of magnesium, chloride of sodium, nitrates, and a little oxide of iron.

It is evident, from the large quantity of chloride of sodium, nitrates, and organic matter in this water, that it is obtained from a well which receives surface-drainage, and on this account, as well as from its hardness, is not a fit supply for domestic use.

A considerable portion of the district is still supplied by the Exeter Water Company.

All these samples were taken in the first week in August 1869, after a continuance of dry weather.

On the Decomposition of Carbonic Oxide by Spongy Iron. *By* I. Lowthian Bell, *F.C.S.*

In a communication on the chemistry of the blast-furnace, made to the Chemical Society of London last June, the author mentioned a circumstance in connexion with the action of iron on carbonic oxide, which, so far as he knows, had not previously been observed.

On exposing fragments of ironstone, either raw or calcined, containing in the one case $FeO\,CO_2$, and in the other $Fe_2\,O_3$, to the escaping gases of blast-furnaces, there was, when the current of heated gas had a temperature sufficiently elevated, an impregnation of black matter, which was ascertained to be carbon.

The heat required to produce a slight appearance of this change was apparently a little above that of melting lead, but at that of melting zinc the deposition of carbon was very marked.

The explanation ventured upon at the time was, that the oxide of carbon was resolved into carbon and carbonic acid, even at the low temperature of 337° to 361° C, as may be expressed by the formula $2CO = C + CO_2$.

It has since been suggested that the action in question might have been caused by traces of hydrocarbons still existing in the coke employed in the smelting-process.

To satisfy himself that this explanation was not the correct one, the author has, upon several occasions, repeated in the laboratory the decomposition performed by the blast-furnace, employing carbonic oxide, prepared both from oxalic acid and from ferrocyanide of potassium, in the usual way.

The author was induced to submit the results of these experiments to the Association, not only from the interest they may have in a chemical point of view, but also from the circumstance that it is, from recent observation, possible that the decomposition of carbonic oxide at this low temperature may have a practical value in the smelting of iron.

To prevent the reactions which accompany the deoxidation of an iron-ore complicating the inquiry, a quantity of calcined Cleveland ironstone was reduced to a coarse powder, and the oxygen expelled. It was first exposed in a muffle to a red heat for some hours in a current of air, so as to secure its perfect oxidation, and removal of every trace of organic matter. The powdered ore was then placed in a red-hot porcelain tube, and a stream of hydrogen gas passed over it until all the oxygen of the peroxide of iron was removed. The completeness of the deoxidation was judged of by weighing the water produced by the operation.

A quantity of carbonic oxide, in this instance prepared from ferrocyanide of potassium, was examined, and its freedom from water, carbonic acid, oxygen, and other impurity carefully secured by passing it successively through a series of tubes containing pyrogallate of soda, potash, and sulphuric acid.

Two hundred grains (=12·9598 grammes) of the deoxidized ore were placed in a glass combustion tube, and heated by a Hofmann's gas-lamp, so that the necessary temperature was under easy control.

Ten litres of the carbonic oxide were passed over the ore, which was never permitted to be red-hot, and to secure the temperature being high enough, a piece of zinc placed on the tube was maintained in a melted state. Four hours and a quarter were required for the operation.

The gas, as it passed away, was exposed to the action of a solution of potash, which of course absorbed any carbonic acid generated, and which was found to amount to 9·9 grains (=0·641 gramme).

The ore on cooling, without exposure to the atmosphere, was ascertained to have increased 3 grains (=0·1942 gramme). The 203 grains (=13·155 grammes) thus obtained were mixed with chromate of lead, placed in a tube, and heat applied.

The resulting carbonic acid was collected in the usual way. It weighed 10·66 grains (=0·6903 grm.) equal to 2·907 grains (=0·1882 grm.) of carbon.

This experiment then gives 9·9 grains (=0·641 gramme) of carbonic acid, produced directly by the action, and 10·66 grains (=0·6903 gramme) obtained by the deposited carbon, the difference being probably due to error of manipulation.

In another form of experiment 1000 cubic centimetres of carbonic oxide were passed and repassed from one graduated vessel over the heated ore into another similar vessel (both over mercury), so that the change of composition, as denoted by the change in volume, could be ascertained. It was found in this experiment and in others that, as the temperature was raised above that of redness, the action gradually diminished. At a heat approaching whiteness the carbonic acid obtained from the ore which had been exposed for some hours to the action of carbonic oxide was so minute (·25 per cent of the weight of the ore) as to render it probable that it was due to the occlusion of a portion of the oxide of carbon, a view which was confirmed by the fact that no flakes of carbon were perceptible on dissolving the ore in hydrochloric acid.

When the treatment is continued long enough, the deposition of carbon in the interstices of some pieces of the ore is so copious that they are burst open as lime is with water on being slaked. Upon one occasion the ore was found, after nine hours' exposure, to contain 24 per cent. of its weight of carbon.

On Extraction of Ammonia from Gas-Liquor. By Frederick Braby, *F.C.S.*

Gas-liquor was formerly a drug in the market and a nuisance to the manufacturer; it was given away to any one that would use it, now it is the principal source of ammonia and of its salts. The object of this paper is to show how the demand for gas-liquor, which far exceeds the supply, can be met, and to prove how (by reduction of bulk for transit) small and remote gas-works may export their residual products at a profit; it is also to show how the production of ammonia may be very greatly increased.

In its crude state, gas-liquor usually contains one part of ammonia, by weight, to eighty parts of liquor. For all purposes of transit, a very serviceable solution would contain one part, by weight, of ammonia to four parts of water; this very considerable reduction of bulk is effected by means of a rapid and economical process, described in the specification of a patent recently secured by the author, in conjunction with Mr. Baggs.

According to this process, a quantity of slaked lime is added to the ordinary gas-liquor. This is maintained at a temperature of between 100° and 200° F., the liquid being constantly stirred. A powerful air-blast, blown continuously through the liquor, liberates the ammonia as gas in a very perfect and rapid manner. The mixture of air and ammonia passes through water, leaving the ammonia in solution, and the air passes off. With a very moderate-sized apparatus, several thousand gallons of gas-liquor may thus be converted into a portable form in a single day. Ammonic sulphate, or ammonic chloride, is obtained by conducting the ammoniacal gas into sulphuric acid or hydrochloric acid respectively.

In the working plant at Deptford, constructed by the author, a wrought-iron still, or ammonia-generator, 30 feet long and 6 feet diameter, is capable of being charged from a reservoir that can contain over 9000 gallons of gas-liquor. The gas-liquor is pumped from the reservoir into the still, and heat is applied by means of an underneath fire. Air is forced into the hot liquor through suitable apertures in the lower part of cast-iron pipes that proceed longitudinally through the still at its bottom. The streams of air are thoroughly disseminated through the liquor by the fans of a revolving stirrer. The various constituents of the gas-liquor (water, ammonia, carbonic dioxide, sulphuretted hydrogen, sulphocyanides, &c.) are thus brought continuously into intimate contact with air and with lime that has been placed in the vessel. The mixture of air and ammonia passes into a purifier, which consists of a small wooden vessel containing lime, and about one-third full of water. This purifier has a tight head and a perforated false bottom, also a small agitator, together with trial-taps and a pipe for conveying away liquid accumulated from condensed vapour. The other adjuncts are a "safety-tube," safety-valve, and vacuum-valve; the two latter are fixed on the tube from the ammonia-generator. After passing through the purifier, the mixture of ammoniacal gas and air traverses a coil (in a cold-water cistern) to a deep closed vessel, or receiver, about one-third full of pure cold water. A series of these receivers is used, so as to afford a succession of vessels to retain the ammonia. The air, having fulfilled its function, passes off into the atmosphere. The last receiver contains a strong solution of ferric chloride. The liquid residuum of this process is run off into a draining pit, thence into the sewers; the solid inodorous lime-compounds are carted away. In the draining-pit certain perforated shelves carrying sand, also gravel and cement, facilitate the separation of the solid from the liquid parts of the residuum.

The commercial value of the ammoniacal liquor augments in a ratio increasing with its concentration. The advantages of the above-described system may be summed up as effecting a considerable economy in labour, time, and occupation in plant, together with a facility of extracting the whole of the ammonia from the gas-liquor in a pure condition.

On the Registration of Atmospheric Ozone in the Bombay Presidency, and the chief Causes which influence its appreciable amount in the Atmosphere. By Dr. H. Cook, *F.G.S., F.R.G.S., Surgeon H.M. Bombay Army, late Meteorologist to the Abyssinian Expedition.*

The registration of ozone was commenced in the Bombay Presidency by the direction of the Government, at the author's suggestion, in the year 1863 at the following stations, viz. Ahmedabad, Deesa, and Mhow in the northern division; Ahmednugger, Poonah, and Sattara in the Dekkan; Belgaum and Kholapore in the southern Mahratta country; Bombay, Tanna, and Surat on the coast; at Kurrachee and Hydrabad in Scinde; and at Mahableshwur, the Sanatorium, on the western Ghats.

Previous to this no systematic observations had been made in India.

Printed forms, which when filled in would embody the following details, were issued to the various stations, viz. the quantity of ozone by day and by night, the direction of the wind, character of the clouds, amount of rainfall, occurrence of dust-storms, thunder-storms, &c.; a summary of the temperature, and the daily number of cases in hospital suffering from cholera, dysentery, diarrhœa, and intermittent fever.

These forms were filled in and forwarded monthly to the author, who prepared an annual report on the whole.

The results (to state them as briefly as possible) of the four years' registration go to prove that practically the same conditions of atmosphere are present in India as in Europe when the full manifestation of atmospheric ozone is present. Elevation above the sea-level, the prevalence of the equatorial current, proximity to the ocean, and prevalence of sea breeze, a certain amount of moisture, the fall of rain, hail, and dew, the occurrence of thunder-storms and dust columns, or other indications of excited electrical conditions, all influence the evolution of ozone alike in India as elsewhere. Thus at the station of Mahableshwur, which is 4500 feet above the sea, the daily mean average of ozone is 7 of the scale. At Belgaum, in the southern Mahratta country, and at Poonah and Sattara in the Dekkan, at heights from 1500 to 2000 feet above the sea-level, the average is from 4·3 to 5·5, while in the northern division (the mean distance from the sea of the three stations which it includes being 194 miles) the average falls slightly below 2·0 of the scale.

During the prevalence of the S.W. winds and the rainfall of the monsoon season, while the great equatorial current is sweeping up from the ocean to the south, high averages are obtained, varying from 3·5 to 5·3 as a mean for all stations; but during the prevalence of the north-easterly or polar current, from November to March inclusive, the average monthly mean falls to 2·6 or 2·9.

The influence of these winds on the presence of atmospheric ozone is shown in the Table, where the returns of four consecutive years are grouped.

Table giving the Mean Monthly Quantities of Atmospheric Ozone deduced from registration of four years at the several Stations.

Months.	1863–64.	1864–65.	1865–66.	1866–67.	Means.	Winds.
August	3·6	4·4	4·2	5·9	4·5	S.W. & W.
September	3·4	2·9	3·2	4·8	3·6	S.W. & W.
October	4·0	3·1	2·4	3·9	3·3	W. & variable.
November	3·0	3·6	2·4	2·2	2·9	N. & Easterly.
December	3·5	2·8	2·6	2·2	2·8	N. & Easterly.
January	3·2	2·6	2·8	2·3	2·7	N. & Easterly.
February	3·2	3·1	2·5	2·2	2·7	N. & Easterly.
March	2·9	2·3	2·4	2·9	2·6	N. & Easterly.
April	3·7	3·0	2·3	3·4	3·1	W. & variable.
May	4·0	3·2	3·9	4·3	3·8	W. & S.W.
June	5·0	3·6	6·1	5·5	5·0	S.W.
July	5·4	4·6	6·0	5·3	5·3	S.W.

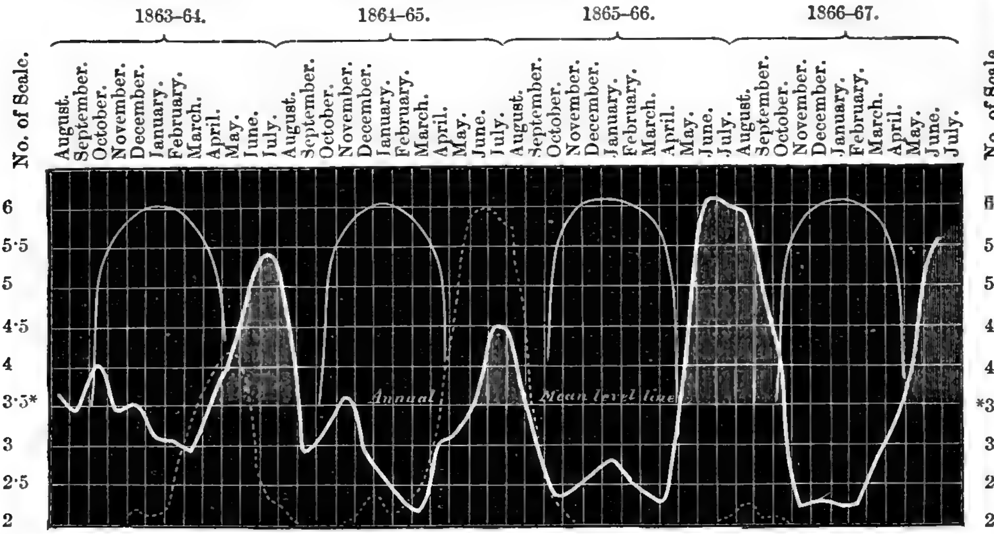
The mean average for each month of the year, obtained from the results of all stations, is here shown in separate columns for each year, and the mean for each month deduced in the last column. The prevailing winds for every month are also given. The Table, therefore, contains the broad results of the four years of registrations.

The occurrence of occasional storms of thunder and rain during the dry weather of the cold and hot seasons is always marked by a sudden and decided increase in the amount of ozone, appreciable by the resulting coloration of the test-paper, and the dust-storms; and other remarkable indications of electrical disturbance, which so frequently occur in the Dekkan and in Scinde, have a like, though less marked effect.

A diagram was shown giving the curves of average monthly mean quantities of atmospheric ozone for four years, an attempt being made to exhibit at a glance the chief results obtained by the registration of these years, and the causes which chiefly influence the depression of the ozone-line below its normal position.

The chief causes which influence the depression of the *ozone-curve* appear to be, the dryness of the atmosphere, the occurrence of the land wind or N.E. or polar cur-

Diagram illustrating the curves of average monthly mean quantities of Atmospheric Ozone, and of the comparative prevalence of Epidemic Cholera during four years' registration in the Bombay Presidency.



* Thick line. Ozone-curve showing monthly variations of ozone.
Dotted line. Curve showing relative prevalence of epidemic cholera.
Thin line. Showing prevalence of north-easterly winds.

rent, and the prevalence of epidemic cholera, or of that *materies morbi* in the air which brings about the epidemic condition.

The returns for the years 1863 and 1864 give many illustrations of the coincidence of low ozone readings, *i. e.* readings below the average of the particular months or relatively lower than those of the preceding weeks, and the occurrence of epidemic cholera; several instances of this were given in detail.

Although in many of them the presence of the epidemic was marked by an almost total absence of ozone, as indicated by the test-paper, in the majority of cases it was a *relative* deficiency that was most apparent, a decrease of ozone numbers below the level of the normal quantities of those particular periods.

The depression of the *ozone-curves* during these two years of epidemic cholera, as compared with the curve of the following years, is more decidedly marked if we consider it in reference to the *mean-level line* afforded by the results of the four years' registration.

In the year 1864 the numbers of stations in which this condition was present, from the month of February to the month of July inclusive, were consecutively 1, 3, 4, 6, 3, 2, thus amounting in the month of May to 6 out of the fifteen stations; while in the following year the numbers rose to nine-tenths, in the month of June, of the whole number of stations under review.

The cone formed by the ozone-curve of this year was thus seen to be proportionately small, extending only through part of June, July, and August in breadth, and to the level of 4·6 in height; while that of the following year, in which there was little or no epidemic cholera prevalent, extends from May to October in breadth and to 6·2 in height.

On the Amount of Soluble and Insoluble Phosphates in Wheat-Seed. *By* Professor F. Crace-Calvert, *F.R.S.*

The author said that the result of various experiments he had made was that 100 parts of cotton-fibre yield, when repeatedly washed with water, a quantity of acid phosphate of magnesia. Both husks and seeds also yield certain proportions, and these results show that the phosphates exist in much larger quantity in the seed than in the other parts of the pod. Experiments upon wheat-flour of various kinds show that whilst the flour contains only a trace of phosphates, especially soluble ones, the bran contains a large quantity. These facts tend to prove that the phosphates and the mineral matters contained in wheat are not combined with the organic matter, but are in a free condition. Other investigations go to prove that although habit and pride have gradually led us to prefer white bread to brown, yet this is an error when we consider the nutritious properties of wheat, especially as food for children, phosphates being essential for the formation of bone and blood.

On some Reactions of Chloro-Sulphuric Acid. By J. Dewar *and* G. Cranston.

Notes on Structural Change in Block Tin. By D. Fritsche.

On the Electro-deposition of Iron. By* H. M. Jacobi, *Member of the Imperial Academy of Sciences, St. Petersburg.*

The fact that it is possible to deposit iron by means of electricity has long been known, but the process has hitherto been beset with many difficulties. The author has, however, completed a long series of experiments with M. E. Klein of St. Petersburg, the result of which proves that iron may be very readily deposited from a solution of a double salt, the protosulphate of iron, combined with sulphate of magnesia, offering great facility for the deposition of iron. The solution should be as neutral as possible, and the strength of the current so adjusted that very little hydrogen is developed.

Nature of the Iron.—Electro-deposited iron is hard, almost sufficiently so to scratch glass, and it is somewhat brittle, but by annealing (particularly in hydrogen) it becomes malleable, soft, and silver-white.

It shares with palladium the power of occluding hydrogen. By heating the deposited iron *in vacuo* seventeen to twenty times its volume of hydrogen gas was extracted.

The specific weight is 7·675; after annealing it increases and becomes 7·811, equal to that of the best forged iron.

Sur le Spectre de la vapeur d'eau. Par M. Dr. Janssen.

Mes études sur le spectre de la vapeur d'eau ont été continuées.

Pour identifier les raies de la vapeur d'eau dans le spectre solaire, j'ai fait passer un faisceau de lumière solaire dans le tube de 37 mètres qui contenait la vapeur, et à côté du tube, un second faisceau. Ces deux faisceaux étaient reçus dans un même spectroscope et leurs spectres étaient superposés. Toutes les raies du spectre dues à la vapeur d'eau étant beaucoup plus foncées dans le spectre correspondant à la lumière qui avait traversé le tube, on pouvait obtenir facilement la distinction.

Les raies du spectre solaire dues à la vapeur d'eau sont extrêmement nombreuses. De D à A †, leur nombre est décuple des raies solaires proprement dites.

Dans la partie de la chaleur obscure, l'absorption de la vapeur d'eau est très-énergique aussi, ce qui confirme les résultats obtenus d'une autre manière par M. Tyndall.

Il en est de même pour la partie violette et ultra-violette du spectre. A Simla, dans les Himalayas, j'étais à 7000 pieds environ d'altitude, et pendant les mois de Décembre et de Janvier, j'avais une sécheresse extrême de l'atmosphère; or, j'ai pu constater dans ces conditions, que le spectre ultra-violet, photographié par M. Mascast, était directement visible (avec un spectroscope à vision directe du modèle de ceux que j'ai proposés en 1862 ‡, et que M. Hoffmann a exécutés le premier).

* The paper was illustrated with beautiful specimens of the electro-iron.

† Dans son beau Mémoire sur le Spectre du Soleil M. Ångström dit que j'attribue à la vapeur d'eau la raie A. Ceci est inexact; voir Compte Rendus de l'Académie des Sciences de Paris, 27 Août 1866, p. 411, et 29 Octobre, p. 728.

‡ Comptes Rendus de l'Académie des Sciences de Paris, 6 Octobre 1862, p. 976.

Ceci montre combien une atmosphère est transparente pour la lumière ultra-violette, et explique comment les phénomènes photographiques sont si influencés par la présence de la vapeur d'eau dans l'atmosphère. On soit, par exemple, que dans l'après-midi, la puissance photogénique diminue rapidement. Ceci s'explique d'après les observations ci-dessus, en remarquant que l'eau dissoute dans notre atmosphère augmente à mesure que le soleil s'élève sur l'horizon. En général, abstraction faite des modifications apportées par les vents, la quantité de vapeur doit être la plus grande vers 2 et 3 heures de l'après-midi, et alors le soleil baisse rapidement; les deux causes concourent donc pour amener une diminution très-prompte du pouvoir photogénique de la lumière solaire. Le matin, avant que la chaleur solaire ait eu le temps de vaporiser toute l'eau répandue à la surface de la terre, la puissance photographique doit être la plus grande, et c'est en effet ce que l'expérience confirme.

Si l'atmosphère sèche est transparente, d'après ces observations, pour la lumière violette et ultra-violette, elle l'est également pour la chaleur obscure. Ainsi, à Simla, j'ai pu constater, par des expériences pyrhéliométriques, que le rayonnement calorifique du soleil augmente beaucoup avec la sécheresse de l'atmosphère, toutes choses égales d'ailleurs, sous le rapport de la pureté de l'air, de l'élévation de la station, etc.

J'ai pu constater aussi la puissance de la vapeur d'eau dans une classe d'étoiles qui sont en général les étoiles rouges, et dans lesquelles manquent souvent les raies de l'hydrogène.

J'espère avoir bientôt l'honneur d'envoyer à l'Association, des cartes du spectre de la vapeur d'eau pour les régions obscure, lumineuse et ultra-violette.

Note sur une nouvelle Méthode pour la recherche de la Soude et des composés du Sodium par l'Analyse Spectrale. Par M. Dr. Janssen.

On sait que la recherche de la soude présente, en analyse spectrale, des difficultés très-grandes qui tiennent à ce que la raie du sodium se retrouve dans presque toutes les flammes, en raison de la présence presque constante du sel marin dans l'atmosphère.

Or, on peut lever facilement cette difficulté en employant, au lieu d'une flamme très-chaude et fort peu éclairante comme celle de Bunsen, une flamme très lumineuse comme celle d'un bec de gaz ordinaire dans la partie la plus brillante.

En effet, tandis qu'on aperçoit presque toujours la raie du sodium dans la partie bleue et transparente de la flamme d'un bec de gaz, on ne l'aperçoit plus dans la partie la plus lumineuse à cause de l'abondance des rayons qui avoisinent la raie du sodium dans cette région.

Voici donc la manière d'opérer.

On dirigera le spectroscope sur la partie brillante de la flamme de manière à obtenir un spectre brillant et continu dans lequel la raie du sodium n'apparaisse pas sensiblement. On prendra un fil de platine qui aura été préalablement porté au rouge dans une flamme pendant quelques minutes, pour le débarrasser de toute poussière salée, et avec ce fil on portera une goutte de la solution à essayer, dans la flamme du spectroscope. En cet instant, si la liqueur contient un composé du sodium réductible par la flamme, la raie D apparaître immédiatement.

On peut rendre aussi peu apparente qu'on voudra la raie du sodium en employant les parties les plus brillantes des flammes, ou même en plaçant outre le spectroscope et la flamme d'essai, une ou deux flammes auxiliaires qui rendront la raie D encore moins perceptible. Dans ce dernier cas, il faudrait employer du sel en assez grande quantité dans la flamme d'essai pour voir apparaître la raie D dans le spectroscope. Si au contraire, la liqueur ou le corps à essayer contient fort peu du composé sodé, on pourra employer une partie plus transparente de la flamme. Dans tous les cas, il sera prudent de faire des expériences comparatives avec les fils de platine et de l'eau distillée pour s'assurer que les raies qui apparaissent sont bien dues à la substance qu'on analyse.

Je continue ce sujet, et j'espère arriver à une analyse *quantitative* des substances à analyser.

On a Method of determining with accuracy the Ratio of the Rotating Power of Cane-sugar and Inverted Sugar. By the Rev. Professor Jellett, *M.A.*†

On the Action of Hydrochloric Acid on Morphia Codeia. By Dr. A. Matthiessen, *F.R.S., F.C.S., and* C. R. Wright.

Are Flint Instruments of the first Stone Age found in the Drift? By W. D. Mitchell.

On the Economic Distillation of Gas from Cannel-Coal. By Dr. Stevenson Macadam, *F.R.S.E., F.C.S.*

The experimental observations which form the basis of the present communication were undertaken for the purpose of determining the quantity and quality of gas obtained from certain mixtures of cannel-coals as contrasted with the gas distilled from the coals taken separately. The coals selected for examination by destructive distillation were sixteen in number, and they comprehended examples of the larger coal-fields in Scotland. The experiments were conducted in a small gas-work attached to the laboratory of the author, and connected with fully equipped photometric apparatus. The quantity of coal experimented upon at a time was six pounds, and the volume of gas yielded therefrom amounted to about thirty cubic feet. Every possible care was taken to keep the retorts at a uniform temperature during the course of the trials, and the testing of the same coal on several occasions showed that such was practically done.

The coals employed in the experiments, and the quantity and quality of gas obtained therefrom, may be observed from the following Table:—

Yield and Quality of Gas from Cannel-Coals taken separately.

No.	Name of coal.	Gas, per ton of coal in cubic feet.	Illuminating-power of the gas (5 cubic feet per hour) in candles.	Cost, 10,500 cub. ft. of gas of 30-candle power. s. d.
*1.	Bredisholm or Provanhall	9,434	26·81	12 5½
2.	Shields	10,703	21·22	13 10½
3.	Bank, main seam	11,524	19·82	18 7½
*4.	Clewch	11,452	29·39	14 11¾
5.	Wilsontown	10,666	25·31	18 11½
*6.	Muirkirk	10,552	37·16	16 10½
7.	Rigside	11,490	32·31	20 4½
*8.	Climpy	10,928	38·68	18 7½
*9.	Bank, 5 ft. seam	9,768	27·07	16 1
*10.	Pollok	11,525	30·26	14 0
11.	Huntershill	10,030	22·66	12 5¾
12.	S. Boig or Lower Lanemark	9,881	24·39	17 7¾
13.	Upper Lanemark	10,479	24·56	16 6¼
14.	Raploch	10,966	17·05	16 10
*15.	Haywood	11,153	30·97	15 6
*16.	Kinneil	11,789	30·60	17 0¼

Considering the original cost of the coals, the eight samples marked with an

† *Vide* p. 23.

asterisk were selected as most econom cal, and the basis was laid down that the coals, or mixtures of coals, should yield 10,500 cubic feet of gas of 30-candle power. Calculations were made so as to observe what coals or mixtures of such ought to yield the requisite quantity and quality of gas, and the coals were used in the definite proportions calculated to yield the best results. The second series of trials proved that the illuminating-power of the gas obtained from the mixtures of coals as determined by experiment was always in excess of that arrived at by calculation from the quality of the gas yielded by the individual coals taken separately, as may be observed from the following Table:—

Gas from Cannel-Coals taken separately and mixed.

No.	Name of coal.	Quantity and quality of gas from one ton of					
		coals taken separately.		mixed coals. Calculated.		mixed coals. Experiment.	
		Cub. ft.	Candles.	Cub. ft.	Candles.	Cub. ft.	Candles.
1.	Pollok (1st trial)	11,525	30·26				
1.	Pollok (2nd trial)	11,013	31·52				
2.	1 Bank, 5-ft. seam	9,768	27·07	10,806	30·09	10,714	32·27
	3 Haywood	11,153	30·97				
3.	1 Provanhall	9,434	26·81	10,479	31·22	10,677	32·96
	1 Clewch	11,452	29·39				
	1 Muirkirk	10,552	37·16				
4.	1 Provanhall	9,434	26·81	10,722	30·73	10,938	32·86
	2 Clewch	11,452	29·39				
	1 Muirkirk	10,552	37·16				
5.	2 Provanhall	9,434	26·81	10,618	30·94	10,603	33·32
	3 Clewch.	11,452	29·39				
	2 Muirkirk	10,552	37·16				
6.	1 Climpy	10,928	38·68	10,540	30·30	10,565	32·91
	2 Provanhall	9,434	26·81				
	2 Clewch	11,452	29·39				
7.	4 Haywood	11,153	30·97	10,809	30·24	10,640	32·19
	1 Provanhall	9,434	26·81				
8.	1 Kinneil	11,789	30·60	10,882	29·97	11,125	31·38
	2 Haywood	11,153	30·97				
	1 Provanhall	9,434	26·81				
9.	1 Kinneil	11,789	30·60	11,011	30·03	10,752	32·48
	2 Haywood	11,153	30·97				
	1 Provanhall	9,434	26·81				
	1 Pollok	11,525	30·26				
10.	2 Provanhall	9,434	26·81	10,553	31·43	10·864	33·96
	2 Haywood	11,153	30·97				
	1 Clewch	11,452	29·39				
	2 Muirkirk	10,552	37·16				

These results will probably be best contrasted by throwing the quantity and quality of the gas into lbs. of sperm, and the following Table gives the results of the illuminating-power of the coals and mixtures as determined by calculation from the yield of the individual coals taken separately, and the respective proportions obtained by the distillation of the coal previously mixed, the value in each case being given in lbs. of sperm.

Illuminating-power of Gas from Coals in lbs. of Sperm.

No.	Name of coals.	Illuminating power of the gas from one ton of coal in lbs. of sperm. Calculated from separate results.	Calculated from mixed results.	Difference in favour of results from the mixed coals.	Percentage of increase in illuminating-power.
		A.	B.		A and B.
1.	Pollok	1195·70	1190·16		
2.	1 Bank, 5-ft. seam; 3 Haywood	1114·81	1185·39	70·58	6·33
3.	1 Provanhall; 1 Clewch; 1 Muirkirk	1121·67	1206·56	84·89	7·57
4.	1 Provanhall; 2 Clewch; 1 Muirkirk	1129·67	1232·45	102·78	9·09
5.	2 Provanhall; 3 Clewch; 2 Muirkirk	1126·36	1211·29	84·93	7·54
6.	1 Climpy; 2 Provanhall; 2 Clewch	1094·95	1192·09	97·14	8·87
7.	4 Haywood; 1 Provanhall	1120·68	1174·29	53·61	4·78
8.	1 Kinneil; 2 Haywood; 1 Provanhall	1118·17	1116·92	78·75	7·04
9.	1 Kinneil; 2 Haywood; 1 Provanhall; 1 Pollok	1133·76	1197·34	63·58	5·68
10.	2 Provanhall; 2 Haywood; 1 Clewch; 2 Muirkirk	1137·03	1264·94	127·91	11·25

Average percentage of increase in illuminating-power 7·57, or $\frac{1}{13}$ of whole light.

The increase in illuminating-power is undoubtedly due to the presence of a larger proportion of the heavy hydrocarbons, as the condensation by bromine rose in each trial on an average of one per cent. of increase. The larger proportion of the heavy hydrocarbons may probably arise from several causes:—

(1) The intermixture of the lighter gases of the inferior coals with the heavier gases of the better coals, thus tending to save the heavy hydrocarbons from being decarbonized or reduced by the heat of the retort.

(2) The mixture of the lighter gases with the heavier gases and vapours, tending to keep the latter from separating in the condensers, purifiers, and gasholder; and

(3) Probably also the reaction of the gaseous bodies upon each other during the moment of their liberation from the coals by destructive distillation, and when the gases are in the condition known as that of the nascent state, and when, as is well known, chemical reaction is most energetic.

In England so much attention is paid to coke that necessarily the quality of the resultant fuel obtained from the mixtures of coals must be considered. In all the experimental trials referred to in this paper the mixed coke was at least of fair quality. The general results of the inquiry therefore is, that, given a certain quantity of coals of different gas-producing powers, it is more economical to mix these coals, and thereafter heat the mixture in the same retorts, than to distil each coal separately in different retorts, and thereafter mingle the gases in the ordinary way.

On the Oxidation of Phosphorus, and the Quantity of Phosphoric Acid excreted by the Kidneys in Connexion with Atmospheric Conditions.* By THOMAS MOFFAT, *M.D., F.R.A.S., F.G.S.*

On the Phosphorescence of the Sea and Ozone.
By T. MOFFAT, *M.D., F.R.A.S., F.G.S.*

The results given in this paper are deduced from observations taken between the lat. 58° and 79° N., and long. 6° E. and 67° W.

It would appear that the phosphorescence of the sea takes place under the conditions of the south or equatorial current of the atmosphere, and that there is a connexion between periods of phosphorescence and ozone periods.

On Aceto-sulphuric Acid. By A. OPPENHEIM, *Ph.D.*

The subject of this note forms part of researches on the action of sulphuric acid on organic chlorides with which the author has been occupied for some time. The monochlorinated hydrocarbons generally exchange their chlorine for HSO_4. When they are non-saturated, then either a second molecule of H_2SO_4 is added to the compound so formed, as is the case with $C_3\,H_5\,Cl$, monochlorinated propylene, which forms $C_3\,H_6\,(HSO_4)_2$, decomposed by water into acetone and sulphuric acid, or one molecule of sulphuric acid is added to the non-saturated chloride without any separation of hydrochloric acid, as is the case with chloride of allyle. The latter is thus transformed into $C_3\,H_6\,Cl\,HSO_4$, which with water yields monochlorhydrine of propylic glycol.

Hydrocarbons with more than one atom of chlorine are generally decomposed entirely, and carbonized by the action of sulphuric acid. The chlorobenzole, $C_6\,H_5\,CH\,Cl_2$, however, is entirely and easily transformed into $C_6\,H_5\,CH\,(HSO_4)_2$, which with water yield the theoretical quantity of oil of bitter almonds. Most oxygenated chlorides are very easily attacked by sulphuric acid. They either combine directly, as does epichlorhydrine, or they yield hydrochloric acid, as is the case with the chlorhydrine of glycol, $C_2\,H_4\,Cl\,OH$, which thus forms the acid $C_2\,H_4OH\,SO_4$, formerly obtained in a different way by Dr. Maxwell Simpson. The chlorides of acid radicals, such as chloride of acetyle or of benzoyl, give very energetic reactions as sulphuric acid, streams of hydrochloric acid being evolved as soon as the two substances are brought into contact. It appears probable at first sight that the results of this reaction are the two anhydrides of the acetic and the sulphuric acids, according to the equation

$$2\,C_2\,H_3\,OCl + H_2\,SO_4 = \left.\begin{matrix} C_2\,H_3O \\ C_2\,H_3O \end{matrix}\right\}\,O + SO_3 + 2\,HCl.$$

Such is, however, not the case; one molecule of each substance entering into the reaction thus,

$$C_2\,H_3\,OCl + H_2\,SO_4 = HCl + C_2\,H_3\,O\,SO_4H.$$

The resulting substance is half anhydride, half acid. The aceto-sulphuric acid or acid anhydride is decomposed at about 180°C., and cannot therefore be distilled. Water decomposes it into the two acids.

In following out these researches, the author intends to study the action of sulphuric acid on other oxygenated and nitrogenized chlorides.

On Bromo-iodide of Mercury. By A. OPPENHEIM, *Ph.D.*

Iodide of allyle and bichloride of mercury, when mixed in alcoholic or ethereal solutions, form at once a red precipitate of iodide of mercury, while the iodide of allyle is transformed into the chloride. When bibromide of mercury is substituted for the bichloride the reaction is somewhat changed. No iodide of mercury is then precipitated, but in course of time yellow crystals separate out, which are particularly fine, when acetone is taken for dissolving the two substances brought into

* Published in the 'Chemical News,' Oct. 1, 1869.

contact with each other. Most other organic iodides may be substituted for the allylic iodide, those of amyle or ethyle for instance. The reaction is, however, slower in these cases, and sometimes requires an elevation of temperature. The crystals mentioned contain no organic substance; they are freely soluble in ether, and show exactly the composition of one atom of bromine and one atom of iodide for one atom of mercury. They form rhombic prisms exactly isomorphous with the yellow unstable modification of biniodide of mercury. Dr. Grothe found the angle of $p : p = 114° 25'$, while for the yellow iodide Mitscherlich determined $p : p = 114°$, the corresponding angle in the bibromide being $= 111° 26'$. The angular differences of the three isomorphous compounds do not therefore correspond exactly with their chemical differences.

It is quite evident that this iodo-bromide is not an isomorphous mixture, but a chemical individual, although the author has not been able as yet to give the most decisive proof of it by taking the vapour-density of the compound, its boiling-point being considerably higher than that of mercury; this being also the case with the biiodide and bibromide of mercury. The bromo-iodide is, however, a very stable compound. It may be sublimed without breaking up into the bromide and iodide; and what appears decisive, its melting-point lies just in the middle between the fusing-points of the bromide and of the iodide, viz. at 229°C.

The fusing-point of $Hg\,Br_2$ is situated between 222° and 223°C., and that of $Hg\,I_2$ at 238°. The latter compound is transformed into its yellow modification between 148° and 154°, the bromo-iodide shows no such changes. Lastly, it should be remarked that when the quantity of bibromide of mercury acted upon by the organic iodide is insufficient to produce the reaction described,

$$C_3\,H_5\,I + Hg\,Br_2 = C_3\,H_5\,Br + Hg\,I\,Br,$$

then crystals of red iodide of mercury are formed at the same time, but never any intermediate bromo-iodides, save the one described. Its existence may therefore be fairly taken as an additional proof for the atomic weight of mercury, such as it is now generally accepted.

The author has been particularly careful to ascertain the complete absence of bromine in the crystals of iodide of mercury formed along with it, because they show a peculiarity not hitherto observed. The red crystals, although belonging to the tetragonal system, show the phenomenon of double refraction, but this evidently only in consequence of a certain pressure they were subjected to in the mother-liquor from which they crystallized. The reaction described is by no means the only one which engenders the bromo-iodide of mercury. When corresponding quantities of $Hg\,Br_2$ and $Hg\,I_2$ are dissolved in acetone, the same compound will crystallize out; as also when iodine is added to an acetonic solution of the bibromide.

On the Solubility of Lead and Copper in pure and impure Water.
By Dr. T. L. Phipson, *F.C.S. &c.*

In this paper the author compares the action of certain natural waters upon various metals. The waters were—Surrey spring water, yielding 17 to 24 grains of solid matter per gallon; spring water from Crawford, yielding only $10\frac{1}{2}$ grains per gallon; pure distilled water, and Thames water as supplied to the inhabitants of Putney, yielding 40 to 49 grains per gallon. The metals were submitted to prolonged friction, and to contact of air whilst these waters acted upon them. They were iron, lead, union metal, copper, tin, and zinc, of various qualities, both pure and commercial varieties. The most important conclusion arrived at in these experiments was, that in the above conditions all these different waters attacked and dissolved lead, union metal (an alloy of lead, antimony, and tin), copper, and perhaps zinc. The method of experiment consisted in placing some 5 to 10 grammes of the metal, cut into small pieces, into a pint stoppered bottle, three-fourths full of the water to be tested. The whole was submitted to violent shaking for about 36 hours; the liquid was then filtered through the finest Swedish filtering paper, and received in a white porcelain capsule 6 inches wide. A drop of sulphide of ammonium added to the filtrate showed that metal had been dissolved by immediately giving a brown tinge to the whole liquid. The experiment was slightly altered for zinc. Iron was rapidly oxidized in these experiments, but none dissolved in the water. Thames water containing a certain amount of sulphates and carbonates dissolved lead and union metal almost as well as pure distilled water did.

On some new substances extracted from the Walnut. *By* Dr. T. L. Phipson, *F.C.S. &c.*

When the episperm of the walnut is digested for several hours in alcohol a yellowish liquid is obtained, from which a new species of tannin, *nucitannic acid*, or *nucitannin* can be procured. This is the principle to which the thin walnut skin chiefly owes its disagreeable bitter taste. When it is boiled for eight or nine hours with dilute hydrochloric acid, it yields, among other substances, *glucose* and another acid, *rothic acid*, the composition and properties of which the author has determined. Considerable quantities of ellagic acid and gallic acid are obtained at the same time.

Rothic acid is easily separated from these by a weak solution of ammonia, which dissolves the new product, forming a purple red solution from which hydrochloric acid precipitates the rothic acid. A second treatment yields it quite pure.

Rothic acid is insoluble, or nearly so, in cold water, but dissolves somewhat in hot water; it is readily soluble in alcohol; it forms a reddish-brown amorphous substance, combining with ammonia, in which it is soluble, and with other alkalies, but forming insoluble salts with lead, lime, and silver. Dried at 118° C. its composition was found to agree with the formula $C^{28} H^{12} O^{14}$.

The lead-salt leaves metallic lead when calcined; its composition was found to be $C^{28} H^{16} O^{12} 2PbO$; it is insoluble in cold acetic acid. The lime-salt contains only 1 equivalent of base, $C^{28} H^{14} O^{12} CaO$. The rothates of soda, potash, and ammonia are soluble. The salt of silver is a fawn-coloured precipitate, becoming darker on drying, but is not reduced, and does not appear to be very sensitive to the action of light. Rothic acid belongs to a somewhat numerous group of substances, and is evidently related to gallic acid, ellagic acid, and rufigallic acid:—

$C^{28} H^{14} O^{12}$=1 equiv. of Rothic acid.
$C^{28} H^{12} O^{20}$=2 equivs. of Gallic acid.
$C^{28} H^{6} O^{16}$=1 equiv. of Ellagic acid.
$C^{28} H^{8} O^{16}$=2 equivs. of Rufigallic acid.

The last of these is similar in many respects to rothic acid, but differs in its colour and that of its solutions, as well as by its composition.

Nucitannin, from which rothic acid is derived, has not yet been submitted to analysis.

On a Specimen of Obsidian from Java. *By* William Chandler Roberts, *F.C.S., F.G.S.*

This paper, which was illustrated by numerous drawings and microscopical specimens, was intended to demonstrate the extreme importance of microscopical examination of rocks and minerals.

The specimen of obsidian was from Java, but the exact locality is unknown.

Examination with a 1-inch objective revealed the presence of three distinct minerals. These were diopside, orthoclase, and magnetic iron. Each of these was beautifully crystallized. The optical properties of the orthoclase crystals were minutely given, but without drawings it is impossible to describe them here.

The obsidian contained fluid-cavities, but unlike many specimens of obsidian from other localities, it was free from occluded gas.

On the Measurement of Gases as a branch of Volumetric Analysis. *By* W. J. Russell, *Ph.D., F.C.S.*

The object of the paper was to show that many quantitative determinations could be made with great ease and accuracy by measuring the volume of gas evolved in certain reactions. A specimen of calc-spar gave a volume of carbonic acid, in five experiments, which varied from 43·89 to 43·97, the calculated amount being 44·00 per cent. Pure carbonate of soda gave 41·52, 41·50, and 41·48 per cent. CO_2. The calculated amount is 41·51 per cent.

Peroxides are estimated by heating with sodic oxalate and hydric sulphate. A specimen of manganese gave—

1st experiment, 58·16 per cent. MnO_2.
2nd experiment, 58·10 per cent. MnO_2.

It was further shown that potassic permanganate and potassic bichromate could be easily and accurately analyzed by this process.

By dissolving certain metals in dilute acid and measuring the volume of hydrogen evolved, the purity of the metal could be easily tested. It was shown that different specimens of zinc gave an amount of hydrogen which varied considerably. A specimen of pure iron prepared by Dr. Matthiessen gave, in the first experiment, a volume of hydrogen corresponding to 100 per cent. iron, and in the second experiment to 99·93 per cent. iron.

Other experiments with steel wire and cast iron were also given. A specimen of magnesium gave an amount of hydrogen corresponding to 99·18 per cent. of metal. The atomic weights of nickel and cobalt it was stated had been determined by this process.

On Jargonia.* *By* H. C. Sorby, *F.R.S.*

I herewith send for exhibition at the Chemical Section what I believe to be nearly pure zirconia and jargonia, prepared by a modified combination of the methods described by Mr. David Forbes and myself. You will notice at once that the zirconia is perfectly white, whereas the jargonia is of a clear straw-colour. This exactly corresponds with the difference between the opaque borax blowpipe beads heated to redness, as described in my paper in the 'Proceedings of the Royal Society,' and I am strongly inclined to believe that it is a characteristic peculiarity. At first I thought it might be due to the presence of a small quantity of iron, since zirconia containing a little of this peroxide is of a similar yellow colour. When, however, that is digested in sulphide of ammonium it quickly turns to a deep green colour, whereas this yellow jargonia does not turn at all green. Subsequent experiments may show that the colour is due to some other substance; but, taking all the facts now known into consideration, it seems extremely probable that, after ignition, jargonia is of a clear straw-colour, paler than that of tungstic acid, but deeper than that of ceroso-ceric oxide.

On raising a Temperature higher than 212° *F. in certain Solutions by Steam of* 212° *F.* *By* Peter Spence.

Some twelve to fifteen years ago the author had occasion to require large masses of liquor to be raised to a temperature of 228° Fahr. (108°·8 C.), for the purpose of extracting, by means of long-continued digestion at that temperature, alumina in the form of sulphate of alumina from minerals containing that earth. As time was an element of importance in his calculations, the author's aim was to heat the liquors as rapidly as possible, but lead vessels only could be used with the acid liquors, and as it was requisite to have an iron outside vessel next the fire, the heating was a tedious operation. To overcome this loss of time, the author fitted up a digesting vessel so as to raise the heat rapidly to 212° F. (100° C.), by injecting steam from a steam-boiler into the mass of liquor; and as soon as he had obtained that temperature he stopped off the steam and allowed the external fire to operate alone, so as to raise the additional 16° F. (8°·8 C.) required, and to maintain the temperature at 228° F. (108°·8 C.), his impression being that above 212° F. (100° C.) the steam, if kept on, would act as a cooling agent and prevent the temperature rising. The combined operation was perfectly successful and went on for some time, acting, as the author supposed, in accordance with his preconceived theory; but some circumstances led him subsequently to doubt whether it was so. He found that if

* Extract from a letter to Mr. Crookes.

inadvertently both steam and fire were left acting after the higher temperature was obtained, the temperature continued notwithstanding. Again, when the fire was in a condition, through neglect, in which it was obviously of no use, the author was still astonished to find that, as the apparent result of the steam alone, the temperature was at a satisfactory point. This last observation led the author to test the matter in the laboratory in the following manner. Being convinced that the high boiling-point of his liquors had something to do with the phenomenon, he selected a solution of a salt (nitrate of soda) having a high boiling-point, about 250° F. (121°·1 C.). The nitrate of soda was placed in a vessel surrounded by a jacket, steam was let into the intervening space until a temperature of nearly 212° F. (100° C.) was obtained; the steam was then shut off and an open pipe immersed in the solution. Steam from the same source was thrown directly into the liquor; in a few seconds the thermometer slowly but steadily moved, and minute after minute progressed until it touched 250° F. (121°·1 C.). This thoroughly explained the results obtained in the digesting vessel, and became to the author of immense practical value. He discarded the use of fire applied to his vessels, which had not only been tedious and troublesome in operation, but involved a loss of many hundreds of pounds per annum in destruction of apparatus, and used only steam as a vehicle of heat. As a corroboration of the theory which seems to explain the apparent paradox, the author finds that the temperatures of his solutions are in the exact ratios of their specific gravities, and have no connexion with the temperature of the steam, which never exceeds 212° F. (100° C.): the greater the specific gravity of an acid solution the higher the boiling-point, and therefore, whatever the boiling-point of the solution in water of any salt, to that point, or nearly, will steam of 212° F. (100° C.) raise it.

A Chemical Method of treating the Excreta of Towns. *By* Edw. C. C. Stanford, *F.C.S.*

In this paper the author advances arguments to show that the present water-closet system cannot be a permanent one, and submits a rational method by which, using charcoal instead of earth, the dry system can be universally employed in cities. The specified objections to the use of water are:—

1. The enormous cost of the works required in proportion to the small amount of noxious material to be removed.

2. The large annual outlay required to keep the closets in order, and their unfitness for the dwellings of the poor.

3. The immense quantity of water required (365 times the weight of the excreta) where, as in many towns, there is much difficulty in obtaining it.

4. It results in a subterranean flood of filthy water, which must flow somewhere, and wherever it flows it pollutes the region, thus disseminating and distributing the evil.

5. The material removed has its value of 30*s.* per ton reduced by dilution to 1*d.* per ton, which it is impossible by any known chemical method to extract with profit.

6. The sewers generate an abundance of noxious gases, which diffuse malaria into our streets and dwellings.

Instances are given of large outbreaks of gastric and other fevers entirely traceable to this source; and authorities are quoted to show the extreme danger of these poisonous emanations. Dr. Fergus, of Glasgow, first pointed out a fruitful cause of escape of these gases into dwelling-houses. He frequently noticed a peculiarly offensive sickly odour in attending patients suffering from gastric fever, and in all cases traced it to the lead siphon and soil-pipes of the water-closet. On examination, these were always found to be perforated with small holes, through which the gases freely escaped into the house. In some cases the whole interior of the pipe is eaten away, and lined with a light-brown powder, the nature of which was investigated by the author of this paper. From the several analyses given, it contains 86 to 92 per cent. carbonate of lead and 2 to 3 per cent. carbonate of lime. The carbonic acid, aided by the other gases of decomposition, act on the lead, producing carbonate of lead under similar conditions which obtain in its manufacture on the large scale, the carbonate of lime being derived from the solid excreta. The evil exists in many houses where it is long unsuspected, and it shows that lead pipes are quite unsuitable for conveying house excreta.

Dry System.—None of these disadvantages can be urged against the dry closet, still less can any serious evil attend its use, for it meets every sanitary requirement. Its machinery is simple and effective, cheap in first cost and in use. It effects at once a great saving of water, and it enables us to secure the whole value of the excreta.

When dry earth is used, the only objections to its adoption in large cities are,—

1. The difficulty of obtaining the supply of dry earth, three and a half times the quantity of the excreta being required.

2. The cost of removal, involving the carriage of $3\frac{1}{2}$ times the weight of the excreta into the city, and $4\frac{1}{2}$ times its weight out.

Both these difficulties are at once removed by the use of charcoal, of which only one-fourth the quantity, as compared with earth, is required; and given a stock to commence with, by reburning the product the supply of charcoal is obtained from the excreta itself. It is not necessary to reburn it after each use; for dry closets it may be dried and used again five times before being reburned, and for urinals alone it may be used ten times. The reburning is conducted in apparatus which admits of collecting the ammonia, acetic acid, and tar, which distil over, in the usual condensers.

The whole of the ammonia is thus collected, whilst the phosphoric acid, potash, and mineral matters accumulate in the charcoal, together with the carbon, from the organic constituents of the excreta. The weight of the charcoal is increased to the extent of about 5 per cent. with each use; and if dried and re-used five times, about 25 per cent. with each reburning.

With this constant addition the charcoal does not require replacing with fresh material, the ultimate result being that the excreta are absorbed and deodorized by a charcoal derived from itself. Thus a city working this process would, in addition to securing the whole of the ammonia and other products of destructive distillation, become sellers of a charcoal second only in value to that from bones, the product in fact of disintegrated bone and muscle. A city of 500,000 inhabitants, for instance, would produce 19 tons a day, or 6935 tons a year—the total quantity of excreta to be removed being calculated at 385 tons a day, and its value at 29*s.* 6*d.* a ton = £568. The ultimate result being the same, any charcoal may be used at first, but that from seaweed is preferred as the best and the cheapest.

Attention is drawn to the fact that in such a population as that referred to the fat passed in the solid excreta would amount to 7 tons a day; and this would appear among the fatty oils of the tar, and form another of the products recovered.

Starting with seaweed charcoal, a lengthened series of experiments with urine were undertaken, the results of which were tabulated. The same charcoal was used 100 times, and reburnt 10 times, during which it had increased 183 per cent., and given off ammonia equal to 316 per cent. of sulphate. The tables show the increase of potash, phosphoric acid, &c. for each reburning, the phosphoric acid appearing as phosphate of lime. The charcoal, containing at first 20 per cent. carbonate of lime and 5 per cent. phosphate, gradually decreases the carbonate to 2 per cent., and increases the phosphate to 25 per cent., at which it remains stationary, forming a sugar-refiner's charcoal. The phosphate of lime thus gradually deposited is equal to soluble phosphate for manurial purposes, from its finely divided condition.

The results of a series of experiments with a dry closet were also tabulated. The quantity of charcoal used was only 48 oz., to which 18 oz. were added after, the total amount employed being 66 oz.; the amount at the end of the experiment was 123 oz., 57 oz. having been derived from the excreta; this small stock had served 181 uses, and absorbed 808 oz. of mixed excreta, having been dried and returned to the closet 17 times, and reburnt 10 times. The analyses show this to be a prolific source of ammonia, the average yield of sulphate being 7 per cent. of the wet excreta, and 31 per cent. of the dry. The yield of acetate of lime was 4 per cent., and of tar 9 per cent. of the dry excreta. A portion of the ammonia is combined with acetic acid. The chars become uniform at about 24 per cent. phosphate of lime, and 12 per cent. carbonate. This process, then, presents the following advantages:—

1. Total freedom from all odour, even in an invalid's bedroom.

2. Certain prevention of infectious diseases arising from sewer-leakage into wells, or sewer-gases into houses.

3. Enormous saving in water, and in cost of closets.

4. It confines the nuisance instead of distributing it. 1 cwt. of charcoal per month is sufficient for each closet when used by six persons daily, and the whole may be allowed to fall at once from the closet through a 12-inch pipe to a cesspit below the house, and emptied once a year. The quantity is not more than the house ashes.

5. By this process alone can the whole of the valuable material be recovered for the use of the land. Instead of forcing on the farmer a large quantity of sewage when he does not want it, it enables us to store up the manure in a convenient form until he requires it, and can pay its full value.

On a remarkable Structural Appearance in Phosphorus.* *By* CHARLES TOMLINSON, *F.R.S., F.C.S.*

On the Supposed Action of Light on Combustion. *By* CHARLES TOMLINSON, *F.R.S., F.C.S.*

There is a popular idea that "light puts out the fire," and accurate experiments on this point seem to be wanting; but it is difficult to get rid of disturbing causes, as every one engaged in photometrical observations is aware. In comparing candles of the same make, the light is affected both in quantity and economy by a number of small circumstances, such as the warmth of the room, the existence of slight currents of air, the extent to which the wick curls over when burning, and so on. In testing the quality of gas, the standard candle defined by Act of Parliament is a sperm candle of six to the pound burning at the rate of 120 grains per hour. From such a standard we get the terms "12-candle gas," "14-candle gas," &c. Mr. Sugg, in his 'Gas Manipulation,' has pointed out some of the difficulties in obtaining a uniform standard candle. The wick does not always contain the same number of strands; they are not all twisted to the same degree of hardness; the so-called sperm may vary in composition, one candle containing a little more wax than another, or variable quantities of stearine, or of paraffine; the candle may have been kept in store a long or a short time; the temperature of the store-room may have varied considerably, and the temperature of the room in which it was burnt may have been high or low. All these circumstances affect the rate of combustion and the illuminating-power of candles irrespective of the action of light, if such action really exist.

The author had a good opportunity of testing this action at the works of Price's Patent Candle Company at Battersea. Under the direction of Mr. Hatcher, the chemist of the Company, care is taken to ensure identity of composition and illuminating-power in candles of the same name. There has lately been an extensive series of experiments on the photometrical value of sperm candles, during which, at the request of the author, Mr. Hatcher noted the rate of combustion of such candles in a darkened room, and also in broad daylight and even in sunshine.

In the first observation, three hard and three soft candles were burned each for four hours in a dark closet. A similar set of candles taken from one and the same filling were burned during the same time in open daylight, partly in sunlight. The average consumption per hour of each candle was as follows:—

Sperm in the dark................	134 grains.
Sperm in light	141 "
No. 2 composites in the dark	133 "
Composites in the light............	140 "

The temperature in the light was 72°, and in the dark 71°. There was also in

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the light a much greater motion of the air than in the dark closet. Both these circumstances would operate in producing a larger consumption of candle.

In a second trial with No. 2 composites the results were—

In the dark............ 140 grains each candle.
In the light............ 134 " "

In a third, also with No. 2 composites, the results were—

In the dark.............. 131 grains.
In the light.............. 129 "

In these two trials the flames were protected as far as possible from currents of air, and in the third trial the temperature both in the light and in the dark was nearly equal.

The fourth trial was made on a bright sunshiny day with hard sperm candles, which are less affected by variations of temperature than the composites. The results were—

In the dark (temp. 81°)................ 544 grains,
or 136 grains per hour.
In the light (temp. 84°)................ 567 grains,
or 142 grains per hour nearly.

It is evident that in this case the increase of temperature caused by the bright sunshine led to an increased consumption of material.

It will be seen that in the first and fourth trials there is a greater consumption of material in the light than in the dark, and in the second and third trials the consumption is greater in the dark than in the light; but in any case the difference is so small, amounting only to from 2 to 7 grains per hour, that it may fairly be referred to accidental circumstances, such as differences in temperature, in currents of air, and in the composition and make of the candles, the final conclusion being that the direct light of the sun or the diffused light of day has no action on the rate of burning, or in retarding the combustion of an ordinary candle.

On the Manufacture of Chlorine by means of perpetually regenerated Manganite of Calcium. By Walter Weldon.

Since the last Meeting of the British Association chlorine has begun to be manufactured extensively by a process which depends on the production and perpetual regeneration of a compound no mention of which as yet exists in chemical literature. This process, besides thus producing and continually reproducing what the author believes to be a new compound, reduces by fully 80 per cent. the principal item in the cost of the manufacture of chlorine, greatly increases the quantity of chlorine which can be practically obtained from a given quantity of hydrochloric acid, and, moreover, enables the manufacture of chlorine to be carried on without the production of any offensive residue.

What has hitherto been the ordinary process of manufacturing chlorine consists simply in digesting with hydrochloric acid ores containing peroxide of manganese. The reaction which takes place, besides liberating chlorine, produces chloride of manganese, which remains behind in solution after the chlorine has gone off, and has hitherto been usually thrown away. There have been proposed and tried a great number of processes for transforming this chloride into peroxide for use over again, but the only one of them which has met with the slightest measure of practical success, prior to that which is the subject of this paper, is the one which is known, from the name of its inventor, as Dunlop's process. Dunlop's process decomposes the chloride of manganese by heating its solution, under a pressure of from two to four atmospheres, with milk of carbonate of lime, and then, in the dry way, transforms the resulting carbonate of manganese into a mixture or compound of two equivalents of peroxide with one equivalent of protoxide, by subjecting it for 48 hours to the action of air at a temperature of about 600° Fahr. The product of Dunlop's process is a sufficiently satisfactory one, containing about 72 per cent. of MnO_2; but the process requires a very formidable amount of apparatus, and in this and other ways is so costly that its use has never extended beyond a single firm of manufacturers.

Three years ago the author began to endeavour to work out the idea of decomposing by either lime or magnesia the chloride of manganese in the residual liquors of the chlorine manufacture, and then blowing air through the resulting mixture of hydrated protoxide of manganese with solution of chloride of calcium or of chloride of magnesium, as the case might be. He took for granted that one-half of the protoxide of manganese so treated was the largest proportion of it that could thereby be converted into MnO_2—in other words, that one could obtain only sesquioxide by this method; but it was soon found that, when using lime to decompose the chloride of manganese, considerably more than half the protoxide operated upon was frequently converted into MnO_2. It was found eventually that more than half the protoxide was thus peroxidized only when more lime was used than simply the quantity necessary to decompose the chloride of manganese, and when what was treated with air was thus a mixture of protoxide of manganese and lime; and it was also found that in all such cases there was a definite relation between the quantity of lime associated with the protoxide of manganese and the quantity of the protoxide, in excess of half, which became peroxidized. This led to the discovery that whereas when protoxide of manganese by itself is treated with air in the wet way one-half is the maximum proportion of it which can thereby be converted into MnO_2, the association of a certain proportion of lime with the protoxide so treated will enable the whole of it to become converted into MnO_2. It is to this fact, together with that of the much greater rapidity with which protoxide of manganese can be peroxidized by treatment with air in the wet way when lime is present than when lime is not present, that the practical success of the new method of manufacturing chlorine is mainly due.

The action of lime in increasing the proportion of protoxide of manganese which can be peroxidized by treatment with air in the wet way, evidently consists in the lime substituting itself for that part of the protoxide which, when protoxide of manganese not having any other basic substance associated with it is treated with air in the wet way, does not undergo peroxidation. It would seem that the production of MnO_2 in the wet way, by direct combination between hydrated MnO and atmospheric oxygen, absolutely requires the presence of a base with which the MnO_2 can combine as it forms. When protoxide of manganese, not having any other basic substance associated with it, is treated with air in the wet way, a part of the protoxide itself has to act as the required base; and this is the reason why, in that case, not more than half of the protoxide can become peroxidized, the other half being required to combine, as MnO, with the half which becomes converted into MnO_2. When, however, the protoxide of manganese which is treated with air in the wet way has lime associated with it, the MnO_2 which forms (or a part of it, according to the proportion of lime present) combines with CaO instead of with MnO, thus leaving free to undergo peroxidation that part of the MnO which, but for the presence of the CaO, this MnO_2 must have combined with, and which would thus have got locked up in a state in which it would have been incapable of being peroxidized, at least in the wet way and by air alone. Hence the presence of enough lime to take the place of that half of the protoxide which, if no lime were present, would have to go into combination as base, and also to supply enough base for that half itself to combine with after undergoing peroxidation, will enable the whole of the MnO operated upon to be raised to the state of MnO_2. The minimum quantity of lime which is enough for this purpose is an equivalent for each equivalent of MnO operated upon, or the quantity necessary to supply an equivalent of lime to all the MnO_2 which can be produced by the peroxidation of all the MnO.

By treating with air, then, a mixture of protoxide of manganese and lime suspended either in water or in solution of chloride of calcium, there is formed a compound containing MnO_2 and CaO in the proportion of an equivalent of one to an equivalent of the other. This compound may be regarded as sesquioxide of manganese, or Mn_2O_3, the MnO in which is replaced by CaO. The author calls it manganite of calcium, and believes it to be a new compound. Gorgeu, in 1862, described a compound which he called manganite of calcium; but his compound contained five equivalents of MnO_2 per equivalent of CaO, and the CaO in it was so feebly combined that it readily decomposed chloride of manganese. The author's compound contains only one equivalent of MnO_2 per equivalent of CaO, and has no action upon salts of manganese.

This compound has now been produced and reproduced to the extent of some hundreds of tons. The process of producing it and applying it to the manufacture of chlorine is conducted as follows:—The residual liquor which remains after a charge of manganite has reacted upon hydrochloric acid in any suitable still is run from the still into a well or other receptacle in which it is treated with carbonate of lime, to neutralize any free acid, and to decompose any sesquichloride of iron or sesquichloride of aluminium which may be contained in it. The neutralized liquor is then pumped up into an elevated cistern, in which it is left at rest for a few hours in order that it may deposit certain solid matters which it now holds in suspension. The most abundant of these is usually sulphate of calcium, due to the somewhat considerable quantity of sulphuric acid which is nearly always contained in the hydrochloric acid produced in alkali works; but there are also small quantities of sesquioxide of iron, derived from the sesquichloride of iron in the hydrochloric acid, and sometimes partly from the lime used in the process, and larger or smaller quantities of alumina and silica, due to the lime. These impurities having deposited, the supernatant liquor, which is a mixed solution of chloride of manganese and chloride of calcium, and is now quite clear and of a beautiful rose colour, is run off into another vessel, where there is added to it the quantity of lime necessary to decompose the chloride of manganese in it and nearly an equivalent more. A blast of air is then injected into the resulting mixture, and what was at first a perfectly white mud, all the manganese in which was in the state of MnO, soon becomes a very black mud, nearly all the manganese in which is in the state of MnO_2. This is then allowed to settle for about twelve hours, at the end of which time it has separated into a denser black mud and a supernatant clear solution of chloride of calcium. This solution of chloride of calcium having been drawn off, what remains is ready for use in the still. It is used as mud, without drying, being conveyed to the still by pipes and entering by a hydraulic lute. In the still it meets with hydrochloric acid, from which it liberates chlorine, at the same time reproducing exactly such a residual solution as was commenced with. With this solution the round of operation is recommenced; and so on, over and over again, continually. The samples exhibited were portions of a charge of manganese which, at the works of Messrs. J. C. Gamble and Sons, of St. Helen's, has actually generated chlorine, from which bleaching-powder has been made, about fifty successive times.

Hitherto the principal item in the cost of chlorine has been that for native peroxide of manganese. Last year, in Great Britain, France, Belgium, and Germany together, there were produced about 120,000 tons of bleaching-powder, which cost, on an average, for native oxide of manganese, not much, if any, less than £5 per ton. The author's process substitutes for this cost for native oxide of manganese a cost for the regeneration of manganite of calcium not exceeding 15*s.* per ton of bleaching-powder, being about 10*s.* for lime, 1*s.* for steam, 1*s.* for wages, and 2*s.* for interest and wear and tear. Moreover, whereas hitherto, at least in this country and in all but an extremely few exceptional cases, the production of a ton of bleaching-powder has required the acid from about 75 cwt. of salt, this compound yields chlorine enough for a ton of bleaching-powder from the acid from less than 45 cwt. of salt. This larger yield of chlorine is mainly due to the artificial manganite being so easily soluble that it can very readily be caused to neutralize from 95 to 99 per cent. of the acid employed, which is a very much larger proportion of it than can be neutralized when working with manganese ores. A third very important advantage of the new process over the old one consists in this, that whereas the immense quantities of acid which escape neutralization in the old process are usually (and have almost necessarily to be) sent into the rivers, as free acid, the only product of the new process which has to be thrown away is a perfectly neutral solution of chloride of calcium.

On the Action of Phosphoric Chloride on Hydric Sulphate. *By* Stephen Williams.

Dr. Williamson first described this important reaction as the replacement of one molecule of hydroxyl in hydric sulphate by monovalent chlorine, with the formation of chlorophosphoric acid and a body having the formula $HCl\,SO_3$, which he termed chlorhydrated sulphuric acid. The further investigation of this reaction quite confirms Dr. Williamson's observations, but at the same time shows that the operation goes further than was at first supposed; the chlorophosphoric acid reacting on the hydric sulphate in the same manner as the phosphoric chloride. The whole operation may be represented in three steps:—

$$(1)\ H_2\,SO_4+PCl_5 = POCl_3+HCl+HCl\,SO_3.$$
$$(2)\ H_2\,SO_4+PO\,Cl_3 = PO_2\,Cl+HCl+HCl\,SO_3.$$
$$(3)\ H_2\,SO_4+PO_2\,Cl = HCl\,SO_3+HPO_3.$$

It was also ascertained that the chlorhydrated sulphuric acid, when added to hydric sulphate, breaks up into hydric chloride and sulphuric acid (SO_3), which explains the apparent contradiction in Gerhardt's statement, viz. that one of the products of the reaction of phosphoric chloride on hydric sulphate was sulphuric acid.

GEOLOGY.

Address by Professor Harkness, *F.R.S., President of the Section.*

It has of late become the custom to open the several Sections of the British Association with an introductory Address.

This custom I believe had its origin in this Section when the Association met at Aberdeen; and upon that occasion Sir Charles Lyell made the important discovery of M. Boucher de Perthes of the occurrence of flint weapons with the bones of large extinct mammals in the gravels of the Valley of the Somme the subject of his opening address.

In some instances new matter of importance in connexion with geology has furnished materials for this opening address, but more frequently subjects of local interest have supplied the matter for this purpose; and it is in connexion with the latter that I shall occupy for a short time your attention.

In no portion of Great Britain have we a better development of the series of rocks which forms the link between the well-established Devonian formation and the succeeding well-recognized Carboniferous group than in this county. The rocks which form the link I have referred to are known to geologists as the Pilton beds, deriving their name from the locality in Devonshire where they are best developed. These rocks have been made the subjects of investigation by Sir Roderick I. Murchison, Prof. Sedgwick, Sir H. T. De la Beche, Mr. Weaver, Mr. Godwin-Austen, Prof. Phillips, and others; and of late they have been carefully examined by Mr. Jukes, Mr. Salter, Mr. Townshend Hall, and Mr. Etheridge.

My reason for referring to these rocks is to point out their relations to certain strata which are very well exhibited in the south-west of Ireland, and which occur in a horizon corresponding to the Pilton shales.

The Irish representatives of the Pilton shales are marked by a mineral aspect, very nearly allied to their equivalents in this country; and they contain organic remains of a type very closely approximating to such as are found in the Pilton rocks.

Before alluding to the Pilton beds, I will refer to their Irish representatives, and the rocks upon which these repose.

In doing so I shall avail myself of the labours of the late Mr. Jukes, and the officers of the Irish branch of the Geological Survey, who were for several years engaged upon these rocks. Before doing so I must, however, pay a passing tribute to the memory of one who has so recently been removed from the scene of his labours.

For more than eighteen years the late Mr. Jukes filled the office of Director of the Geological Survey of Ireland; and the numerous maps and memoirs which have emanated from this Survey while under his control speak alike of the labour and accuracy with which this work has been done. Every geologist personally acquainted with the late Mr. Jukes must know how ready he was on every occasion to impart all the knowledge he possessed to those who sought it, and that earnest love of his subject and kindness of heart which so distinguished him caused him to be beloved by all who had the pleasure of his acquaintance. On many occasions this Section of the British Association has had valuable communications from him, and many who are now present will well remember the apt and vigorous manner of Mr. Jukes when he had anything to address to this Section.

The portion of Ireland nearest Devonshire where we have rocks which can be compared with those of this country is the neighbourhood of the town of Wexford. Here are strata reposing upon Cambrian rocks which have been assigned to the Old Red Sandstone by the officers of the Irish Survey, attaining a thickness of about 200 feet. At the western extremity of the County of Wexford, at Hook Point, the Old Red Sandstones are from 600 to 700 feet thick. In the Comeragh Mountains, to the north-west, they have a thickness of not less than 1700 feet; and south-west, from the Comeraghs near Dungarven, they are upwards of 3000 feet in thickness. In the west of the County Cork we have from 5000 to 6000 feet of Old Red Sandstones exposed; and here the upper portion is denuded, and the base is not seen. In the Glengariff and Killarney country from 8000 to 10,000 feet of these strata are exhibited, and here also the base is not visible.

On the south side of the Dingle promontory the Old Red Sandstones occur under different circumstances. They are here from 3000 to 4000 feet thick, and are seen resting *unconformably* on rocks which are of a reddish-purple colour, and at least 10,000 feet thick. These reddish-purple beds repose conformably on the representatives of the Ludlow series.

The strata of the south of Ireland which represent the Old Red Sandstones, and which in the neighbourhood of Glengariff and Killarney attain a greater thickness than 10,000 feet, are extremely barren in organic remains. Several thousand feet of strata, consisting of purple, red, and green beds, which, from being well developed in the district of Glengariff, have received from the Irish Geological Survey the name of "Glengariff Grits," have never yet afforded a fossil. It is only in the upper portion of the series, which is comparatively thin, and which consists of "yellow sandstones," that organic remains occur. These consist of remains of plants, which at Kiltorkan, in County Kilkenny, are in a beautiful state of preservation. Fish-remains are also found, referable to the genera *Coccosteus* and *Gyrolepis*, likewise a very characteristic shell, *Anodon Jukesii*, and crustacean remains in the form of a species of *Eurypterus*.

In Ireland, the strata which succeed conformably the Yellow Sandstones have been called by Sir R. Griffith the Lower Limestone Shales. In the south of Ireland these strata have a great thickness; and where they possess a slaty cleavage, the term Carboniferous slate has also been applied to them. These strata, in the eastern portion of the County Wexford, where the Old Red Sandstones are thin, have no distinct existence. In the western part of the same county, at Hook Point, where the Old Red Sandstone deposits are thicker than in the eastern portions of Wexford, the Lower Limestone Shales make their appearance as a distinct group, separating the Carboniferous Limestones above from the Yellow Sandstones below; and here their thickness is between 10 and 20 feet.

We have already seen how the Old Red Sandstones have increased in thickness in the neighbourhood of Dungarven. The Carboniferous slates also attain a much greater development here than at Hook Point, for the officers of the Geological Survey give their thickness at 700 feet; and near Youghal, still further westward, they have a thickness of about 900 feet.

On the west side of Cork harbour we have examples of a still greater development of the Carboniferous slates, for here they are at least 1500 feet thick. At the Old Head of Kinsale 6500 feet represent their thickness, and further westward they attain to even a greater development.

In the County of Cork gritty bands make their appearance in the Carboniferous slates. In the eastern portion of the area, where these grits first occur, they are thin and very irregular. They become very thick in the western portion of this county, and in Coomhola Glen they have their greatest development, being at leas 3000 feet in thickness. These gritty beds have been termed "Coomhola Grits." They contain some peculiar fossils, and they have others in common with the Carboniferous slates. They are interstratified with slate bands; and although most extensively developed near the base of the Carboniferous slates, they are merely local members of this series, emanating from conditions somewhat different from those from whence the great mass of the Carboniferous slates have originated.

Having described generally the arrangement of the rocks of the south of Ireland which represent the Pilton beds, and also the deposits which support them, we have now to refer to North Devon. On the north side of Baggy Point and eastward thereof, there are hard purple sandstones, possessing many of the features of the Old Red Sandstones of the south of Ireland, which immediately underlie the "Yellow Sandstones," and upon these in North Devon are light-coloured beds, which represent the Irish Yellow Sandstones.

In the neighbourhood of Marwood, reposing on the equivalents of the Yellow Sandstone, are greenish-grey grits, affording a group of fossils intimately allied to those contained in the Coomhola grits; and among these are plant-remains identical with such as occur near the base of the Carboniferous slates. These have been obtained by the Rev. M. Mules. The mineral nature and the fossil remains place the Marwood sandstones and the Coomhola grits on the same horizon.

The fossil plants which occur near the base of the Carboniferous slate, and in the Marwood sandstones, are specifically identical with such as are found at the base of the Carboniferous formation in the north of England. Here *Filicites linearis* and *Sagenaria Veltheimiana* occur, and these are the forms which the base of the Carboniferous slates afford.

The Pilton rocks succeed the Marwood sandstones, and these Pilton rocks in their mineral nature are intimately allied to the Carboniferous slates. The strata which make up the Pilton group consist of shales and slates, generally of a dark colour, with associated sandstones and gritty beds, and occasional thin bands of limestone full of corals. The fossils of the Pilton rocks are very closely connected with those of the Carboniferous slates. Some forms, however, which occur in the Pilton rocks have not yet been recognized in their Irish representatives.

There are species of *Phacops, Strophalosia productoides,* and a few other species. But such fossils as are most abundant in the Pilton rocks are those most common in the Carboniferous slates.

There is an idea prevalent among many English geologists that the Coomhola grits are a series of rocks distinct from, and lying beneath the Carboniferous strata, and this idea has, I believe, given rise to erroneous impressions concerning this series. I have pointed out that this is *not* the conclusion of the officers of the Irish Geological Survey, and my own observations have led me to results similar to theirs. I hope this Meeting will afford more information concerning the Marwood beds and the Pilton rocks, and that we shall have further evidence which will enable geologists to say whether these strata shall be referred to the Devonian group or to the Carboniferous formation. A band of pale slates, with a few bivalves, lies between the purple sandstones of Mort Bay and the greenish-grey grits of the Marwood series. It is desirable that further information should be afforded concerning these strata and their fossil contents.

It appears to me that the boundary between the Devonian or Old Red Sandstone and the Carboniferous formation is in the British Isles placed in different horizons. In Ireland the Carboniferous slates and interbedded Coomhola grits are referred to the latter, while in this country the equivalents of these are looked upon as appertaining to the Devonian formation.

Besides the Marwood sandstones and the Pilton rocks, there are other matters of greater interest in connexion with the geology of Devonshire.

The Triassic strata of this country, in the neighbourhood of Budleigh-Salterton, has within it some peculiar pebble-beds, which have been described by Messrs. Salter and Vicary. These pebble-beds abound in fragments containing fossils similar to those which the Silurians of Normandy afford. Recently these Triassic strata have yielded to Mr. Whitaker important palæontological evidence, in the form of reptilian remains, which Prof. Huxley has referred to the genus *Hyperodapedon*. This evidence goes a long way towards supporting the conclusion that the Lossiemouth sandstones near Elgin are of a much newer age than their stratigraphical arrangements would seem to indicate, and that they belong to the Trias rather than to the Old Red Sandstones, to which they have previously been referred by many geologists.

In Devonshire also we have a better development of Miocene strata than is to be found elsewhere in the British Isles; and the locality where these strata occur is within a short distance of Exeter: I refer to Bovey Tracey and its lignite beds. These latter have been made the subject of a valuable communication to the Royal Society by Mr. Pengelly. The plant-remains which have been obtained therefrom have been described by the eminent Swiss botanist, Dr. Oswald Heer; and, thanks to the generosity of that noble-hearted lady Miss Burdett Coutts, who is alike desirous to promote science and to alleviate human suffering, the fossils obtained from these Bovey Tracey lignites are now well known to geologists. The plant-remains which these strata contain are the relics of a vegetation which, during the Lower Miocene epoch, spread over a large portion of the Continent of Europe, and extended into the arctic regions of America; a vegetation which clothed not only Europe with lofty forest trees, and a rich undergrowth of smaller plants, but which also covered Greenland and Spitzbergen, lands which are now the abode of ice and snow, with an equally rich vegetation.

This extensive diffusion of similar forms of plants during the older Miocene period, speak to us of widely extended uniform climate, contrasting strongly with the climates which now prevail in the temperate and arctic zones of the Northern Hemisphere.

There is another matter connected with the geology of Devonshire which has special interest—the caves of this county and their contents. These have been made the subjects of many valuable communications to this Section by Mr. Pengelly, and the gentlemen who are associated with him on the Committee for the Exploration of Kent's Hole.

Met, as we now are, in a locality so near the source from whence so much of interest has come, I believe that this Section will again have before it important matter referring to Kent's Hole and other Devonshire caverns; and I cannot doubt that many Members of the British Association will avail themselves of the opportunity of examining the spot from whence so much valuable information has been derived, bearing upon the early history of the human race.

Geology and archæology are now blending into each other; and although the early history of man remained for a long time, like distant land, dim and ill-defined, of late, owing to the labours of Sir Charles Lyell, Sir John Lubbock and others, we are now acquiring a clearer conception of our early ancestors, of their mode of life, and of the conditions under which they existed.

On the Elevation and Depression of the Greenland Coast. By ROBERT BROWN, *F.R.G.S., Geologist to the West Greenland Expedition* (1867).

The author in this paper attempted to reconcile the conflicting statements of different writers regarding the elevation and depression of the Greenland coast. The American explorers in Smith's Sound declare that the coast is rising, while it is a notorious fact, observed by the author and others, that in the Danish possessions, south of 73° N. lat., the contrary holds true. Both statements were partially correct, but not in an exclusive sense. I. That there is a depression going on is proved by (α) the walls of old houses being submerged, (β) houses choked in by ice, where no native would now build them, (γ) poles on which the Eskimo Kayaks are suspended being submerged; and amongst numerous other similar instances quoted, (δ) it was mentioned that the blubber-house of Claushavn, in lat. 69° 7′ N., originally built on a little island off the shore, had in 1866 to be removed, the lower floor being invariably submerged at high tide. From various data supplied, the author did not consider that the rate of depression was more than five feet in a century.

II. This depression had been noted as far as the Danish trading-posts extended and there was little likelihood that it ended there; only it had not been observed further, no civilized men having passed a sufficiently long time in Smith's Sound, or elsewhere north of Danish Greenland, to obtain accurate data. Hence Drs. Kane and Hayes, observing certain terraces near their winter-quarters, concluded that the coast was there rising, and for want of further information, their opinions have been tolerably extensively adopted, even though they were in direct contradiction of the long-continued and well-established observation made to the southward of their point of observation.

The author explained these terraces by supposing that there *had been* a rise, though there *is now* a fall going on. These terraces, or their counterparts, are seen all along the Greenland coast, and were fully described from his observations made in 1861 and 1867. The interval between Hayes's and Kane's winter-quarters has been so little examined, either by the geographer or the geologist, that little could be said about it, but southward of 73° N. lat., this raised portion of the sea-bottom is seen at intervals. The hills (as described in the author's 'Florula Discoana'*) are in general low and rounded, and everywhere scattered with perched blocks and boulders, many of them brought from more southern and northern latitudes. These angular blocks are very different from the rounded and worn boulders which have been subjected to the grooving action of superincumbent ice. They bear the impress of having been dropped on the former sea-bottom by icebergs, which had borne them downward from the moraines of old glaciers. In other localities, in the hollows or along the sea-shore, we see several feet of the glacial clays (the counterpart, in fact, of the "brick-clays" of some parts of Great Britain) full of Arctic shells, Crustacea, Echinodermata, &c., such as are now living in the neighbouring sea, while in other places the clay is bare of organic remains. In this glacial clay of Greenland (which the author considered the counterpart of the upper laminated boulder-clays of Great Britain and the North of Europe) all the shells &c. are recent species, living in the Greenland sea to this day, with two exceptions. These are *Glycimeris siliqua* and *Panopæa Norvegica*†; but as both of these are found in the Newfoundland sea, we may expect them yet to be shown to be living in Davis Strait. This "fossiliferous clay" has been found up to the height of more than 500 feet above the sea, on the banks overhanging glaciers, where frequently the old shells are deposited on the glacier among the moraine, and carried out by icebergs, by which they are again deposited on the sea-bottom, thus completing a second revolution of change. In some portions of this clay, in knots, the author found impressions of the Angmaksak of the Eskimo, the Capelin of Newfoundland (*Mallotus arcticus*, O. Fab.), which was doubtless the fish referred to by Professor Louis Agassiz, when he speaks of knowing only one fossil fish as perfectly identical with living species, "a *Mallotus*, which is found in nodules of clay of *unknown age* in Greenland." Among other instances given as evidences of a former elevation was cited the fact of two huts, or their remains, being found on an island high above the sea, in places where no Greenlander would ever fix his habitation. He also heard of a lake in which there was said (on excellent authority) to be marine shells naturalized. The author of this paper therefore concluded that there (1) had been a former rise of the land, and (2) that at the present time the coast is gradually sinking. Thus we see in Greenland two appearances: 1st, in the interior *mer de glace*, what Scotland once *was* during the glacial epoch; 2nd, on the coast what Scotland now is, as far as her glacial clays and other remains are concerned.

On Reptilian Eggs from Secondary Strata. By WILLIAM CARRUTHERS, *F.L.S.*

On "Slickensides." By WILLIAM CARRUTHERS, *F.L.S.*

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* Transactions of the Botanical Society of Edinburgh, vol. ix. p. 430.

† Mörch in Rinks, *Grönland*, Bind ii. Tillæg, p. 143.

On a Fossil Mussel-shell found in Drift in Ireland. *By* EUGENE A. CONWELL, *M.R.I.A.*

The author exhibited a marine mussel-shell measuring $3\frac{1}{8}$ inches in length, $1\frac{1}{4}$ inch at its broadest part, and $\frac{1}{2}$ inch in internal depth, still in as perfect a state of preservation as when worn by its ancient occupant. An oblong-shaped pearly excrescence, about the eighth of an inch in length, is attached to the centre of the interior part of the shell, and some of the fine sand in which this bivalvular fossil has lain deposited for ages still adheres to the inside of it. It was pronounced to be a specimen of the *Mytilus vulgaris* inhabiting our present British seas. It was dug up on Saturday, August 22, 1868, by a labourer employed by the author to raise gravel for walks, from the bottom of an ancient sand-hill, or escar, within a quarter of a mile of the town of Trim, in a portion of the grounds of the District Model National Schools, established there by the Commissioners of National Education in 1849. This fossil was found resting under the ægis of a large boulder, which in some degree may account for its very perfect state of preservation, and in a situation at present 25 miles from the nearest sea-coast, and about 200 feet above the present sea-level. And here the consideration arises, how vast must be the period of time that has elapsed since the sand and gravel in which this shell has been imbedded were rolled about by the waters of an ocean which has retreated at least 25 miles from this spot; and, still more, how vastness of time must be piled on vastness since the lowest of the stratified rocks under this old escar was deposited; and how many times "Old Ocean" must have advanced on this land and again retreated to submerge other lands!

The gravel, or drift, in which it was found consists of dark Carboniferous limestone pebbles, utterly devoid of flint nodules, thus proving the antiquity of the drift, and rests upon a portion of that large bed of Carboniferous limestone-rock which occupies the greater part of the middle of the island.

The hills and ridges of sand and gravel, so conspicuous across the centre of Ireland, are supposed to have been formed in the eddies of opposing and conflicting currents, at a period when the present dry land was the bed of an ocean. Sometimes they are to be seen in single heaps, and at other times in narrow ridges, of all degrees of fineness and coarseness of material, varying in height from 20 to 80 feet, and extending in some parts from 1 to 20 miles in length. The prevailing direction of the line of subsidence of these ranges of drift in Ireland, running, as they generally do, nearly due east and west, has always appeared to the author to be in some degree connected with the rotation of the earth on its axis during the process of their being accumulated on the ocean-bed.

These hills of gravel are popularly known (and only in Ireland) by the name of *escars*, from a purely primitive Irish word (*eiscir*) meaning *a ridge of high land*, but generally applied to a sandy ridge. The term, usually taking the form of *esker* (as it is pronounced), is the name of about fifty townlands in Ireland, and combines to form the names of many other places, more especially across the middle than in either the north or the south of Ireland. Although the nomenclature of *escar* for sand-hill is peculiar to Ireland, it is curious to remark that we have now a town situated on a sand-hill, at the base of the Pyrenees, called *Escar*, which is a Basque name; and it is understood that the Basques have had a language peculiarly their own, but they have also had easy communication with Ireland.

Not far from, or indeed belonging to, the escar in which this shell was found, there is a line of gravel hills extending, with slight interruption, from Dublin to Galway, called *Esker-Riada*; and this is the most historically celebrated *escar* in Ireland, having been fixed upon as the boundary between the northern and the southern half of Ireland when the country was divided, in the second century, between Owen More and Conn of "The Hundred Battles." This ridge probably has its name, as the late eminent Irish scholar, Professor Eugene O'Curry, thought, from the chariots that used to run on it.

On the Occurrence of a large Deposit of Terra Cotta Clay at Watcombe, Torquay. *By* ROBERT ETHERIDGE, *F.G.S.*

Notes on the Brachiopoda hitherto obtained from the "Pebble-bed" of Budleigh-Salterton, near Exmouth, in Devonshire. *By* T. Davidson, *F.R.S.*

On the 16th of December, 1863, Messrs. W. Vicary and J. W. Salter made a communication to the Geological Society on the pebble-bed at Budleigh-Salterton, wherein some thirty-six different fossils were described, and attributed, with greater or lesser confidence, to the Lower Silurian period. Of these, ten or twelve are Brachiopoda. Subsequently the author of this paper, having had from Mr. Vicary and others the opportunity of examining several hundred specimens from the same locality, was able to determine beyond doubt that a large proportion of the shells were of Devonian age, while others may be of Silurian origin.

A great mystery is stated to hang over the derivation of the boulders composing that "remanier" deposit; the mélange of fossils does not seem to occur in the same pebble, but, on the contrary, every individual boulder contains species referable to the one or to the other epoch, so that no real mingling of Silurian and Devonian fossils has been hitherto detected in the same pebble. The rock is usually a sandstone or quartzite, and it is difficult to conceive how fossils of two distinct ages (if true) should occur in the same kind of rock, and be accumulated in the same locality, so that many geologists have, rightly or wrongly, supposed all the boulders to be of a similar age. It has not hitherto been possible to discover from where these pebbles have been drifted, or where is the parent rock, but they are supposed to be of French origin, although no similar rock in Normandy or in Great Britain has produced the assemblage of species contained in the Budleigh boulders.

The fossils occur in the shape of internal casts and external impressions, and only a small proportion of the boulders are fossiliferous. The author has detected some thirty-seven species of Brachiopoda, which he described and illustrated. Of these about ten, or perhaps less, are considered to be Silurian, twelve or more are without doubt Devonian, while fifteen are either new or not yet identified with described species, or have not hitherto been found associated in the same pebble or rock with any of the others recorded as Silurian and Devonian, but most of them seem to possess more of the Devonian than Silurian facies. It is highly probable that when the species of the other classes, also occurring in these pebbles, shall have been carefully and critically examined, that the true age of the above fifteen species will be established, as the whole series must be taken into consideration before we can arrive at any definite conclusion.

On the Occurrence of the Mineral Scheelite (*Tungstate of Lime*) *at Val Toppa Gold Mine, near Domodossola, Piedmont.* *By* C. Le Neve Foster, *B.A., D.Sc., F.G.S.*

The author stated that Scheelite (tungstate of lime) is now occurring at the Val Toppa Gold-mine. It is associated with quartz, iron pyrites, galena, zinc-blende, calc-spar, brown spar, and native gold; whilst wolfram, tinstone, molybdenite, fluor-spar, apatite, topaz, and tourmaline, which usually accompany Scheelite, are entirely absent. The Scheelite is called "Marmor rosso" by the Piedmontese miners, and is looked upon as a good indication for gold.

P.S. Since this paper was written, the author has received a letter from Mr. David Forbes about the occurrence of Scheelite. In his 'Researches on the Mineralogy of South America,' p. 40, he speaks of Scheelite as one of the "minerals of the Post-Silurian Granite eruptions, and their accompanying metallic veins."

The Devonian Group considered Geologically and Geographically. *By* R. A. C. Godwin-Austen, *F.R.S., F.G.S.*

The object of this paper was to define the general arrangement of land and water over the northern hemisphere during the period of the accumulation of the "Devonian" group.

After a short account of physical changes during earlier Palæozoic times, it was shown that the northern hemisphere had acquired and presented a great extent of terrestrial surface immediately antecedent to the "Devonian" or Middle Palæozoic period. Commencing the inquiry with reference to the American area, the extent and range of the "Hamilton marine group" indicates that the relative position of the coast-line, whence its materials were derived, was in the north and east, whilst the arrangement of all the subordinate members of that group point clearly to the direction of distribution having been south and west.

In like manner the marine Devonian group has a well-defined northern boundary-line across the Europeo-Asian region. Wholly wanting in Ireland, it is well exhibited, in its early facies, in North Devon (Linton), next seen in the Boulonnais, and has been proved to underlie the Cretaceous formation of the north of France, as far as beyond Lille and Tournay, from near which latter place it presents a well-defined limit across Belgium eastwards. At Gembloux it is seen to have been accumulated unconformably upon a much older Palæozoic series (Lower Silurian).

The further extension of the "Devonian" sea-beds is concealed for a considerable interval by Jurassic, Cretaceous, and Nummulitic groups, but they reappear in the mass of the Harz Mountains, where, as in the Belgian sections, they present unconformity.

The gradation of change, resulting from shallow to deeper water conditions, is well marked in the Harz "Devonian" series, and hence may be inferred with certainty that the boundary-line lay to the north. Like considerations applied to the Devonian depositions of Germany, to the south and east of the Hartz, put that part of Central Europe in the condition of sea, and place the boundary-line as trending north-east, conforming to the mass of the old Scandinavian land, as from above Magdebourg to the Gulf of Riga, and thence, by St. Petersburg, to the White Sea.

From this, its northern limit, the "Devonian" sea stretched southwards, over Devon and Cornwall, France, the north-east parts of Spain, and over North Africa; eastwards, across Europe, to the shores of the Black Sea, into Central Asia (Altai); and we have its characteristic fauna from Thibet and China.

The form of the continental area of the time is thus closely marked out. On the American side it lay, for the whole breadth of that region, as at present, with an irregular line on the south between 40° to 45° N.E., reaching as high as 75° to 80° N.E. Greenland and Newfoundland were portions of the same continent.

From the south-eastern extremity of this great continent there was an extension of the land south-west along the present Atlantic sea-board, much as Tenasserim and Malacca stretch away at present from the East-Asian continent.

On the European side the extent of land-surface was much less; it included only the Scandinavian mass, together with the greater portion of the British-Islands group, the whole having a common strike from north-east to south-west; but this land had a much greater extension on the Atlantic side than at present; and it is very probable, on other considerations, that at that time this old part of our present European land-surface was one with that of the American, the whole forming a great circumpolar continent, ranging across more than 180° of longitude.

The positions of certain insular masses, such as the central plateau of France and others, were indicated.

These geographical features of "Devonian" times were represented on a map of the northern hemisphere.

In spite of the persistency with which the notion of the marine origin of the "Old Red Sandstone" of the British Islands, and its equivalency to the true "Devonian" group, has been maintained by a few geologists, contrary opinions have very generally gained ground, both at home and abroad. The evidence in this direction has been greatly strengthened, both geologically and zoologically:—First, the Old Red Sandstone on the north side of the Bristol Channel is for the most part distinguishable only by its external characters; viewed in this way, the red sandstones and conglomerates of the Foreland, of Countesbury, and the hills about Porlock (North Somerset) seem to be identically the same with the "Old Red" of South Monmouthshire, whilst they are wholly unlike, and indicate a very different origin from the sandstones of the Linton group, which are true fossiliferous marine Lower "Devonian." If this identification of the Foreland series, and of Countesbury, be correct, then stratigraphically the lacustrine Old Red Sandstone passes as a mass beneath the Devonian (Valley of the Lynn).

Since Prof. Sedgwick and Sir R. Murchison proposed to substitute "Devonian" for "Old Red Sandstone" very much has been done, by very accurate observers, with respect to the latter local accumulations. It has been ascertained to be certainly a duplex, if not a triplex group, each division being dependent on contemporaneous physical changes, and each of which may be representative of the three severally distinct stages, on the systematic marine scale; namely, of part of the Upper Silurian of Sir R. Murchison's system, of the true "Devonian," and, lastly, in some cases of the Lower Carboniferous period.

The great geological interest which attaches to the true "Old Red Sandstone" consists in this—that, as does the "Huronian" for an earlier Palæozoic stage, and as does the Purbeck-Wealden group for the great break in the Secondary (Jurassic and Cretaceous) formations, it serves by its magnitude to illustrate the vast lapse of time which really separates the marine groups of formations which geologists place in immediate sequence, and serves also to show the nature of the subaërial operations of the time.

Owing to the length of the communication the second part, relating to the geographical distribution of the Devonian marine fauna, was not read.

Notes on the Discovery of some Fossil Plants in the Cambrian (Upper Longmynd) Rocks, near St. David's. By Dr. HICKS.

The plant-impressions occur on some thin layers of shale facing the surfaces of rough grit-beds, at a place called Trellerwr, two miles to the east of St. David's. These beds form a part of the section which underlies the "Menevian" rocks of the well-known creek of Porth-y-Rhaw, and belong to the same series of grey beds as those in which the fossils, mentioned in the author's paper read at the Norwich Meeting last year, were discovered; they are lower down than the zone of the Trilobites (a *bivalved crustacean* and *Lingulella ferruginea* have been discovered over 800 feet deeper in the section). These beds are strongly ripple-marked, and give indications of having been deposited in shallow water. The ones immediately above, and which contain the other fossils (*Plutonia Sedgwicki, Conocoryphe Lyellii*, &c.), are of a finer grain, and indicate a somewhat deeper water-deposit. No other fossils have been discovered as yet along with the plant-impressions, though, as already stated, others occur below, and also almost immediately above. These beds are entirely separated from the "Menevian group" by a good thickness of *purple and red rocks.*

One of the specimens exhibited was obtained by the author some years ago from the "Menevian group;" it was shown because of some amount of resemblance to the plants just found. This, however, came from a deep-sea deposit, and is therefore most probably a distinct species.

The Extinction of the Mammoth. By H. H. HOWORTH.

After a survey of all the authorities within his reach, the author concluded that no existing theory accounted for the following facts, which are indisputable:—

1. That the Mammoth lived in the area where his remains are found.

2. That a great portion of that area is now a moss-covered tundra, or an ice and boulder heap, as in the Bear Islands.

3. That no herbivore of the size and plentiful development of the Mammoth could find food in that area now.

4. That although covered with wool, and therefore adapted to a much more rigorous climate than that of India and Africa, neither Mammoth nor Rhinoceros could survive the present winter temperature of Northern Siberia.

5. The remains of the food eaten by the Mammoth and Rhinoceros, found and examined by Midderndorff and Brandt, are remains of plants only found now in more southern latitudes.

The only possible conclusion from these facts is, that the climate and condition of things in Siberia have altered very greatly since the days of the Mammoth. In support of this conclusion, such facts as the following are conclusive:—the bed of the Arctic Sea north of Siberia is rapidly rising, and exposing banks of sand containing Mammoth-remains, the land is rapidly gaining on the sea along the whole coast-line, and successive terraces or beaches are mentioned by Wrangel and other travellers. The appearance of the tundra seems to point to a not very distant submergence of the whole of Siberia, as far south as the high lands, which roughly mark the present northern limit of trees.

This being so, we have to ask ourselves what causes led to the change of condition of things, and to the extinction of the Mammoth. The hand of man is quite inadequate, and we must seek for it in the draining of the vast Mediterranean sea, which once existed from the Euxine to the Klingar Mountains, of which the author gave descriptions from authorities. The drainage of this sea must have been sudden and overwhelming, and not gradual; for we find the Mammoth remains aggregated in hecatombs on the pieces of high ground, and not scattered indiscriminately. This alone would account also for such an immediate change of climate (from an insular one to a continental) as should allow the bodies of the mammoths to be immediately frozen and thus preserved intact.

On the Source of the Quartzose Conglomerate of the New Red Sandstone of the Central portion of England. *By* EDWARD HULL, *M.A., F.R.S., F.G.S.*

The source of the peculiar quartzite pebbles, which form the largest proportion of the Conglomerate beds of the Bunter Sandstone of England, had formed a subject of inquiry for geologists from the days of the late Dr. Buckland downward. Professor Ramsay, F.R.S., had shown that the quartz rock of the Lower Lickey could not have given birth to the vast supplies of these pebbles of quartz, which were originally spread over several hundred square miles of country, as this ridge was buried under Permian strata at the Triassic period; and Mr. Hull had come to the conclusion, on mineralogical grounds, that neither the Carboniferous or Silurian rocks of the north of England or south of Scotland were capable of supplying pebbles of the nature of those found in the Bunter Conglomerate.

With the exception of a few fragments of Carboniferous and Silurian rocks, the Bunter Conglomerate was found to consist of rounded pebbles of coloured quartzite. Their invariably rounded form and small size (seldom exceeding 6 inches in diameter) had for some years suggested to the author that they might have been subjected to attrition during more than one geological period, and he had anticipated that in the Old Red Conglomerate of Scotland the source of these pebbles might be found.

Recent visits to the Old Red Conglomerate of Dumbartonshire and the district of Lesmahago had confirmed this anticipation. In these districts the formation was found to be composed for the most part of pebbles and boulders of quartzite, precisely similar to the peculiar "liver-coloured"* quartzite pebbles of the New Red Sandstone; and in proof of this, specimens of the pebbles from the two formations were exhibited to the Section †.

This view of the northerly drift of the quartzite pebbles was shown by the author to be in harmony with the stratigraphical arrangement of the Bunter Sandstone of England, which thins away towards the south-east of the country; and the absence in this formation of any of the large boulders of coloured quartzite, such as were found in the Old Red Conglomerate, was attributed to the additional wear and tear to which the boulders had been subjected in travelling from Scotland into England, or to the inability of a probably weak oceanic current to impel blocks of large size to the required distance from their source.

On the Crag Formation. *By* CHARLES JECKS.

The author considers that the Crag is but *one formation* divided into many

* A term often applied to them by the late Professor Jukes.

† These conglomerates have been described by Sir R. Murchison and Mr. A. Geikie as they occur in the Lesmahago district, and by Prof. Nichol and Dr. Bryce in the district of Dumbartonshire.

sections, as Coralline, Red, and Fluvio-marine, &c., all these sections being only different parts of one continuous deposit, occurring generally in estuarine or shallow water, and subjected to gradual changes of temperature &c., by which the character of the fauna was gradually altered, and that it thus presents a striking instance of that continuity, not only of life, but of lithological formation, which we find more or less exemplified in all geological strata.

On the Action upon Earthy Minerals of Water in the Form of heated Steam, urged by wood fuel, an experiment reported to the Association at its Meeting at Glasgow in 1840. *By* JULIUS JEFFREYS, *F.R.S.*

The experiment was made at Futtehgurh in India, in 1830, its object having been to determine the action of water in the form of steam at an intense heat, as a solvent of minerals insoluble in it at lower temperatures.

The instrument employed was a cylindrical kiln surmounted by a cone, and interiorly about 30 feet high and 16 in diameter, employed for vitrifying stoneware.

Four furnaces, 8 feet long and 4 wide, projected radially from the exterior of the kiln, and heated it through fire-throats about 3 feet wide and a foot high, each inrush of flame being allowed in part to flow towards the centre of the kiln, in part laterally, but the larger portion being turned upwards by dwarf chimneys in the kiln, built against its sides. These chimneys were as wide as the throats, say a yard, and about 18 inches from front to back.

For the experiment, a pit was dug between each furnace and the kiln, about 4 feet wide, 5 deep, and 10 inches broad from front to back. A fire-brick bridge, or low wall, kept the fuel from falling into the pits. These pits were kept filled with water.

Specimens of minerals, rock, and stones, and of ceramic ware and fire-brick were ranged in the fire-chimneys, or fire-bags as they are called by potters, also on the floor of the oven, and on the shelves on which were placed a few unbaked specimens of the stoneware (chiefly bottles for mineral waters), for firing which the kiln was usually employed.

It should be mentioned that the arched shelves were made of a highly aluminous and contractile clay, practically infusible, made into bricks (in a manner for describing which space is not here afforded) so dense that any fragments of them would scratch glass readily; whereas the fire-bags were built with an inferior and much more porous and siliceous brick, nearly similar to English Stourbridge, specimens of these being amongst them.

The fuel was wood of mango, dawk, and a peculiar light wood from the Tewai Jungle. These woods abounded in alkali. They grow in the valley of the Ganges, the soil of which is disintegrated mica and felspar.

The ordinary action of high firing with this fuel was to slightly melt the surfaces of the fire-bags into a glassy coat, sometimes with tears of glass trickling down, burning a little slag; but the dense shelf-bricks were but slightly affected by the alkali.

After an intense firing of more than forty-eight hours, during which the water had to be renewed in the pits, on opening the kiln all the glazing had disappeared, and the minerals in the fire-bags had been reduced in volume. Their walls were eroded to a depth varying from one to two inches. The specimens of ware on the lower shelves were in some places eaten through. The unbaked stoneware was fully vitrified, but the micaceous "slip" glaze on the surfaces, ordinarily a glossy brown coat, was dissipated, the body of the ware being also eaten into. The dense brick-shelves were but slightly affected. The specimens of this ware on the uppermost arch of the kiln, where the heat was not above a full red, were in the usual state of any ware placed there, viz. under-fired in the body, and coated with a rich brown glaze, the heat sufficing to melt it. But the surfaces, especially the shoulders of the ware, were covered with a mineral hoar-frost—a loose incrustation evidently deposited before the glaze had melted, and under which the ware had contracted in hardening, so as to raise up the frosty coat more clear of the surface, excepting at the few points of contact, than the sugar on candied citron; and under this crust the glaze-wash had, as the heat rose, melted into a complete glass.

What could this incrustation be but a small part of the mineral matter which had been so largely dissolved away below, by steam at an intense heat (aided no doubt by the alkali in the wood fuel), as to have much exceeded two hundredweight, and which left traces of its flight in a sprinkling of hoar-frost, precipitated at a red heat; the glaze happily intervening to prove that it had a source altogether extrinsic from the ware on which it had lighted?

An Estimate of the quantity of Sedimentary Deposit in the Onny. By the Rev. J. D. La Touche.

The Onny is a small stream in the south-west of Shropshire, the waters of which are collected over an area of 81 square miles. It is well known to geologists as flowing through the principal strata of the Silurian rocks.

The following means have been taken to ascertain the rate of denudation of this valley.

At the commencement of the present year a gauge-post was erected at a convenient spot in the river, at Stokesay, and a register has been kept of the height of the flood by means of it.

A number of experiments have been made to determine the maximum surface-velocity of the stream, and from these a Table (A) has been constructed, which at a glance gives approximately the mean rate for every decimal of a foot, and the amount of discharge per minute in cubic feet. For this purpose Table VII. in Neville's 'Hydraulics' was used.

At the commencement of each flood, at its full height and decline, specimens of water were collected in ordinary quart bottles, which contain about 26 ozs. each, and the sediment after subsiding was filtered and accurately weighed, the filter-paper being first carefully dried. Table B is an extract from the register of these experiments. The entries only include the more important floods.

The headings of the columns will speak for themselves; with reference to the fourth column, it has been found that the number of grains in the 100 ozs. of water varies considerably with the place from which it is taken. That collected close under the edge of a weir was 20·5 per cent. higher than that collected about thirty yards lower down. The difference is evidently due to the greater disturbance of the water there than elsewhere.

I think of constructing a filter on a large scale, with wire gauze or some such material, to be suspended for a certain time under the weir during a flood, to arrest the coarser sand and pebbles, which cannot be estimated by the foregoing process.

The fifth column gives the number of pounds of dried sediment which pass down the stream per minute.

To give an idea of what may be done with these data, I have made the following calculation. The specific gravity of dry Silurian rock is about 2·5. Supposing the highest rainfall and the highest observed percentage of deposit to take place for six weeks in each year (and this seems to be a very extreme estimate), it would take 430 years to wear away a single inch of the surface of the valley of the Onny. Of course this is far from being an accurate estimate, but it is evident that it would be possible to approach indefinitely near to accuracy by these means, and therefore to a true estimate of the rate of denudation of the land.

The last column gives the average rainfall of four rain-gauges placed at different points of the basin of the Onny.

It will be seen that, as might be expected, a certain relation exists between the sedimentary deposit and the rainfall, though many things tend to interfere. The suddenness of rain, its occurrence after a drought, or after long-continued wet weather, will do so. But there is reason to expect that extended observation will establish a general correlation between the average rainfall and the average rate of denudation.

TABLE A.

River-gauge.	Maximum velocity per 100 feet.	Mean velocity per min.	Area of section at gauge.	Discharge per min.
ft.	sec.	ft.	sq. ft.	cub. ft.
·3				
·4	110	45·95		
·5	80	62·65	122	7686
·6	52	96·05	128	12288
·7	39	125·25	137	17125
·8	34	146·15	146	21316
·9	30	167·00	158	26386
1·0	28	179·55	164	29520
1·1	26	192·05	173	32225
1·2	24	208·75	182	37992
1·3	22	229·65	197	45310
1·4	20	250·50	206	51500
1·5	18	279·50	218	61040
1·6				

TABLE B.

Date.	Hour of day.	River-gauge.	Deposit in 100 ozs. of water.	Discharge of sediment per min.	Average of four rain-gauges.
1869.	h.	ft.	grs.	lbs.	in.
Jan. 4......	....	......	....	....	·30
„ 5......	....	......	26·2	....	·09
„ 30......	....	·7	....	....	·66
„ 31......	....	2·0	7·84	610·4	·54
Feb. 1......	....	1·7	5·7	407	·09
„ 2......	....	1·0	3·8	147·41	·19
„ 12......	....	·64	5·7	100	·55
March 1...	....	......	....	....	·34
„ 2...	....	·75	7·7	290	·043
„ 19...	4 P.M.	·35	....	....	·586
„ 20...	8 A.M.	1·1	7·3	307·8	·07
„ „ ...	10 A.M.	·9			
„ „ ...	4 P.M.	·65			
„ 21...	....	......	5·0		
May 7......	....	·35	....	....	·42
„ 8......	10.30 A.M.	·85	7·7	190	·25
„ „......	3 P.M.	·9			
„ 9......	10 A.M.	·55	....	....	·40
„ 10......	9 A.M.	1·0	2·7	101·8	·16
„ „	12 A.M.	1·0			
„ „	4 P.M.	·75	11·9	448·0	
„ 11......	9 A.M.	·85			
„ 21......	....	......	....	....	·305
„ 22......	9 A.M.	·6	6·0	146·8	·08
„ 25......	3 P.M.	·65	....	....	·925
„ „	7 P.M.	1·2	18·5	794·4	
„ 26......	11 A.M.	1·65	17·0	1100·4	·515
„ „	2 P.M.	2·0			
„ „	(P.M.	1·65			
„ 27......	10 A.M.	1·65			

On Spheroidal Structure in Silurian Rocks. *By the* Rev. J. D. La Touche.

Spheroidal masses of various sizes are frequently met with in the Silurian and some other rocks. In the Wenlock shale smaller nodules, arranged in lines with the regularity of bricks in a wall, as well as huge masses of rich limestone, called ball stones, may be observed. These latter concretions give plain evidence of having been formed subsequently to the deposition of the whole stratum, inasmuch as they have disturbed the lines of stratification both above and below. A discoloration, owing to the infiltration of moisture, is often found to accompany nodular structure. The section of an oblong piece of Caradoc sandstone has been found to exhibit three bands alternately of yellow and blue stone, the former apparently more sandy than the latter. Here not only the colouring, but the physical character of the stone seemed to have undergone a change from the effects of weathering. A railway-cutting at the southern extremity of the Longmynd presents an instructive example of the same kind. The cubical masses of rock almost invariably weather into spheroids, the form of which is indicated by fine lines on the faces of the stone, long before the edges fall off and reveal their perfect shape.

Another very beautiful instance may be seen in the Whitcliffe, near Ludlow, where three large spheroids, of several feet in diameter, appear enclosed in concentric layers of Upper Ludlow rock, which surround them like the coats of an onion, the stratification of the general stratum, however, passing through them.

Has this peculiar structure been the result of an original deposition of nodules or calcareous matter at certain spots, or is it owing to more recent causes?

The fact that the shape of nodules frequently depends on the shape of the masses in which they are contained, and that their position is determined by joints in the rock, also that weathering produces a certain physical change in rocks, rearranging to some extent their materials, would lead to the latter conclusion. It would appear that if a quantity of soluble or crystallizable matter is equally distributed through a large mass, and that some external agent, such as moisture, is brought to bear on it, it may drive inwards the more soluble constituents, produce those concentric layers above alluded to, and in many cases be the cause of a central nodule.

If this be so, we have here further evidence of an incessant change and motion among the particles of the apparently motionless rocks, suggesting that some important results are taking place in them, slowly, in immense periods of time.

Notice of remarkable Glacial Striæ lately exposed at Portmadoc. *By* John Edward Lee, *F.S.A., F.G.S.*

The object of this notice was to bring before the Section the fact, that probably one of the best specimens of glacial action had lately been exposed in the small town of Portmadoc, and will very shortly be destroyed, the locality being wanted for building-sites. The part now exposed is about 100 feet wide by 50 feet long; many of the striæ can be traced the whole length. It is nearly a plane, with the exception of a furrow about 13 inches deep in the middle. Most of the striæ run from S.E. to N.W., but a few run from S.S.E. to N.N.W. (magnetic). The angle of inclination varies from $14\frac{3}{4}$ to $16°$.

As the plane slopes to the N.W., and the hill behind is comparatively low, while the highest ground in the neighbourhood is almost immediately in front, though on the other side of the valley, it would appear that if the glacier which caused these striæ originated in the highest ground, it must have taken a sudden turn when nearing the shore. If this is not thought probable, there must have been two sets of glaciers meeting in the valley.

Denudation of Western Brittany. *By* G. A. Lebour, *F.R.G.S.*

The conclusions brought forward in this paper are as follows:—

1. That, with the exception of a central range of *hills of elevation*, Western Brittany consists of two great *plains of marine denudation*.

2. That the last time these plains were exposed to the levelling action of the sea was probably during the Upper (?) Miocene period.

3. That the rivers of this district are identical, at least in their higher regions, with those which flowed formerly from the central dry land into the Miocene sea.

4. That the valleys at the bottom of which these rivers run are the result of their own erosive action, aided by other subaërial agents.

5. That the uniformity of width and depth of these valleys is due to the degree of hardness of the rocks in this country, being in an order of succession exactly corresponding to the time during which they have been exposed to the action of subaërial denudation.

Notes on some Granites of Lower Brittany. *By* G. A. Lebour, *F.R.G.S.*

This paper is an attempt to determine, as far as possible, the relative ages of the granites of Lower Brittany, and various sections are given, illustrating their apparent bedding in the westernmost part of the province.

The author believes the granite to the north of Cléden to be metamorphic.

On the Distribution of the British Fossil Lamellibranchiata.
By James Logan Lobley, *F.G.S.*

This paper gave the results of an investigation into the distribution of the fossil Lamellibranchiata found in British strata; and was accompanied by a series of diagrammatic tables showing the details of the distribution, and by lists of the species hitherto discovered in each formation.

On the Gold of Natal. *By* R. J. Mann, *M.D., F.R.A.S.*

On the Trappean Conglomerates of Middletown Hill, Montgomeryshire.
By G. Maw, *F.G.S., F.L.S., F.S.A.*

This was a description of the contemporaneous traps of Lower Silurian age in the ridge known as Middletown Hill, running parallel with the Breiddens, on the borders of Shropshire and Montgomeryshire. Especial reference was made to the great beds of bouldered trap, consisting of boulders of compact felstone imbedded in a softer matrix of felspathic tuff. The nodules occupy about half the mass of the conglomerate, and are unaccompanied by pebbles of any other rock. They vary from the size of a walnut to rounded masses of more than a hundredweight. Sir R. Murchison's description of these beds was referred to, and the author took exception to the term "concretionary trap" employed in the 'Silurian System,' as he considered that the rounded outline of the boulders was unquestionably due to mechanical causes. The interbedded traps, bounded on either side by Lower Llandeilo Flags, are of a collective thickness of about 780 feet, including bouldered felstone, alternating with a whitish-green felspathic breccia. The line of separation between the breccia-bed and boulder-trap is remarkably sudden, and no gradation of character occurs between them. The breccia is worked for hard felspar used for pottery purposes, and contains small nests of steatite. The bouldered condition of the felstone-bed was considered due to its partial breaking up on being erupted under water, the soft matrix of felspathic tuff being the portion more intimately divided, and the compact boulders fragments that had resisted disintegration. The sudden alternation in Middletown Hill of eruptive beds of very dissimilar character was noticed; they seem to have been emitted in immediate succession, as, although overlain and underlain by sedimentary deposits, there is no evidence of interstratification of sedimentary beds. The author, in conclusion, pointed out the close geographical association with these bedded traps of the much later porphyritic greenstone of the Breidden Hills, which, it was suggested, might have been emitted from the same point of eruption; and the local association of the intrusive greenstone with the Lower Silurian interbedded felstones was noticed as being very general in North Wales.

On Insect Remains and Shells from the Lower Bagshot Leaf-bed of Studland Bay, Dorsetshire. By G. MAW, *F.G.S., F.L.S., F.S.A.*

The author exhibited a large series of insect-remains, collected by Mr. W. R. Brodie, from the Lower Bagshot Leaf-bed of Studland Bay, the species of which had not yet been determined. Also six or seven shells belonging to the Unionidæ; these were of special interest, as being the first mollusca that had been found in the beds separating the Middle Bagshots and London Clay, and determined the freshwater origin of the Lower Bagshot clays, a view Mr. Maw had previously advocated from the physical characters of the beds.

Experiments on Contortion of Mountain Limestone. By L. C. MIALL.

The author cited previous experiments illustrating the behaviour of various materials when subjected to pressure, and briefly described the geological phenomena of contortion. An apparatus was exhibited, which had been prepared to produce artificial contortions in laminæ of rock, and to ascertain the amount of deflection capable of being caused by sudden and continuous strains respectively.

The lamina is clamped at one end to a block, the length to be bent is regulated by sliding the block along a groove, and a known weight descends upon the free end. Provision is made that the weight shall act upon a knife-edge, which is always perpendicular to the surface of the slab, and always applied to the same line. By means of an index the deflection can be read accurately to hundredths of an inch.

In the annexed Table the results of one series of experiments are given. A number of observed facts are neglected in order to give prominence to the chief point, viz. the difference in the deflections produced by the sudden application of a considerable weight, and by the prolonged action of a force of low intensity. The angles have been deduced from the amount of perpendicular deflection, and they are consequently all taken as rectilinear.

No. 1, $\frac{7}{100}$ inch. 2 lbs. Immediately. (Broke at) 2°·2.	7 oz. 3 weeks. 7°·4.	7 oz. 2 months. 11°·5.	Recovered in 3 weeks. 2°·7.
No. 2, $\frac{6}{100}$ inch. 2 lbs. Immediately. (Broke at) 2°·5.	7 oz. 3 weeks. 8°·15.	7 oz. 2 months. 10°·15.	Broke after 6 days.
No. 3, $\frac{7}{100}$ inch (bituminous). 2 lbs. Immediately. (Broke at) 2°·75.	7 oz. 3 weeks. 7°·55.	7 oz. 2 months. 11°·2.	Recovered in 3 weeks. 3°·1.
No. 4, $\frac{9}{100}$ inch (bituminous). 2 lbs. Immediately. (Broke at) 2°·15.	5 oz. 3 weeks. 7°·10.	5 oz. 3 months. 12°·5	Broke after 11 days.

On a Specimen of Teleosaurus *from the Upper Lias.* By C. MOORE, *F.G.S.*

In connexion with this paper the author exhibited a specimen of *Teleosaurus temporalis*, Blainville, about 4 feet in length, which was enclosed in fine sections of nodular yellow stone, as they originally came from the Upper Lias quarry, and which, when joined, looked like an elongated French loaf, in the centre of which the bones were covered up. It was stated that, when developed, the Saurian was likely to be found in very fine preservation. The beds in which it occurred and the other associated organic remains were shortly noticed.

*On some New Forms of Graptolites**. *By* H. Alleyne Nicholson, *M.D., D.Sc., M.A.*

In this communication the author described twelve new species of Graptolites, which had recently come under his notice. Of these, six were from the Skiddaw Slates, raising the total number of Graptolites from this formation to thirty-four. Three were from the Graptolitic Mudstones of the Coniston series, making, with those already described by the author, a total of twenty-seven species (see Quart. Journ. Geol. Soc. vol. xxiv.). The remaining three were from the Upper Llandeilo rocks of Dumfriesshire.

The following is a list of the species here described:—

Trigonograpsus lanceolatus.	Diplograpsus Hughesi.
Dichograpsus fragilis.	—— sinuatus.
—— annulatus.	Graptolites argenteus.
Didymograpsus fasciculatus.	Diplograpsus insectiformis.
Diplograpsus Hopkinsoni.	—— bimucronatus.
—— armatus.	Climacograpsus innotatus.

Sketch of the Granite of the Northerly and Easterly Sides of Dartmoor. By G. Wareing Ormerod, *M.A., F.G.S.*

The district known popularly as "Dartmoor" consists of the forest of that name, and portions of the adjoining parishes; it is estimated as being twenty-two miles from north to south, and twenty from east to west, and is formed of granite or granitoid rocks. The granite, for the most part, is a coarse-grained mixture of quartz, felspar, and mica, which is sometimes white; large crystals of felspar are often seen, and schorl or tourmaline is of very frequent occurrence both in veins and as an integral part of the rock; near Chagford the author has found *scapolite*. The granite to the north of the Teign is more crystalline than that to the south of that river. The rock-basins, with very few exceptions, are in the district south of the Teign. Perpendicular joints often occur; the greater part have a direction from N.N.W. to S.S.E., and other lines run at right angles to these. The joints that have an easterly and westerly direction vary more from the perpendicular than the others. Minor lines of joints, which cross at rather acute angles, give a basaltiform character to the rocks in which they occur; these occupy only small areas. The sides of joints are sometimes smooth and shining, and of a dark colour, caused by schorl, and the faces are occasionally intersected by numerous minute lines, which penetrate about an inch. The beds of granite rarely exceed 2 feet in thickness, and the adjoining beds, whether horizontal or perpendicular, often differ in character. The division of granite into tabular masses and beds having a stratiform appearance, is very general; and the beds are occasionally seen to curve beneath the schistose rocks (as near Belstone Tors), and to dip to the valleys on each side of the range, probably causing the contour of the district, as at Kestor and Middletor, between the North and South Teigns. To the south of the Teign a spheroidal structure occurs, and masses resembling boulders are seen *in situ* in decaying granite; a good example exists near the Lustleigh Station, and to this peculiar structure the forms of the granite masses, often regarded as transported blocks, is in a great degree to be attributed. The Elvans of Dartmoor do not equal those of Cornwall either in size or extent; veins of granite of the same composition as the adjoining granite often penetrate the neighbouring sedimentary rocks; these can be studied near Chagford, on the left bank of the Teign, at Hunt's Tor and Sharpy Tor; at Sharpy Tor the vein is about 18 feet wide, and contains large crystals of felspar, and masses of the adjoining carbonaceous rock. Veins of porphyry rarely occur; a vein of coarse porphyry containing pseudo-opal is exposed in the farmyard at Forder near Easton, and also at Sandy Park; and a vein of fine-grained porphyry may be seen on the old road from Moreton Hampstead to Exeter, near the cross of the roads at the top of the hill. The decay of granite was next noticed; various particulars as to granite-gravel were pointed out,

* Published *in extenso* in 'Annals and Magazine of Natural History' for Oct. 1869.

and the manner in which the perpendicular joints, the stratiform beds, and the spheroidal structure combine to produce the tors and rocking-stones, and the most characteristic features of the moor.

In conclusion, the author said that he had not seen any glacial markings on the Dartmoor granite, but that Professor Otto Torrell, when visiting the Moor with him last autumn, gave an unqualified opinion that many of the gravels were the remains of moraines.

Notice of the Discovery of Organic Remains in the Rocks between the Nare Head and Porthalla Cove, Cornwall. By C. W. Peach, *A.L.S.*

In May last, after assisting to arrange a collection of Cornish fossils in the new Museum of the Geological Society of Cornwall, at Penzance, the author examined there the interesting series of the rock specimens of Cornwall, made by Dr. Boase many years ago, to see whether any of them contained organisms. One of them, a dark limestone, marked 733, from Porthalla Cove, attracted his attention; it evidently contained organisms which were so indistinct that they had hitherto escaped notice.

The authorities kindly had it rubbed down and polished, and thus Encrinites and a coral, probably *Favosites polymorpha*, were well shown.

Owing to this interesting discovery, the author resolved to visit the spot and to try to find the rock *in situ*. He met with a few specimens of blackened remains, enclosed in a dark slaty rock, between tide-marks, in Nelly's Cove, called "Betsey's Cove" at page 95 of the 'Geology of Cornwall, Devon, &c.,' by the late Sir Henry De la Beche. One of the specimens shows one septum of an *Orthoceras* and part of another. The others are evidently portions of organisms. Similar blackened Orthocerites, &c. are not uncommon in a similar kind of rock at Fowey, Polruan, &c.; many such obtained there by the author are in the Museum at Penzance. Those from Nelly's Cove are to be added to them.

On the alleged occurrence of Hippopotamus major *and* Machairodus latidens *in Kent's Cavern. By* W. Pengelly, *F.R.S., F.G.S.*

The author, having reminded palæontologists that Prof. Owen (Brit. Foss. Mam. &c. pp. 410 and 175, &c.) had mentioned *Hippopotamus major* and *Machairodus latidens* as having been found in Kent's Hole, and that the late Dr. Falconer had not been convinced that either of them had been met with there, proceeded to give, in each case, a brief summary of the evidence furnished, first, by the published and unpublished statements of the early explorers of the Cavern, Mr. Northmore, Mr. (now Sir) W. C. Trevelyan, Rev. J. M'Enery, Rev. Dr. Buckland, and Mr. Godwin-Austen; secondly, by their figures of the specimens they found; and, thirdly, by the specimens themselves.

The following are the chief conclusions at which he arrived:—

1st. That there is no trustworthy evidence that *Hippopotamus major* had been found in the Cavern.

2nd. That Mr. M'Enery found five canines of *Machairodus latidens* there.

3rd. That at present one of the five is in the British Museum, one in the Museum of the Royal College of Surgeons, one in the Museum of the Geological Society of London, one in the Oxford Museum, and one in the private collection of Sir W. C. Trevelyan.

Source of the Miocene Clays of Bovey Tracey.
By William Pengelly, *F.R.S., F.G.S.*

In this communication the author stated, in reply to some remarks by Mr. Maw (Quart. Journ. Geol. Soc. vol. xxiii. pp. 392–393, 1867), that he had been led to the conclusion (Phil. Trans. part ii. 1862, p. 1027) that the clays in question were derived from the degradation of the Dartmoor granite, by the following facts:—

First, the proximity to Dartmoor; secondly, that all the beds of clay and of sand thin out eastward, that is, with increased distance from Dartmoor; thirdly, the beds of sand thin out in that direction before the beds of clay, and the coarse beds of each kind before those which are finer; fourthly, because the beds of sand, and especially the "twenty-seventh," are little more or less than disintegrated granite, being made up of quartz frequently unrounded, crystals of felspar sometimes quite angular, and grains of schorl; and fifthly, because of the presence of sand in the clay-beds, and of clay in those of unmistakeable granitic sand.

Denudation of the Shropshire and South Staffordshire Coal-fields. By John Randall.

The author described a line of denudation in the Shropshire coal-field, familiarly known as the Symon Fault, in which the coals and ironstones disappear in succession, more particularly at the Kemberton and Halesfield pits, in the Madeley Wood Co.'s Field, where it was stated that the workmen of one pit were stripping the Fault in the top coal, whilst workmen in the adjoining pit were doing the same thing in the clod coal, 60 yards lower down, and 900 yards nearer to what is supposed to be the trough of the estuary, which would give a slope of 1 in 15. In some instances portions of coal were stated to have been broken off and rounded by the action of waves or currents; in others, as at the Hill's Lane and Shaw Field pits, the strata on approaching the line of denudation was disturbed, and often vertical. Instances were also given, as at Caughley, where the measures having been denuded, excepting the lowest, a younger series had been formed above them; and again, as at Linley, where, the whole of the older series having entirely disappeared, a younger group rested upon Old Red Sandstone. Looking at the island-like form of the Brown Clu Hills, and at the wide tracts from which the coal-measures had been swept clean away to the south, and along what might be supposed to be the mouth of the estuary, also at the result of the borings made through the red rocks, and at the fact that first the Permians, then the Bunter, and lastly the Keuper sandstones came in one after the other as receding from the coal-field, the author was of opinion that for sixteen miles (that is, from the margin of the Shropshire to that of the Staffordshire coal-fields) the measures had been swept away, with the exception of such portions only as might have been saved by depression, the results of faults prior to denudation, or others to the north-east in the direction of Cannock Chase, which might have been out of reach of the waters of the estuary.

The author added that, so far as he was aware, there was nothing on the opposite or western side of the South Staffordshire coal-field inconsistent with this view. There were perhaps a greater number of slip faults on that side on approaching the western boundary of the coal-field, but these and similar facts, when read by the light of those found on the Shropshire side, afforded grave reasons for further inquiry, if not for the belief that either by some strait or estuary the coal-measures had, with the exception hinted at, been destroyed over a very wide surface.

On the Physical Causes which have produced the unequal Distribution of Land and Water between the Hemispheres. By J. W. Reid.

On certain Phenomena in the Drift near Norwich. By J. E. Taylor.

The Water-bearing Strata in the neighbourhood of Norwich. By J. E. Taylor.

"Paléontologie de l'Asie Mineure." By M. Tchihatchef.

M. Tchihatchef, in presenting to the Association a work entitled "Paléontologie de l'Asie Mineure," and Atlas of Plates, stated that this work contained descriptions of fossils collected by him in Asia Minor, by Viscount d'Archiac, E. de Verneuil, and M. Fisher. All the new and rare species are figured in the Atlas. The total number of species enumerated and described in this work is about

600; at the time M. Tchihatchef began his explorations in Asia Minor the total number of the known fossils of this country did not amount to 30. It was also stated that the treatise on the geology of Asia Minor, of which this work was a part, had been lately completed. In conclusion, a reference was made to the flattering notice of this work by Sir Roderick Murchison in his last Address to the Geographical Society.

At the Nottingham Meeting, the author presented to the Association a topographical and geological map of Asia Minor, and on that occasion gave a sketch of the principal geological features of Asia Minor.

On the Diamonds received from the Cape of Good Hope during the last year. By Professor J. Tennant, *F.G.S.*

On new forms of Pteroplax *and other Carboniferous Labyrinthodonts, and other* Megalichthys. By James Thomson (*Glasgow*), *F.G.S. With Notes on their Structure,* by Professor Young.

During the past year the author has continued his investigations into the vertebrate forms of the Lanarkshire Coal-field, and has added many specimens of reptiles and fishes to those brought under the notice of the Meeting last year. Some of them are so well marked as to supply characters sufficient to admit of them being referred to their systematic position, and he had been fortunate in securing the cooperation, for their anatomical description, of Professor Young of the Glasgow University. The author anticipated that in the course of the next year Professor Young would be able to figure and describe them in a way which will satisfy the systematic or anatomical student.

They are found resting upon a thin seam of coal, which varies from five to fifteen inches in thickness; upon the surface of this coal there occurs a thin seam of shale, which forms a parting between the coal below and an ironstone band above. It is in this parting that the remains are found, and to the fact of their having been imbedded in the soft pulpy mass of the shale may be attributed the perfect state of preservation in which they are found. In the superimposed ironstone are also found similar remains, but owing to the hard matrix, they are seldom obtained in good preservation.

The ironstone belongs to the Upper Coal-measures, and represents a basin of limited extent, and is situated upon the south side of the river Avon. The same stratum has been identified in other parts of the Lanarkshire coal-field, but in no place have there been discovered so many fossil remains as at Quarter, and it is to be regretted that, from the limited extent of the basin and the length of time it has been wrought, it is now almost exhausted, and a few weeks will terminate the present workings.

Notes on their Structure, by Professor Young.

Among the specimens in Mr. Thomson's cabinet, Prof. Young distinguished two new species of Labyrinthodonts, for which he proposed the generic name *Megalerpeton.* Generic characters:—Cranium narrower than that of *Anthracosaurus* in the proportion of 4 to 5; posterior nares between first and second pairs of tusks; pterygomaxillary apertures commence an inch behind them; mandible tapering rapidly to symphysis, coarsely pitted externally; teeth regular, equal, their base oval transversely to jaw; crown circular, blunt, slightly recurved. The vertebræ differ somewhat in proportion from those of *Anthracosaurus*; their transverse processes are oblique downwards, those of *Anthracosaurus* horizontal.

Megalerpeton plicidens. Convolutions sinuous, occupying larger part of transverse section, encroaching very much on pulp-cavity.

M. simplex. Pulp-cavity larger; folds straight, the alternate long plicæ reaching only halfway from circumference to pulp.

Pteroplax brevicornis, n. sp. The characteristic tooth (formerly known as *Rhizodus lanceiformis*) of *Pteroplax* is found associated with crania which differ from *P. cornuta,* Hancock & Atthey, in the proportions of the muzzle, and the position and dimensions of the orbital cavities, as well as in the dimensions of the occipital cornua. Measurements of two crania in inches:—length 12 and 13, breadth 6·5 and 9·5; breadth between cornua 2·87 and 2·75. The characters do not in the meantime justify the establishment of a new genus for these crania.

Megalichthys. The following species were defined from specimens in Mr. Thomson's cabinet, obtained from the Lanarkshire coal-field:—

M. Hibberti. Scale covered with fine-grained, smooth, glossy enamel. In this species occurs most frequently that imperfect development of ganoin referred to in Q. J. Geol. Soc. 1866, pp. 607–8.

M. coccolepis, n. sp. Scale usually of a rich brown colour, set with stellar tubercles, recalling the "berry-bone" of the Old Red Sandstone.

M. rugosus, n. sp. A less frequent form; the scale is usually pale, not enamelled, covered with asperities more or less confluent, never stellar. With this scale is associated a tooth which Dr. Young described as diagnostic of *Rhomboptychius* (Q. J. Geol. Soc. 1866, p. 606), but which turns out to be common to two distinct genera.

On Teeth and Dermal Structure associated with Ctenacanthus. *By* James Thomson, *F.G.S.*

The author stated that he had discovered in the spring of this year, in the neighbourhood of Airdrie, Lanarkshire, a slab of ironstone measuring 30×14 inches; although only a fragment, yet it exhibits, 1st, a mass of shagreen; 2nd, two spines of *Ctenacanthus major*; 3rd, a number of teeth, *Cladodus mirabilis*, Agassiz, evidently in their proper relative position, the slightly curved line in which they are disposed suggesting the contour of the mouth, and lying at a higher level than those which were exposed; 4th, a fragment of a small spine, the cross section of which gives as its outline a spherical triangle with the posterior side less than the others; the anterior face is round and smooth, while the posterior face is flat. Along the margins of the posterior face there are two rows of pointed tubercles curving inwards and downwards. Being thus formed on the upper surface of the head, it is natural to infer that it was situated on the occipital region of the fish. This inference is supported by subsequently finding another spine imbedded in another slab, which, like the former, is associated with the teeth of *Cladodus mirabilis*.

On removing the ironstone from the underside of the slab immediately over the mouth, the author laid bare the skin, and found imbedded on its surface numerous minute bodies, consisting of two, three, and four curved diverging points rising from an expanded base, from which a sharp keel on the convex side passed to the apex of each.

On other parts of the slab are found similar bodies, larger than those found on the crown of the head, but possessing similar tooth-like characters, divided into two, three, four, and in a few instances into six divergent points, and keeled along the convex or dorsal side; and on a slab which Dr. Rankin Carluke allowed the author to examine, were found a mass of similar teeth-like bodies, which exhibited similar characters, in one instance divided into fifteen divergent points, and also associated with the teeth of *Cladodus*.

In another slab, found at the same place and at the same time, were imbedded in a patch of shagreen the so-called teeth of *Diplodus gibbosus*, very numerous, and crowded together without order. We have associated with these another form of teeth-like tubercles, smooth, enamelled and circular in section; they are relatively larger, while the recurved apex is more pointed than the tubercles before described; they are occasionally found in patches of greater numbers; in some instances in clusters of eight and nine, and are attached to broad flat bases. Finding such an amount of co-related evidence, the author prepared microscopic sections of patches which were detached from the mass. After doing so, he was led to refer to the results of other investigators, and found that Professor Owen had got forwarded to him from Mr. Craggs similar forms found in the Newcastle coal-field, and which he described in a paper read to and published by the Odontological Society. He describes them as teeth, some of which he names *Ditodus divergens*, *Mitrodus quadricornus*, *Ochlodus crassus*, *Gastrodus prepositus*.

In a paper by Messrs. Hancock and Atthey, published in the Northumberland and Durham Natural-History Society's Transactions, they describe similar bodies, which they found attached to patches of shagreen, and much resembling those found in the Scottish beds.

As some of the forms described by Professor Owen agree in detail with the sections made by himself, the author felt much puzzled at finding the different forms distributed over and attached to the same shagreen; in order to arrive at a somewhat satisfactory conclusion, he examined a number of the recent Rays.

Founding on the analogy of existing rays his conclusions are:—

1st. That the two spines of *Ctenacanthus* belonged to the same animal, both probably spines of dorsal fins, the smaller being the anterior.

2nd. That the animal was provided with the teeth known as *Cladodus* of Agassiz.

3rd. That the body of the animal was covered with fine shagreen.

4th. That among this fine investure were scattered large structures of *Diplodus* of authors, which stand to the shagreen in the same relation as does the placoid armature to the fine denticulate tubercles of existing Rays.

5th. That among the living forms the sexual differences are to be noticed in the dermal development, differences which find their probable counterpart in the fossils. The dermal characters in the fossils are those of Rays.

Whether the views here stated be accepted or rejected, the author hopes the identification attempted may serve as a basis for further observation.

On the distribution of shattered Chalk Flints and Flakes in Devon and Cornwall. By N. Whitley.

On the Occurrence of Stylonurus *in the Cornstone of Hereford. By* H. Woodward, *F.G.S.*

The author exhibited drawings of the great *Stylonurus Scoticus* and of the smaller *S. Powriei*, both which species have been obtained in a nearly perfect state in the Old Red Sandstone of Forfarshire.

He referred to the finding of *S. Symondsii* in Herefordshire, a species agreeing in size with the *S. Powriei* of Forfarshire, and showed that in the new species we have evidence in Herefordshire of a crustacean belonging to the *Merostomata* and to the genus *Stylonurus* as large as the great *S. Scoticus.* The specimens (which were exhibited) were discovered by Dr. M'Cullough of Abergavenny.

On the Discovery of a large Myriapod of the genus Euphoberia *in the Coal-measures of Kilmaurs. By* H. Woodward, *F.G.S.*

The author referred to the original discovery of a Myriapod (*Xylobius Sigillariæ*) in the coal of Nova Scotia by Dr. Dawson in 1859*, and to its subsequent discovery by Mr. Thomas Brown in the coal-measures of Kilmaurs, near Glasgow, in 1866, or earlier†.

He mentioned the discovery of a much larger form of Myriapod in the Illinois coal-field, described by Messrs. Meek and Worthen in the 'Geology of Illinois,' vol. iii. (1866), and stated that one equally fine (4 inches in length) had been found at Kilmaurs by the late Mr. Thomas Brown, which he referred to the same genus as that from Illinois (*Euphoberia*), and named it, after its discoverer, *Euphoberia Brownii.* This new Myriapod, of which a specimen and drawings were exhibited, like *Xylobius,* occurs in the ironstone-nodule bed of the Coal-measures.

Freshwater Deposits of the Valley of the River Lea, in Essex. By H. Woodward, *F.G.S.*

The author based his communication upon the observations made during the

* Quart. Journ. Geol. Soc. 1860, vol. xvi. p. 272.

† H. Woodward on *Xylobius,* Trans. Geol. Soc. Glasgow, 1867, vol. ii. pt. 3. p. 234.

formation of new reservoirs and filtering-beds by the East London Waterworks Company. Two new reservoirs are now being made, covering 120 acres in extent, and of an average depth of 10 feet. The "puddle-walls" are excavated to a depth of about 25 feet. The materials removed are all of posttertiary age, consisting of surface soil, loamy clay, peat, shell-marl, coarse and fine sands, rounded and subangular gravels from the Chalk and Woolwich series, with pebbles of chert and sandstone from the older rocks. The deposit is rich in vegetable remains, the peat attaining a thickness of three feet, and containing evidences of the oak, the alder, the hazel, and other trees and plants. The shell-marl is at places equally thick, and is rich in shells, twenty-six species having been determined by the author. The bivalve shells are still united, and the *Paludinæ* &c. have their opercula still in place. Of the animals may be mentioned human remains and works of art of the stone, bronze, and iron age. The wolf, the fox, the beaver, horse, wild-boar, red deer, roebuck, fallow deer, reindeer, the elk, the goat, three oxen (including *Bos primigenius*, *B. longifrons*, and *B. frontosus*), the sea-eagle and some fish-remains complete the list. In the deep trenches of the puddle-walls tusks of the Mammoth and horns of the gigantic *Bos* and *Cervus* have been found. Mr. A. W. Franks, F.S.A., Keeper of the Ethnographical Collections in the British Museum, has obtained from this deposit a flint scraper, two bronze spear-heads, one bronze arrow-head, one bronze knife, an iron sword (late-Celtic), bronze sheath, a Kimmeridge-clay armlet, a pierced axe-head of stag's horn, a bone knife, a stag's horn, club, various earthen pots (some hand-made and some turned on the wheel), besides many cut bones. In 1300 all Essex was one vast forest. In 1154 the forest of Middlesex commenced at Houndsditch and extended north and east for many miles, and the forest is described as abounding in wolves, wild boars, stags, and wild bulls. The Walthamstow marshes have not been disafforested more than 100 years. Of the antiquity of these deposits no doubt can exist, for the presence of the reindeer, the elk (determined by Professor Owen), and the beaver is conclusive. Their preservation so near the surface is entirely due to the protective influence of forest vegetation, which has precluded the inroads of agriculture. The author expressed his belief that the deposits indicated, at places, the effects of beaver-works, tracts of forest having been to all appearance submerged and destroyed by the action of beaver-dams.

BIOLOGY.

Address by C. Spence Bate, *F.R.S., F.L.S., Vice-President of the Section, to the Department of Zoology and Botany.*

Allow me on taking possession of this chair to say, as a resident of Devonshire, how gratified we all feel at receiving you as Members of this Association. It is now nearly thirty years since this county had the honour of last receiving you. In the year 1840 you paid a visit to Plymouth. You were then a Society young in years, with many and powerful enemies to contend against. Since that time you have grown in dimensions, and become a power in the State, and second to none in your influence on, and encouragement of, science among the generally educated masses of the country.

With the importance that the Society has assumed, has sprung up a natural and honourable rivalry among the more important towns in the country as to which shall have the honour of receiving you. On this occasion the good fortune has fallen to Exeter, and well we are assured that the hospitality of Devonshire may be trusted in the safe keeping of the "Ever-faithful City."

But this desire to show welcome to you is not confined to this town; the excursions to Plymouth, Torquay, Bideford, &c. are evidence of a wish on the part of the inhabitants of the county generally to bid you welcome, and to receive you heartily; nay, this desire is not confined to Devonshire, but further west; in

Cornwall the Natural-History Society of Penzance has projected an excursion to the Land's End, to visit the Druidic remains of interest in that district. This they have arranged so as to suit the convenience of such members who, after the Meeting, may like to extend their visit to that locality.

To the Members of the Association who are interested in this Section these two counties must ever have peculiar features of interest. A peninsula jutting out from the rest of England, surrounded on all sides by the Atlantic Ocean, with the exception of a narrow neck of land of about thirty miles in length, must have features exclusive its own.

This position gives it a peculiarity of climate,—a circumstance which also has its influence on its vegetation as well as on its animal life. The isothermal line of these counties is that of nearly the southern part of Europe. This can be best appreciated in the fact that the glowworm may be seen to shine in December, and strawberries not unfrequently gathered at Christmas. Perhaps there is no part of England that affords such varied contrast as may be seen in this county. The wild and rocky district of the north, the uncultivated waste of Dartmoor, together with the fertile valleys of the southern shores, offer every inducement to naturalists to extend their researches in their interesting paths of science.

The narrow neck of land that separates the ancient Damnonia from the rest of England lies between Bridgewater Bay and Lyme Regis, a line running nearly due north and south. It is one, moreover, which corresponds with the most westerly limit of the Nightingale. This in itself has long been a subject of interest to the inhabitants of these counties. That it is not due to food we think is evident; for in the more northerly latitudes the sweet songster keeps nearly to the same line of longitude, and appears to avoid the western district of Wales also.

The influence of the geological character of soil in the growth of plants may be well studied here. Examples may be seen in the luxuriant condition of the elm-trees, when growing in the Red Sandstone valleys of this neighbourhood; while the oak may be seen to flourish as a weed in the abundant coppice, on the slaty and granitic soils of the western extremity of the county. Perhaps to the botanist no more curious and interesting sight can be seen in the west than that of Wistman's Wood. In the heart of Dartmoor has continued, without apparently any young growth, a grove of oaks that have been recorded in the Duchy annals within a short period of the Norman Conquest. Here for a thousand years these knarled and knotted trees have spread out their branches and sent forth their green leaves every year, without apparently having the power to grow higher than some few feet above a tall man's head. Their roots are amongst the granite boulders, from which apparently they can procure no nourishment. They exist as one of the greatest botanical wonders of the county.

But there are more notable distinctions than that of geological conditions to account for the distribution of plants. On the slope of the Dartmoor hill-sides every tourist must have noticed long grassy trackways where the turf has never been encroached upon by the heather that luxuriantly flourished on either side. Here is a suggestive hint that the chemist would be of service. It demonstrates how nearly one branch of science is dependent upon another.

There are many plants more or less common in this county, which the botanist will not find, or only rarely, in other parts of England.

To the zoologist, this western peninsula must have much of interest. Dr. Leach and Col. Montagu stand side by side as pioneers in British zoology. They made most of their collections in Devonshire, and it is but within a few weeks that their old companion, Charles Prideaux of Kingsbridge, died, leaving his collection, many specimens of which were procured in company with Dr. Leach and Col. Montagu, to the museum of his native town.

The Reports to this Association from time to time show that in marine zoology these western shores are among the most variedly rich in the country.

Besides the zoologist and botanist, those Members of this Section who study the science of ethnology will find much to interest them in the antiquities that are known, and which we should be among the foremost to preserve from destruction. When a conspicuous monument of the old stone records is broken down, as the Maen-rock of Constantine, a hue and cry is made, but there are less known, but not less important evidences of the unwritten history of the ancient inhabitants of these islands continually being destroyed, and no man the wiser. A cromlech, that a few years since was standing by Merivale Bridge, being part of a series of antiquities in that locality, has this summer been wantonly cleft in two.

A short time since, near Padstow, a tumulus, in which was found a vessel with bones, was carted away by the farmer of the neighbourhood for the sake of the earth. It was only last summer that an interesting barrow near Tintagel, peculiarly and carefully constructed, with a kistvean in the centre, with a waterproof covering over it, containing bones in a good state of preservation, was opened, and the things all lost. A large landed proprietor in the north of this county has told me that he has often opened burial mounds in his neighbourhood, but found nothing. Such things as bones, pottery, and stone implements he thought not worth observing; by nothing he meant no bronze or gold ornaments.

On the wastes of Dartmoor and the uncultivated lands in Cornwall stand many an unrecorded monument of antiquity; year by year these are gradually passing away. It appears to me that it is the duty of the ethnologists of this Section earnestly to take steps to record all of those that are in existence, to explore those that have not been examined, and to preserve all from destruction.

Zoology and Botany.

On alteration in the Structure of Lychnis diurna, *observed in connexion with the development of a parasitic fungus. By* Lydia E. Becker.

Specimens were produced of the common red campion, *Lychnis diurna*, infested with a parasitic fungus allied to the "smut" in wheat, which fungus developes its fructification in the anthers of the flower. The campion, in its ordinary healthy state, has flowers bearing stamens only, or pistils only, but about half the plants infested with the parasitic fungus bear flowers with both stamens and pistils in the same flower. The writer had never seen bisexual flowers on healthy plants, and attributed the occurrence of that condition in the specimens produced to the presence of the parasitic fungus. The diseased plants very rarely produced capsules, but occasionally, late in the season, perfect capsules, bearing good seed, are found on them. A few of these flowers had been submitted to Mr. Charles Darwin, and he had suggested that the pollen being destroyed at an early period, the pistil was developed in compensation. But though this explanation appeared probable at first sight, further examination of the facts did not seem to sustain it. The writer believed the influence exerted by the pollen to be of a much more subtle and surprising character than this, and that instead of causing the development of a pistil in a plant that would have produced stamens only if left to itself, the fungus has the power to cause a plant which in its natural condition would have produced pistils only, to develope stamens for the accommodation of the parasites. She supposed that the spores of the fungus fell on the stigma of the flower, and infested all the seeds produced by that capsule; that of these, all the seeds which would naturally have produced plants bearing stamens only remain unaffected in structure, but they have their pollen destroyed by it; that those which would naturally have produced pistils only develope these to a certain extent; but as the fungus which pervades the tissues of the campion cannot produce spores without anthers to fructify in, it compels the plant it inhabits to develope these for its accommodation, and the effort of so doing exhausts the forces of the plant, and causes the decay of the capsule, if indeed the previous stunting of the style does not prevent fertilization. The parasite comes like a cuckoo, establishes itself in the flower of the campion, and in order to nourish and find accommodation for the spores of the stranger its own offspring perishes. The production of healthy capsules late in the season may be accounted for by supposing that the vigour of the fungus becomes exhausted, and the pressure being removed the plant resumes its natural functions. The fact that only about half the diseased plants are bisexual favours the theory that the latter are female plants, in which the growth of stamens has been induced by the presence of the fungus.

On the Fauna of British India, and its relations to the Ethiopian and so-called Indian Fauna. By WILLIAM T. BLANFORD, *F.G.S., C.M.Z.S.*

In the various works published of late years on the geographical distribution of animals, it has been almost invariably assumed that the fauna of India proper and the Malay countries is identical. This is not the case, however; the fauna of the Himalayas, especially to the eastward, is purely Malay, and that of the hills along the Malabar coast and in Ceylon has very marked Malay affinities; but the fauna of the plains of India generally is, if anything, more closely allied to that of Africa than to that of Malayasia.

Illustrations of this fact were given from the Mammals, Birds, and terrestrial Mollusca, these being chosen as having been most carefully examined, and their range most accurately ascertained. Thus, taking the common larger mammals found in the very centre of India around Nagpúr, excluding small rodents and Cheiroptera, because their range is less accurately known, it is found that one belongs to a genus peculiar to India, nine to genera common to Africa and the Malay countries, eleven to genera, viz. *Mellivora, Cynailurus, Hyæna, Canis* (two species), *Vulpes, Lepus, Antilope*, and *Gazella*, found also in Africa, but wanting in the Malay countries, and only five to forms, viz., *Presbytis, Cuon, Rusa, Axis*, and *Gavæus*, represented in the Malay countries, but not in Africa. Of the species two are common both to Malayasia and Africa, sixteen are peculiar to India, four (*Felis tigris, Cuon rutilans, Rusa Aristotelis*, and *Gavæus gaurus*) extend to the eastward into the Malay countries, but not to the westward, while three others (*Felis chaus, Cynailurus jubatus*, and *Hyæna striata*) are common to Africa and India, but extend no further to the east. The generic lists, however, give a far more fair view of the real affinities of the Central-Indian fauna, because many Indian forms, like *Mellivora indica, Canis aureus, Lepus ruficordatus, Gazella Bennettii*, are scarcely separable as geographical races from those inhabiting the distant Ethiopian region, while such forms as *Axis maculatus* and *Prochilus labiatus*, although represented in the much less distant Malay countries, are replaced there by forms differing much more widely, and indeed classed by many naturalists in distinct genera. Also it should be noticed that the African and Palæarctic types (excluding Himalayan animals), which extend to India but no further to the south-east, comprise the *Hyænidæ, Canidæ* (with the sole exception of *Cuon*), *Leporidæ*, and *Antelopidæ*, whilst the only great family of Mammals, which extends to India from the Malay countries, and is not found in Africa south of the Atlas, is the *Cervidæ* (*Rusinæ*).

The same is seen amongst the Birds; for instance *Neophron, Pterocles*, and *Otis* occur throughout India, but are completely unrepresented in Malayasia. Amongst common Central-Indian forms are:—

Neophron percnopterus.	Lanius lahtora.
Aquila fusca.	Hirundo filifera.
Circus Swainsoni and C. cineraceus.	Motacilla dukhunensis.
Palæornis torquatus.	Pastor roseus.
Cypselus batassiensis.	Gymnoris flavicollis.
—— affinis.	Ammomanes phœnicura.
Malacocircus Malcolmi and M. Malabaricus.	Pyrrhulauda grisea.
Chattarhæa caudata.	Calandrella brachydactyla.
Oriolus kundoo.	Pterocles exustus.
	Otis Edwardsii.

All are either found in Africa or represented by closely-allied forms, but not found or closely represented in the Malay countries. On the other hand, there are several Malay types equally abundant, as—

Poleornis teesa.	Tephrodornis pondiceriana.
Xantholæma indica.	Orthotomus longicauda.
Eudynamys honorata.	Acridotheres tristis.
Lanius erythronotus.	Pavo cristatus.

But in most cases these are more or less represented in Africa, whilst a larger number of the African types have no closely allied forms in the Malay regions.

In Bengal, however, Orissa, Malabar, and Ceylon, Malay forms are much more largely represented, while the African types disappear. Throughout the southern portion of the peninsula of India, south of the Kistna river, several peculiar forms occur, like *Presbytis Priamus, Macacus radiatus, Tapaia Elliotici, Lepus nigricollis,* some of which have Malayan affinities, though by no means all.

The distribution of the Carnivora and Ruminants was discussed, and that of the Birds also treated at some length. Amongst the operculated land-shells it was shown that the *Cyclophoridæ*, which are chiefly developed in Malayasia, extending to South America, though largely represented in India, are almost confined to the Bengal, Malabar, and Ceylonese subprovinces, whilst *Cyclotopsis*, a genus of *Cyclostomidæ*, a family widely developed in Southern Europe and parts of Africa, is widely distributed over India.

It was further shown that, although many of the African animals belonged to desert types, others, such as *Pterocles bifasciatus, Otis aurita, Tockus gingalensis,* belong to African bush or forest forms, and the absence of species of such marked forest birds as the *Treronidæ* and *Bucerotidæ*, except those most nearly allied to African types in the forests of Central and Western India, was commented upon.

The extraordinary divergence in the migratory birds of Bengal and Western India received notice. Besides the better known cases, it was shown that *Circus melanoleucos, Erythrosterna leucura,* and *Gallinago sphenura* were confined, so far as is known, to the eastern portion of India, whilst *Erythosterna parva*, at least five species of *Saxicola, Emberiza Huttoni*, two species of *Euspiza, Circus cyaneus, Cotyle rupestris,* and others, are only found in the West and Centre.

In Upper Burma there are a few forms with Indian affinities, which are not represented in the Malay countries proper. Such are *Lepus peguensis*, the Jackal (perhaps introduced), *Francolinus peguensis, Pericrocotus albifrons*, a *Chattarhæa*, &c., and two African or desert forms of land shells, *Pupa insularis* and *P. cœnopicta.*

Altogether it was considered that India proper was not an integral portion of the Malay zoological province, but a border land containing a mixture of the Malay and Æthiopian faunas, and it was suggested that the name Indian region might be advantageously changed to Malay, as the employment of the former involves error.

On the genus Boswellia, *with Descriptions and Drawings of Three new Species. By* Dr. Birdwood.

Remarks on a recently discovered Species of Myxogaster. *By* C. E. Broome.

Trichia flagellifer was discovered on shoots of Spruce Fir in the winter of 1865, by the Rev. M. J. Berkeley, since which time it has occurred more abundantly on rotten stems of *Rubus fruticosus*. The specific name was given to it on account of the threads or elaters being repeatedly divided at their ends, thus resembling small scourges. A more careful examination of its structure was made in the winter of 1868, and the result showed that it forms a connecting link between the genera *Trichia* and *Physarum*, possessing the spiral threads of the former combined with the adnate capillitium of the latter. Fries describes the capillitium of *Trichia* as "densely interwoven, and its threads adnate at the base," by which he means, as the context shows, that the threads are attached to each other, but not to the peridia. Corda, in his 'Icones,' followed by Wigand, 'Annales des Sciences' for 1862, describes the capillitium of *Trichia* as developed freely in the centre of the peridium. Wigand says that "sections of the peridium of *Trichia* show the capillitium occupying generally the central cavity of the peridium, the mass of spores filling the space intermediate between the capillitium and the walls of the peridium, and that the individual elaters are generally simple, or only slightly branched, and detached from each other, and characterized by spiral projections." In the nearly related genus *Arcyria* the threads of the capillitium often form reticulations by their adhesion to one another, and are distinguished from the threads of *Trichia* by annular, or unilateral, instead of spiral prominences. Abnormal elaters of *Trichia furcata* are figured by Wigand, combining the spiral threads of *Trichia* with the annular structure of *Arcyria* in one and the same elater, showing the close affinity of the two genera. The elaters of all the species of *Trichia* known previous to the discovery of *T. flagellifer* are pointed at each end, and not attached to the peridium. In the genus *Physarum* the branched threads are adnate to the peridia at or near the base, as in *Trichia flagellifer*, but they have no spiral projections. *Physarum metallicum*, Berkl., exhibits other characters, found also in *Trichia flagellifer*, viz. a metallic lustre on its peridium, and flesh-coloured spores. The latter plant is thus described in the 'Annals of Natural History' for 1866:—"*Trichia flagellifer*, n. sp.; globosa sessilis, metallica; flocci apice flagelliferis; sporis carneis." This species is readily distinguished from its congeners by the metallic peridium and colour of the spores, and from *Physarum* by the spiral bands of its threads, which appear to be four or five in number; its spores are smooth and subglobose, and measure 0·0003 to 0·0004 inch in diameter; where the elaters branch off a line of junction is perceptible a considerable way below the point of union, the same spirals involving both threads. We may regard these gradations of structure in the genera *Arcyria*, *Trichia*, and *Physarum* as a proof of the arbitrary nature of generic characters, and, while we are compelled to retain such divisions for our own convenience, we must regard them as merely conventional; and, not to go the length of some naturalists, who deny the existence of species, even in a modified sense, we are forced to acknowledge that the more each plant or animal is studied and investigated, the more nearly do we find it connected with other individuals, the transition often becoming so gradual that it is impossible to say where one species ends and another commences.

The Mammalian Fauna of North-west America.

By ROBERT BROWN, *F.R.G.S. &c., Botanist to the British Columbia Expedition.*

Looking at North-west America as that portion of the country to the west of the Rocky Mountains, north of California, an extended study of its mammalia had led the author to divide it into several zoo-geographical regions, which may be briefly classified as follows:—

1. The region east of the Cascade Mountains.
2. The region west of the Cascade Mountains.

Again, the region between the Rocky Mountains and the Cascade Mountains, *i. e.* east of the Cascade Mountains, is divisible into:—

(*a*) A north-eastern district. (*β*) A south-eastern district.

In the same manner the region west of the Cascade Mountains and between the Cascade Mountains and the Pacific, can be classed into:—

(*a*) A north-western district. (*β*) A south-western district.

3. A mountain-region.
4. A littoral region, divided into four districts.

(*a*) Arctic. (*γ*) A northern.
(*β*) Sub-arctic. (*δ*) A southern.

I. *Region East of the Cascade Mountains.*

This region extends throughout the whole of North-west America, but ends rather before the termination of forests, the Rocky Mountains, according to Mr. W. H. Dall*, not extending straight north to the Arctic Ocean, but bending off to the westward, and uniting with the Cascade range, to form the Alaskan Mountains of the peninsula of Aliaska. This latter range is the Northern boundary of the true Pacific fauna, the species of animals as well as plants found to the northward of it apparently belonging (when not members of the Arctic fauna) to the fauna and flora of the east of the Rocky Mountains

* Proc. Boston Soc. of Nat. Hist. vol. xii. Nov. 4th, 1868; and with map in Petermann's 'Geographische Mittheilungen,' 1869, p. 364, tafel xix.

rather to the peculiar assemblage of forms included in the region to the west of that range. This region is not so wooded as the one to the west of the Cascades, and possesses a climate cold in winter and hot in summer. North of the limit of trees, certain purely Arctic species (such as the white fox, the polar bear, and the musk ox find a home. These species never come within the tree limit (which is about Kotzebue Sound).

a. North-eastern District.—The species characteristic of it are: *Vulpes macrourus* var. *decussatus, Erethizon epixanthus, Rangifer caribou, Alces Americana* (rare), *Fiber ooogensis, Arctomys okanaganus, Lagomys minimus*, and *Gulus luscus.* The Columbia River may be said to be about the dividing line between it and the next, though their zoo-geographical lines can be but vaguely drawn.

β. South-eastern or Californian District.—The mammalian fauna here partakes more of the Californian type*. The species characteristic are:—*Lutra Californica, Lepus artemesia, Cervus macrotus, Antilocapra Americana,* with many other species common to it and California.

II. *Region West of the Cascade Mountains.*

Most of this province is densely wooded (the northern portion more especially), with a greater rainfall than the country to the east, the rainfall at Sitka sometimes extending to 89 inches per annum. The southern portion of the region is more open, and a break occurring in the range, where it joins the Sierra Nevadas, some of the eastern species come over, but still the difference between the two faunas is sufficiently well-marked to be divided into:—

a. The North-western District.—The characteristic species are all mammals of a wooded country, and among typically representative species comprise—*Sorex Suckleyi, S. Trowbridgii, Scalops Townsendii, Lynx fasciatus, Mephitis occidentalis, Aplodontia leporina,* and various species of squirrels.

β. South-western District.—*Lepus Washingtonii, L. campestris, Canis latrans*, &c.

III. *Montane Region.*

After ascending to an elevation, varying according to latitude from 3000 to 5000 feet on the whole of the higher mountain-ranges throughout N.W. America, a new group of plants and animals make their appearance. They constitute the Alpine fauna and flora of North-west America. Though there is a slight tendency to form a northern and a southern type of mammalian montane fauna, yet the species are very uniform in their distribution throughout this vast region. These are:—*Aplocerus montanus, Ovis montana, Lagomys princeps, Arctomys* (*flaviventer*?) and *Neosorex navigator.*

IV. *The Littoral Region.*

We know too little of the marine mammalian fauna of this part of the world to make any classification more than merely tentative. However, the author considered the following geographical arrangement of the fauna tolerably near the truth:—

a. The Arctic District, represented by *Balæna mysticetus, Delphinapterus leucas*, and *Trichechus rosmarus.* They are almost wholly confined within the Arctic circle, being only stragglers outside that limit.

β. The Subarctic District is represented by the now extinct (?) *Rhytina gigas*, which at one time abundantly characterized this district. It is, however, distinguished by the presence of other animals, so that the division is still retained.

γ. The Northern District, represented by *Callorhinus ursinus, Halicyon Richardsi*, a species of *Orca*, and a *Phocæna*, closely allied to, if not identical with the *Phocæna communis* of the Atlantic.

δ. The southern type of marine mammalian fauna may be said to commence about the Mid Oregon coast-line. It is represented by the sea-lions of San Francisco (*Otaria*, sp.), *Arctocephalus monteriensis, Arctocephalus* (*Zilophus*) *Gilliespii, A. Californicus, Macrorhinus angustirostris*, and various species of Cetacea. The littoral fauna, like the flora of North-west America, partakes of a Japanese type. There are certain cosmopolitan species,—*e. g.*, within the littoral fauna, *Enhydra marina*; in the land fauna, *Ursus horribilis, Cervus columbianus, C. canadensis, Ursus*

* See Dr. Cooper's List of the fauna in Kronises' 'Natural Resources of California,' and in Proc. Cal. Acad. Sciences subsequently.

americana, Procyon Hernandezii, species common to several regions—while the beaver, wolves of various species, the fisher (*Mustela Pennantii*), are found in all the districts of North-west America.

The insular faunas of North-west America are identical with those of the nearest mainland, with the remarkable exception of the Queen Charlotte Islands, about forty miles off the north-west coast of British Columbia. On these islands there are no deer or wolves, and there is rumoured to be no beaver or racoon either, though all of these animals are exceedingly abundant on the mainland.

The prevailing habitats of the mammals of North-west America may be judged from the following enumeration, the numbers affecting each locality being in a direct ratio to the order in which the habitats are mentioned.

1. Sylvan: species affecting woods.
2. Campestral: species affecting prairies and open ground.
3. Periaquatic: species found in swamps, or around streams and lakes.
4. Marine: species frequenting or living in the sea.

Introduced or Extinct Species.

1. In addition to domestic animals, *Mus decumanus* and *M. musculus* have established themselves. The horse was originally obtained from the Comanches, who stole it from the Mexicans, into whose country it was introduced by the followers of Cortes. Among the Indians it has much degenerated, and owing to the wooded character of the country, is not found much north of the Frazer, or to the west of the Cascades.

2. With the exception of the *Rhytina*, there is no evidence of any animal having become extinct within historical periods, unless indeed the vague rumours of the *Mastodon* having been contemporary with man be received as such. The buffalo (*Bos americanus*) has, however, been exterminated in North-west America within the memory of this generation.

Systematic History of the North-west American Mammals.

The following is an approximate enumeration of the species found in each order:—

1. Cheiroptera, about 10 species.
2. Insectivora, 6 species.
3. Carnivora, 31 species.
4. Rodentia, 47 species.
5. Ruminantia, 10 species.
6. Pinnipedia, 7 species.
7. Cetacea (approximately) 12 species.

Total—123 species.

On the Salmon Rivers of Devon and Cornwall, and how to improve them. *By* Frank Buckland.

On Chiaris alba. *By* Robert O. Cunningham, *M.D., C.M.Z.S.*

After referring to the different opinions of ornithologists as to the true place of the Sheathbill in the class to which it belongs, on account of its peculiarities of form and habit, the following notes on the digestive organs of a female bird obtained in the Strait of Magellan were read:—

The tongue was rather thick and deeply hollowed on each side of the mesial line. The entire length of the œsophagus (including the proventiculus) was $6\frac{1}{2}$ inches. It presented a well-marked enlargement, which, though not materially differing in its structure from the rest of the tribe, may be regarded as a modified crop. This crop was empty. The stomach, which contained small pebbles alone, was moderately muscular, and its lining membrane was of an orange-yellow colour. Its long diameter measured $1\frac{2}{8}$ of an inch, and its greatest transverse diameter $\frac{7}{8}$ of an inch. The intestinal canal, from the pyloric orifice of the stomach to the anus, measured a little over 40 inches. The cæca, two in number and of equal size, were 7 inches long, and the distance between their origin and the anus was $2\frac{1}{2}$ inches. They considerably exceeded the diameter of the intestine at their extremities, and tapered to their origin in the intestine, at which point their diameter was much less. They were filled with a pulpy yellow substance.

On the Flora of the Strait of Magellan and West Coast of Patagonia.
By Robert O. Cunningham, *M.D., C.M.Z.S.*

The author of this paper having been engaged during the years 1866–69 in capacity of Naturalist to an expedition for surveying the Strait of Magellan and neighbouring regions, had had many opportunities of studying the fauna and flora of the district, and mentioned some of the principal facts regarding the plants.

Beginning at the eastern entrance of the Strait, and proceeding westwards to Cape Pillar, and northwards through the long line of channels extending along the west coast of Patagonia, between the western entrance of the Strait and the Gulf of Peñas, three regions may be recognized, the first and third of which are most distinctly opposed to one another in their leading features; the second, or intermediate area, forming in some respects a connecting link between the other two. Each of these areas possesses a certain number of species of plants and animals peculiar to itself, as well as a certain number common to its neighbours.

The first region is limited to the north-eastern part of the Strait of Magellan, extending from the eastern entrance to Cape Negro on the Patagonian, and rather further in a south-westerly direction on the Fuegian coasts. It consists of a vast tract of low-lying undulating plains, with here and there a range of low saddle-backed hills; and boulder-clay is the principal geological formation. It is entirely destitute of trees, and almost so of shrubs, covered with yellow grass, dry and arid in its nature, abounding in small lakes and ponds of salt water, and only here and there presenting a green oasis where a small stream finds its way into the waters of the Strait. It may be considered as a continuation of that vast tract of Pampas which extends throughout Patagonia and the Argentine Republic as far north as the extreme of the Plate. Over these plains the Guanaco, Puma, and *Rhea,* hunted by the far-famed Patagonians, roam. The atmosphere is dry and clear, and the climate a delightful and exhilarating one.

The third region is very different in all respects, being formed of very rugged mountainous country, densely covered with impenetrable evergreen woods, with intervals of bare boggy land. It may be defined as reaching from Port Famine to the western entrance to the Strait, and northwards through the channels to the Gulf of Peñas. The climate is one of the most humid in the world, the atmosphere being hardly ever free from mist, and heavy rain falling almost every day throughout the year, frequently for many days and nights together. Magnificent glaciers occur abundantly, and innumerable streams flow down the mountain sides in most places, so polishing the rugged faces of the hills as to render their ascent difficult, if not impossible, and feeding long chains of lakes and tarns which occupy the narrow and winding valleys. Deer are occasionally to be met with in the woods, and otter, seal, and porpoises in the water of the channels; but there is a great paucity of animal life in this district.

The second region intermediate in position between the other two, and also as regards its character, extends from the beginning of the wooded country at Cape Negro as far as Port Famine. Its mountains are not so steep, and its forests not so impenetrable as those of the third or western region; and it presents considerable tracts of land available for pasture. The prevailing tree in the woods is the deciduous or antarctic beech, which imparts a well-marked aspect to the landscape. Though there is a considerable rainfall, the climate cannot be considered as a wet one, and there is much fine bright weather, though the sun has no great strength. It is in this district that the Chilian colony of Punta Arenas (Sandy Point) is situated, and there cattle thrive in the open air, and various green crops come to maturity. Parraquets, Woodpeckers, and a variety of small birds, inhabit the woods; and geese, snipe, and an *Ibis* frequent the open tracts of ground.

The distribution of the various orders, genera, and species of plants throughout these three regions was then considered somewhat in detail, and the existence of a considerable number of species not previously recorded as inhabitants of them was noted. Among the additions to the flora of the first region, *Adesmia boronioides, Arabis Maclovana, Botrychium lunaria, Crantzia lineata, Hippuris vulgaris,* and *Œnothera* were specified. Instances of plants apparently peculiar to the second region, *Codenorchis Lessonii*, *Asarca Kingii*, and a species of *Maytenus* were mentioned; while *Metrasideras stipularis*, *Mitraria coccinea*, *Lomatia ferruginea*, a *Weinmannia*, a *Panax*, *Campsidium gracile*, *Hymenophyllum cruentum*, and *H. pectinatum*, were enumerated as among the more remarkable additions to the flora of the third region.

From an examination of the Phanerogamia and Cryptogamia occurring to the north and south of the Gulf of Peñas, it was concluded that many more species were common to these regions than was at one time supposed, and that no very marked alteration in the flora of the south-western coast of South America was apparent between the Strait of Magellan and Valdinia.

Prof. A. Dickson, M.D., exhibited a specimen of *Primula sinensis*, in which short styles are accompanied by short stamens.

Microscopical Observations at Münster am Stein. *By* George Gladstone, *F.R.G.S., F.C.S.*

This communication contained a list of the principal freshwater animalculæ which the author had found within the week ending August 14 in the River Nahe among the water-plants which border the river. It was very rich in the higher forms of Rotatoria, including even that rare and beautiful creature the *Stephanoceros*. *Floscularia ornata* and *proboscides* were very common, as were also the *Limnia*. *Melicerta ringens* and *Lacinularia socialis* were not rare. *Rotifer vulgaris*, *Salpina*, *Hydatina*, *Pterodina patina*, *Chætonotus*. and other forms of free swimming Rotifera were particularly abundant. Of the Infusoria, the *Vorticellina* were well represented both in respect of number, variety, and size, many of the *Vorticellæ* and *Epistylis* being unusually large. *Vaginicolæ* also occurred. The lower orders included, amongst others, *Chilodon*, *Amphileptus*, and *Amœba princeps*. Of Cypridina there were *Daphnia*, *Cypris*, and *Cyclops*. Diatomaceæ and Desmideæ were very abundant, the former class comprising *Diatom vulgare*, *Fragillaria*, *Bacillaria*, *Navicula*, *Cocconema*, and *Gomphonema*; the latter, *Closterium*, *Pediastrum*, *Micrasterias*, *Arthrodesmus*, and *Euastrum*.

The mineral water, or rather the brine, after having passed through the Gradirsalinen, was also subjected to microscopic examination. Not much was expected, as the water is highly saline, though the tanks contain millions of larvæ. The only other living creatures consisted of a very active kind of worm, some round and oval monads, *Actinophrys*, and *Amœba princeps*. The tanks were full of Diatomaceæ, principally *Fragillaria*. The brine (which is used in Münster and Kreuznach for bathing) is of the specific gravity of about 1·11, and contains about 12 per cent. of chloride of sodium, 2 per cent. of chloride of calcium, besides lesser proportions of the chlorides of magnesium and potassium, and of the bromide of sodium.

On the Law of the Development of Cereals. *By* F. F. Hallett, *F.L.S.*

From his investigations the author had arrived at the following conclusions:—

That where room has been afforded to the plant for its natural development—

1. Every fully developed plant, whether of wheat, oats, or barley, presents an ear superior in productive power to any of the rest on that plant.
2. Every such plant contains one grain which, upon trial, proves more productive than any other.
3. The best grain in a given plant is found in its best ear.
4. The superior vigour of this grain is transmissible in different degrees to its progeny.
5. By repeated careful selection the superiority is accumulated.
6. The improvement which is at first rapid, gradually, after a long series of years, is diminished in amount, and eventually so far arrested that, practically speaking, a limit to improvement in the desired quality is reached.
7. By still continuing to select, the improvement is maintained and *practically* a fixed type is the result.

The accumulation of improvement obtainable on the principles set forth in the paper was very fully illustrated by specimens.

*On some curious Fossil Fungi from the Black Shale of the Northumberland Coal-field**. *By* Albany Hancock, *F.L.S., and* Thomas Atthey.

In this paper the authors described some small lenticular bodies found in the black shale at Cramlington, Newsham, and in other localities in the district; and from the internal structure, which is well preserved, they conclude that these bodies are Fungi, related to the curious Indian form *Sclerotium stipitatum*, of Berkeley and Currey. This relationship is likewise shown by the general form and surface-characters.

Five species were described under the following names:—*Archagaricon bulbosum*, *A. globuliferum*, *A. radiatum*, *A. dendriticum*, *A. conglomeratum*.

On the Occurrence of Rapistrum rugosum, *All., in Surrey, Kent, and Somersetshire.* *By* W. P. Hiern, *M.A.*

This plant the author first noticed on the 24th of June, 1869, in Surrey, near the river Thames, below Barnes. On the 8th of July he also met with it in the Isle of Thanet, growing in corn-fields, in company with *Sinapis arvensis*, L., and other common weeds. Again, in a letter to Mr. Berkeley, dated the 18th July, Mr. Broome writes from Batheaston, in Somersetshire, "*Rapistrum rugosum*, Koch, turned up here the other day in some abundance in one place, and I have since seen it in my own meadows."

On examining the plant, the cruciform flowers, with tetradynamous stamens, refer it to the natural order Cruciferæ. Then the transversely 2-jointed fruit, with the upper joint indehiscent, brings the genus into the tribe Cakilineæ, which limits the plant to about 40 out of the 1200 species or more that are contained in Cruciferæ. Further, the indehiscent and not very small lower joint of the fruit, the conduplicate cotyledons, and the yellow flowers, bring the plant into the genus *Rapistrum*, Desv. The nearest allied British genus is *Crambe*.

The upper joint of the fruit of this plant is hairy, globular, and without two horns at the top, and is provided with meridional ribs like those of a mellon, except that they are interrupted and rugose; and the lower joint is oblong, in the form of an inflated pedicel, unlike the upper joint, and nearly as long as the fruit-pedicel. These characters refer the plant to the species *R. rugosum*, All., *R. hirsutum*, Host. *Rapistrum* contains eight well-defined species, all of which occur in the countries on the shores of the Mediterranean sea; most of them occur in Algiers, and several in the Mediterranean islands. *R. rugosum* has the widest distribution of all. The author has seen specimens in the Kew herbarium from Constantinople, Syria, Austria, Switzerland, and Algiers, from several places in Germany and France, and from the islands of Sicily, Corsica, Teneriffe, Madeira, Canaries, and Azores.

On the Relative Value of the Characters employed in the Classification of Plants. *By* Dr. Maxwell T. Masters, *F.L.S.*

This paper was devoted to the consideration of some of the means employed by botanists in elaborating the "natural" systems of classification, and to the estimation of the relative value to be attached to those means. The characters treated of were the following:—1. Characters derived from the relative frequency of occurrence of a particular form, or a particular arrangement of organs; 2, developmental characters, whether "congenital" or "acquired;" 3, teratological characters; 4, rudimentary characters; 5, special physiological characters; 6, characters dependent on geographical distribution.

To arrive at an estimate of the first class of characters, the plan followed in the paper was to enumerate, in the case of any particular "cohort" or "alliance," all the main points which had been employed by various authors to characterize the group in question, or to distinguish it from its allies, and to arrange them according to the frequency of their occurrence in the several families, placing those characters first which occurred most frequently, and afterwards, in order, those that occurred less often. It this way it was shown that those characters which are most im-

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portant, from their frequency of occurrence and invariability, are those that are congenital in their origin, while those that are least often met with are "acquired," *i.e.* later in their development. While the former are "general" in a physiological sense, the latter are special and peculiar to the smaller groups, perhaps to one family only. Further illustrations were given in explanation of these and other characters, for the purpose of showing their applicability to particular cases. In estimating the value to be attached to certain characters, it is necessary to consider the purpose for which they are required. If the object be synthetical, if we are seeking points of resemblance, so as to be enabled to group together a large number of forms into one or more large aggregates, stress must be laid, in the first instance, on the congenital characters, as serving to bind together the greatest numbers; then on those dependent on frequency of occurrence and special physiological office, afterwards on such others as may be forthcoming. If the object be analytical and discriminative, the special physiological characters demand the first attention, then those which have the merit of frequency and invariability, and then those that are congenital. The systematist can very rarely act up to his own standard. Individual cases have to be treated on their own merits, philosophy has to be sacrificed to expediency, but the tact and insight of a first-class naturalist often lead him to make combinations, or to allocate forms, on what seem mere grounds of expedience, but which afterwards prove, when fuller evidence is gained, to be strictly consistent with philosophical views.

The Rev. A. M. NORMAN made some remarks in introducing to the notice of the Section the following important letter from Prof. Wyville Thomson :—

"Belfast, Aug. 7, 1869.

"MY DEAR NORMAN,—You are already aware that, during the first cruise of this year, Mr. Jeffreys and his party dredged and took most important thermometrical and other observations to a depth of 1476 fathoms. When I took Mr. Jeffreys's place for the second cruise, it was the intention to proceed northwards, and to work up a part of the north-west passage, north of Rockall. I found, however, on joining the vessel, the gear in such perfect order, all the arrangements so excellent, the weather so promising, and the confidence of our excellent commander so high, that, after consulting with Captain Calver, I suggested to the hydrographer that we should turn southwards, and explore the very deep water off the Bay of Biscay. I was anxious that, if possible, the great questions of the distribution of temperature &c., and of the conditions suitable to the existence of animal life, should be finally settled; and the circumstances seemed singularly favourable. No thoroughly reliable soundings have been taken beyond 2800 fathoms, and I felt that if we could approach 2500, all the grand problems would be virtually solved, and the investigation of any greater depths would be a mere matter of detail and curiosity. The Hydrographer at once consented to this change of plan; and on the 17th of July we left Belfast and steered round to Cork, where we coaled, and then stood out towards some soundings, about a couple of hundred miles south-west of Ushant, marked on the Admiralty charts 2000 fathoms and upwards. On the 20th and 21st we took a few hauls of the dredge on the slope of the great plateau, in the mouth of the Channel, in depths from 75 to 725 fathoms, and on the 22nd we sounded with the 'Hydra' sounding-apparatus, the depth 2435 fathoms, with a bottom of fine Atlantic chalk-mud, and a temperature registered by two standard Miller-Six's thermometers of 36°·5 Fahrenheit. A heavy dredge was put over in the afternoon, and slowly the great coils of rope melted from the 'Aunt-Sallies'—as we call a long line of iron bars, with round wooden heads, on which the coils are hung. In about an hour the dredge reached the bottom, upwards of three miles off. The dredge remained down about three hours, the Captain moving the ship slowly up to it from time to time, and anxiously watching the pulsations of the accumulator, ready to meet and ease any undue strain. At nine o'clock P.M. the drums of the donkey-engine began to turn, and gradually and steadily the 'Aunt-Sallies' filled up again, at the average rate of about 2 feet of rope per second. A few minutes before one o'clock in the morning 2 cwt. of iron (the weights fixed 500 fathoms from the dredge) came up, and at one o'clock precisely a cheer from a breathless little band of watchers intimated that the dredge had returned in safety from its wonderful and perilous journey of more than six statute miles. A slight accident had occurred. In going down the rope had taken a loop round the dredge-bag, so that the bag was not full. It contained, however, enough for our purpose—$1\frac{1}{2}$ cwt. of "Atlantic ooze;" and so the feat was accomplished. Some of us tossed ourselves down on the sofas, without taking off our clothes, to wait till daylight to see what was in the dredge. The next day we dredged again in 2090 fathoms, practically the same depth, and brought up 2 cwt. of ooze—the bottom temperature being 36°·4; and we spent the rest of the day in making what will, I am sure, prove a most valuable series of temperature observations at every 250 fathom-point from the bottom to the surface. These enormously deep dredgings could not be continued. Each operation required too much time, and the strain was too great, both upon the tackle and upon the nervous systems of all concerned, especially of Captain Calver and his officers, who certainly did all that could be compassed by human care, skill, and enthusiasm, to ensure success. We crept home, dredging in easier depths. We start again to-morrow, and, as you may suppose, I have enough to do. I can therefore only give you the slightest possible sketch of our results, anticipating fuller information when I have time to collate the diaries and to look over the specimens. First, as to the temperature. The superheating of the sun extends only to the depth of about 50 fathoms. Another cause of superheating, probably the Gulf-stream, extends to the depth of from 500 to 700 fathoms. After that the temperature gradually sinks at the rate of about 0°·2 for every 200 fathoms. This is probably the normal rate of decrease, any deviation being produced by some special cause—a warm or a cold current. Secondly, the aëration of the water. Mr. Hunter, who accompanied me as physicist, found the water from great depths to contain a large excess of carbonic acid, and he found the water from all depths to contain a considerable proportion of dissolved organic matter; thus in every way bearing out the observations of Mr. W. L. Carpenter during the first cruise. Thirdly, distribution of life. Life extends to the *greatest* depths, and is represented by all the marine invertebrate groups. At 2435 fathoms we got a handsome *Dentalium*, one or two crustaceans, several Annelids and *Gephyrea*, a very remarkable new Crinoid with a stem 4 inches long (I am not prepared to say whether a mature form or a *Pentacrinoid*), several starfishes, two hydroid zoophytes, and many Foraminifera. Still the fauna has a *dwarfed* and arctic look. This is, doubtless, from the cold. At 800 to 900 fathoms, temperature 40° Fahr. and upwards, the fauna is rich, and is especially characterized by the great abundance of vitreous sponges, which seem to be nearly related to, if not identical with, the *Ventriculites* of the Chalk. This year's work has produced many forms new to science and many new to the British fauna. Among the most remarkable in the groups I have been working at I may mention a very singular Echinoderm, representing a *totally new group* of the subkingdom, a splendid new Ophiurid, many specimens of Sars's *Rhizocrinus Lofotensis*, many vitreous sponges, including species of *Aphrocallistes*, *Holtenia*, and *Hyalonema*; a fine *Solarium* from the coast of Kerry, and many other things. As I am only writing in the interval of scaling the boiler, with no opportunity of going over the collections, you must accept this sketch. I trust to your contributing the Crustacea, which will be sent to you as soon as possible. I will write again from Lerwick.—Ever truly yours, WYVILLE THOMSON."

On Whale Remains washed ashore at Babbacombe, South Devon. *By* W. PENGELLY, *F.R.S., F.G.S.*

The author exhibited and described three cervical vertebræ which, at intervals during the last six years, had separately been cast up by the waves on a beach near Babbacombe, and which belonged to a whale new to the British fauna (*Balamptera robusta*, Lilljeborg = *Eschrichtius robustus*, Grey). The author stated that an imperfect skeleton found imbedded in the sand on the coast of Sweden, and the vertebræ laid before the Section, were the only known evidence of the existence of the species of whale to which they belonged.

On a Hybrid or other variety of Perdix cinerea *found in Devonshire.* *By* Dr. W. R. Scott.

The author stated that in the year 1859–60 there appeared in the western part of Devonshire a covey of partridges, differing considerably in colour from the common species, *Perdix cinerea*, many of which were obtained and preserved. In 1861–62 a covey of twelve of these birds were observed, differing only from those first seen by some of them having white feathers on their breasts. In 1862–63 birds of the same description were obtained, so that from the year 1859 to 1863 these birds appeared in this district. The plumage of these birds differed from that of the ordinary species by being of a darker and richer brown uniformly spread over the whole body, in having no grey markings, and in the entire absence of the horseshoe on the breast. They had also a black patch on each cheek, extending backwards, with a tendency to form a gorget across the throat. The question was then, What were these birds? were they sports from the ordinary colour of *P. cinerea*, or were they hybrids? In either case they were remarkable; for if considered as the former, then it was certainly unusual to find a whole brood departing at once from the characters of the parents even in colour, while if they were hybrids, they were equally exceptional, as there was no case on record that he was aware of where *P. cinerea* and *P. rufa* had paired. For some time this last supposition was inadmissible, since *P. rufa* was not found in the west of England; but on stricter inquiry, it was ascertained that some had been introduced not far from the district where the birds under consideration were found, and that one of these had associated itself with a covey of the *P. cinerea*. In the eastern counties, where both species are plentiful, no hybridity has ever taken place, and it is stated that *P. rufa* drives the common bird away. But where both birds were numerous and had a sufficient choice amongst those of their own species, remoter alliances were not so likely to occur as when a single individual or so of one species only existed, and was living with a covey of the others. In either case, however, whether they were hybrids or mere varieties, the author considered them remarkable and deserving of record.

On the Land and Freshwater Mollusca of Nicaragua. *By* Ralph Tate, *A.L.S., F.G.S.*

Nicaragua was stated to present two distinct types of soil, vegetation, and climate, and the terrestrial mollusca were found to be restricted to some extent to one or the other of the districts. Of the 55 species of land and freshwater shells catalogued by the author, the following are new to science:—*Tebennophorus auratus*, *Limax meridionalis*, *Helix cæcoides*, *H. Blakeana*, *Tornatellina interstriata*, *T. hyalina*, *Planorbis declivis*, *Unio Tatei*. The molluscan fauna of Nicaragua presents no marked facies, and is characterized by the absence of, rather than by the presence of peculiar genera. The geographical position of Nicaragua would lead us to infer that its species would be in common with those of the Mexican province on the one hand, and with those of the Columbian province on the other. This is the case; thus *Bulimus Berendti*, *B. unicolor*, *B. maculatus*, *B. mimosarum*, *Helix Parkeri*, *Planorbis Fieldii*, *Cyclotus irregularis*, *Amnicola Panamensis*, *Unio Rowelli*, *Sphærium meridionale*, and *Mycetopus Weddelli* ally the fauna specifically to that of tropical South America; and *Helix griseola*, *Glandina Dysoni*, *Succinea inflata*, *Vaginulus floridanus*, *Planorbis tumidus*, *Helicina turbinata*, and *H. denticulata* are more northern forms, which in Nicaragua mingle with those of a more southern origin. *Bulimus zebra* and *Achatina octona* are common to Central and South America and the Antilles; *Guppya Gundlachi* and *Bulimus costato-striatus* are Cuban species.

The generic alliances are *Tebennophorus* with North America, *Glandina* with Central America, *Tornatellina*, *Vaginulus*, and *Mycetopus* with Tropical South America. The species common to Nicaragua and the neighbouring State, Guatemala, are:—*Melania Gassiessi*, *Bulimus zebra*, *Achatina octona*, *Planorbis tumidus*, *P. kermatoides*, *Physa purpurostoma*, *Ancylus excentricus*, *Helicina Salvini*, and *H. merdigera*.

The land snails of Guatemala, Honduras, Yucatan, and Mexico resemble those of the West-Indian Islands in the prevalence of species of *Cylindrella, Macroceramus, Adamsiella, Megalomastoma, Chondropoma, Cistula*, and *Tudora*, none of which genera have been observed in Nicaragua, and south to the Isthmus of Darien. This circumstance, viewed in connexion with the distribution of the Nicaraguan species, points to a different origin for the fauna, and the author is thereby induced to regard Nicaragua as comprised within the Columbian region of the distribution of land and freshwater shells, and not within the Mexican.

On the Effect of Legislation on the Extinction of Animals. By the Rev. H. B. TRISTRAM, *LL.D., F.R.S.*

Five Years' Experience in Artificial Fish-breeding, showing in what waters Trout will and will not thrive, with some Remarks on Fish and British Fisheries. By W. F. WEBB, *F.R.G.S.*

This paper gives the result of many experiments conducted by the author at Newstead Abbey, both in lakes and streams, by which it is evident that temperature is the main point to study. Trout will thrive well in waters the midsummer temperature of which does not exceed 62°, but when it attains 70° and upwards they sicken and die off, even in swift-running streams. The author demonstrates, by numerous examples, that both trout and all the Salmonidæ inhabit and thrive best in waters of low temperature in every part that they are indigenous to. The paper strongly advises the introduction of the Indian Mahseer into the fresh waters of Great Britain, as the author states, from personal experience, that it is a fish attaining very great weight, excellent for the table, giving sport to the angler, and from not being migratory in its habits, exempt from the destruction caused by sewage at the mouths of many rivers. The paper concludes by pointing out the great devastation caused by trawl-nets throughout the narrow Lochs of the Western Highlands, and to the rapid decrease of small fry of all sorts of fish *already* from this cause, which calls for the immediate attention of the Legislature.

On a new Isopod from Flinder's Island. By HENRY WOODWARD, *F.G.S.*

On Rhinodon typicus, *the largest known Shark. By* Professor E. PERCEVAL WRIGHT, *F.L.S.*

ANATOMY AND PHYSIOLOGY.

Human Vaccine Lymph and Heifer Lymph compared. By HENRY BLANC, *M.D., F.R.G.S., Staff Assistant-Surgeon, Bombay Army.*

Compulsory vaccination is a wise and proper measure, but this must be subordinate to one essential condition, namely, that the vaccine lymph forced upon the public shall be as pure and as perfect as we can obtain it. The present human lymph does not possess these characters. This leads us to examine the two following important questions:—

1. Can other than vaccine disease be transmitted by humanized vaccine lymph?
2. Is humanized lymph of long standing a trustworthy prophylactic against smallpox?

If we can prove beyond reasonable doubt that the transmission of disease has taken place, even if only in a few instances, these instances should render us less positive in our denials when in presence of very strong probabilities only.

Science acknowledges two orders of disease that have been transmitted by human vaccine lymph—certain affections of the skin, and syphilis.

On the 3rd of August, Dr. Depaul, the Director of Vaccination in France, in concluding, at the Academy of Medicine of Paris, a very remarkable speech on this question remarked, "Within a very short time more than forty cases of vaccinal syphilis have been observed and accepted as open to no doubt by many scientific men. All the theories, all the false interpretations, all the subtleties of those who, against evidence, persist in their denial, cannot in any way weaken these facts. *Syphilis introduced into the system by vaccination is no myth, it is a sad and terrible reality.*"

As we cannot deny the existence of the transmission of disease, the public should be supplied, in presence of compulsory vaccination, "with an uncontaminated vaccine lymph."

Is humanized lymph of long standing a trustworthy prophylactic against smallpox? It is not. The present vaccine lymph is degenerated, and has lost much of its antivariolic power.

If we begin with Jenner, we find that at that date direct inoculation from the cow, in other words, "animal vaccination," is a most perfect and lasting protection against smallpox. A few cases of post-vaccinal smallpox were noticed as soon as natural animal vaccination was superseded by the use of humanized lymph. This percentage gradually increased. In the London Smallpox Hospital from 1835 to 1845, the admission of patients attacked with smallpox, *after vaccination*, was already 44 per cent.; from 1845 to 1855 it rose to 64 per cent.; from 1855 to 1865 to 78 per cent.; and during the two years 1863 and 1864, it was as high as *eighty-three* and *eighty-four per cent.* respectively.

The deaths from smallpox after vaccination have also gradually increased, *from none in* 1800 they rose above *nine per cent.* in 1863; so that if we consider the increased resusceptibility to smallpox, and the increased fatality amongst the vaccinated, we arrive at very discouraging results; for example, during the ten years from 1855 to 1865, the mortality in the London Smallpox Hospital gives for the unvaccinated only 69 more than for the vaccinated! the number being for the vaccinated 459, for the unvaccinated 528! What does this teach us? To follow the example of those who first practised animal vaccination; do as the milkers of cows did, and seek for a perfect protection in a return to the prophylactic in all its purity.

Animal vaccination offers the following advantages:—

1. The healthy heifer, inoculated with pure spontaneous cowpox, supplies a vaccine lymph free from all morbid and diathetic principles.

2. Spontaneous cowpox, by being transmitted only through the bovine race, retains all its essential qualities.

3. Vaccination direct from the heifer offers all the characteristics of the cowpox, as described by Jenner, Ceely, &c., with such modifications only as are due to the passage of the lymph through young and healthy animals.

4. By animal vaccination we have always on hand an unlimited supply of good vaccine lymph.

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*Voltaic Electricity in relation to Physiology.** *By* W. KENCELY BRIDGMAN.

At the Meeting held in Norwich in 1868, the author read a paper on "Electrolysis in the Mouth," having reference to an occurrence of a very singular character. A ligature of silk-twist had been applied to some front teeth on account of their malposition, and, when removed, it was found to have become encrusted with a crystalline deposit, obtained from the enamel, the surface of which presented a deep groove along the entire course of the ligature.

To identify this proceeding as one of electrolytic transfer, it was sought to obtain a parallel effect with the metals, and which, according to the author's experiments, was successfully accomplished, clearly establishing their unity of origin.

On the Interpretation of the Limbs and Lower Jaw.
By Professor CLELAND, *M.D.*

In this communication the following propositions were laid down and illustrated:—

* Published *in extenso* in the 'British Journal of Dental Science' for November 1869.

1. The various systems of the body are, in at least all the more symmetrical animal forms, arranged in more or less perfect circles round the digestive tube.

2. The visceral or costal arches of the vertebrate skeleton constitute, when fully developed, circles external to those of the vascular system, and internal to the primary stratum of the muscular system, and each visceral arch is a part of a single segment of the body.

3. The limbs consist each of a girdle or limb-arch, and a radiation or appendage. That the limb-arch is not a radiation is sufficiently evident from its circling always more or less round the body, and being sometimes complete above, sometime complete below.

4. Neither the limb-arch nor its appendage is the property of one particular segment. They receive nerves from various segments, not a very definite number, and are very variable in position, especially the hind limb.

5. Probably the typical position of the limb-girdle is superficial to the primary muscular layer, as in the pectoral girdle of most animals, but it varies in position, and this is explained by the development. The appendage is developed before the limb-arch, and is an extension outwards of the ventral plate, while as yet that plate may be considered as forming the periphery of the embryo; and the arch is developed in connexion with the appendage, while as yet the dorsal plates extend little outwards.

6. The suspensorium and lower jaw form an arch corresponding with the limb-arches; and the opercular apparatus of fishes consists of appendages attached to it. In proof of this it may be mentioned that,

a. The jaw is external to the visceral arches of the skull.

b. The jaw is composed of parts more complex than a visceral arch.

c. The suspensorium, quadrate bone, or incus, is usually connected with at least two segments of the skull.

7. The difficulty of distinguishing the jaw as a limb-arch arises from the thinness of the visceral walls in the cephalic and cervical regions. Hence the intimate connexion between jaw and hyoid arch in fishes, and the connexion of the hyoid bone in turn with the branchial arches, which are splanchnic.

8. The three limb-arches may be considered as corresponding with the three great regions of the body, viz. the cephalic, the cervico-thoracic, and the abdomino-pelvic regions, which are respectively the seats of greatest development of the animal, vascular, and vegetative systems.

The crowding forwards of the limbs in many osseous fishes is in harmony with the whole piscine structure, the great regions in fishes being comparatively undifferentiated and crowded under the head, while the mass of the animal is a mere tail.

The Human Mesocolon illustrated by that of the Wombat. *By* Professor CLELAND, *M.D.*

The general arrangement of the small and great intestines in the Wombat is very similar to what is found in the human subject, although they are of greater proportional length. The paper pointed out that the arrangement of the peritoneum in the Wombat exactly corresponded with the conditions which the writer described in the 'Journal of Anatomy and Physiology,' May 1868, as existing in the human fœtus of three months. The descending, and half of the transverse colon are provided, as in the human fœtus, with a mesocolon springing from near the middle line; and the right half of the transverse colon, having crossed the third part of the duodenum, is bound to the commencement of that part of the intestine, near the pylorus, by a narrow fold of peritoneum, immediately above the upper end of the mesocolon just mentioned. That narrow peritoneal fold marks the neck of the primary loop of the intestine which formerly extended out at the umbilicus, and the crossing of the duodenum by the colon is effected by the twist which the loop takes to the right. The mesocolon has no connexion with the pendulous mesogastrium or so-called great omentum. The position which the writer lays down with regard to the human subject is, that while the left half of the transverse colon, together with the descending colon, has originally a mesocolon, and is distinct from the mesogastrium, the right half of the transverse colon has no mesocolon.

On the Myology of Cyclothurus didactylus.

By John C. Galton, *M.A., F.L.S.**

That which Brants (Dissert. Zool. Inaug. de Tardigradis, p. 27: Lugdun. Batav. 1828) has remarked relative to the muscles of the limbs of the Sloths appears to be fairly applicable to the Two-toed Anteater, namely, "Vires motrices anticæ corporis partis esse, posticam vero validis musculis ad anteriorem attrahi atque hujus motus sequi debere,"—and the more so when we contrast the short humerus, rugged with strong muscular ridges, with the long smooth femur, which lacks even a rudiment of a third trochanter.

In addition to a long prehensile tail (at best but a stunted member in the Sloths), naked for the lower third of its length, the fore and hind feet are marvellously modified for arboreal progression, the functional absence of the pollex being compensated for, as Meckel hints, by the enormous development of the pisiform bone, to which are attached numerous strong muscles, while a long strigil-shaped bone, passing backward from the scaphoid, more than makes up for the comparative shortness of the calcaneal process.

After the consideration in detail of the muscular system in this and other Edentates, the question naturally arises—What zoological value do such details possess? None, it must be confessed. For, apart from their bearings upon the question of the serial and general homologies of muscles, they do not enable us in anywise to simplify and improve the classification, as yet very unsatisfactory, of the members of this much-varying order.

On the Homologies in the Extremities of the Horse.

By R. Garner, *F.R.C.S., F.L.S.*

The author expressed a doubt whether the cannon-bone in the horse is the metacarpal or metatarsal of the third finger or toe (as the case may be) *solely*; and his doubts were derived from comparing the so-called monodactyle animal with the fossil horse, and also with the ox; from the articulation of the cannon-bone of the horse with two bones of the tarsus (confining himself to the hind limb), the external cuneiform and the cuboid, and from one or two other considerations, perhaps of less weight. He questions whether the horse is not monodactyle by coalescence, with a trace of the fourth metacarpal or metatarsal; and again, whether in the ox there is not a trace of the first metatarsal in that part of the cannon-bone articulating above with the little bone which is probably the first or inner cuneiform. He is hardly satisfied with the usual rendering of the subject in the above and other points, as, for instance, the supposed want of homology between the side hoofs in the hipparion and the little posterior hoofs of the ruminants.

It does not appear that any use can be attributed to the little horny bodies called *chataignes*, which we see in the fore and hind legs of the horse; they have a musky odour when shaved or cut, and hence they might be supposed to be scent-organs, which, however, is unlikely. They are not merely epidermic, but connected with the *cutis vera* like nails and hoofs. There are traces of the same parts in all other equine animals, and also of another little horny body called the *ergot*, or spur, situated at the fetlock, behind the union of the cannon-bone with the pastern. These cannot be reduced to the same category as the callosities or mere epidermal hardnesses, placed where they are of use as protective shields in certain animals, as on the legs and sternum of the camel. The chataignes appear to the author to be the vestiges of the nails of the missing great toe and thumb, the ergots of the nails of the two minor toes of the fossil horse. In such aberrations, as deficient or supernumerary fingers or toes, it is not rare to find a nail to exist where the phalanges have disappeared, and in some individuals a whole row of phalanges has disappeared, whilst all the nails remain normal. The situation of the bodies in question agrees sufficiently with the theory broached.

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* This paper appears *in extenso* in the 'Annals and Magazine of Natural History' for October 1869.

On the Solvent Treatment of Uric-Acid Calculus, and the Quantitative Determination of Uric Acid in Urine. By the Rev. W. V. Harcourt, *F.R.S., &c.*

The author of this paper having been apprized of the presence of a calculus in the bladder of considerable size*, and consisting in all probability of uric acid, resolved upon giving a trial to the solvent alkaline treatment as proposed by Dr. Roberts, Physician to the Manchester Royal Infirmary, of which the first notice will be found in the Report of the British Association for 1861, and of which he has given a full account in his 'Treatise on Urinary and Renal Diseases.'

In one of the leading experiments made by Dr. Roberts, he passed the urine of a patient who was taking citrate of potash at the rate of 40 grains in 5 ounces of water every two hours, over a fragment of uric calculus, and by this process reduced it in twelve hours from 180·5 to 174 grains, or at the rate, in twenty-four hours, of 13 grains. If the action within the bladder resembles that without it, though the action on an entire calculus could not be expected to equal that on a fragmentary piece, yet there was reason to expect a difference between the quantity of uric acid normally excreted and the excretions under the effect of the alkaline treatment, determinable by chemical analysis. With this view the author instituted a series of experiments in his own laboratory, which, though they did not fully realize his expectations, throw some light on this important subject. The method first employed of precipitating the uric acid was that in ordinary use by hydrochloric acid. The first seven determinations, from the 20th of August, 1868, to the 26th inclusive, were made each day on the urine of the preceding twenty-four hours, in a neutral or slightly alkaline state, brought to that state by doses of from 120 to 165 grains of citrate of potash. The quantities of uric acid obtained varied from 11·08 to 8·43 grains. In the subsequent daily determinations, down to the 5th of September, acid reactions were interpolated, due to the use of smaller alkaline doses, which lowered proportionably the amount of uric acid obtained; and when no alkali had been taken for two days, and the urine was in consequence strongly acid, the quantity of uric acid found was only 2·35 grains.

From this time commenced a course of large quantities of citrate of potash, amounting, during fourteen days, to 315 grains in twenty-four hours, taken in a state of effervescence, in doses of 45 grains, dissolved in 3 fluid-ounces of water†. For ten of these days hydrochloric acid was used to precipitate the uric acid; and the determination of this gave from 11·95 to 6·00 grains. The preference, however, assigned by Dr. Thudichum, in his able and well-known treatise on the 'Pathology of the Urine,' to nitric over hydrochloric acid, as having given him better results, led the author subsequently to employ his method. The quantity of citrate of potash taken in twenty-four hours was then raised to 350 grains for four consecutive days. On the first of these days the uric acid found was 1·54 grain, on the second 1·23 grain. These results were so extraordinary that, for the purpose of corroborating them, or discovering any error, Dr. Thudichum was requested to undertake an analysis of a portion of the urine of the latter day. According to his analysis the uric acid amounted to no more than 0·775 grain.

This result led to one of two conclusions; either independently of any question of the solution of the calculus the presence of the uric acid in the bladder had been almost entirely prevented by the alkaline treatment, or the process for obtaining it was altogether unreliable. The latter alternative appearing the most probable, more attention was given to the method of determination. One half of a urine which had yielded 8·42 grains with hydrochloric acid, was treated with 5 per cent. nitric acid and kept at the temperature of 90° F., the alkalinity and dilution having been brought to a standard corresponding with the urine analyzed by Dr. Thudichum. The uric acid thus obtained weighed 2·07 grains, showing a loss by this method of 6·35 grains. The alkalinity was now determined for every

* The size of the calculus, as determined by Mr. Spencer Wells, and confirmed by Sir H. Thompson, was 1·5 inch in one of its diameters.

† The tides of acidity and alkalinity in urine, consequent on digestion, which occur at different periods of the day and night, deserve attention in the distribution of alkaline doses, especially when the quantity taken is small enough to leave an apprehension of uric acid being deposited in the bladder.

voiding with hydrochloric acid. 2·5 per cent. of that acid was added to each; and as it had been observed that uric acid was lost by decantation, however careful, the portions of urine operated upon were entirely filtered, and the water with which the precipitates were washed was acidified with acetic acid. The secretion of mucus being now a good deal in excess, the quantity of alkali taken was reduced—for five days to 300 grains of the citrate in twenty-four hours, for eight days to quantities varying from 270 to 240 grains, and for thirty-five days more (with the exception of three days, on account of diarrhœa and bleeding) to quantities varying from 285 to 120 grains. The details of these experiments were given in the paper *; but it may be enough to mention here that no proportion could be observed between the determinations of alkalinity and those of the accompanying uric acid. Twenty days, in which the alkalinity of twenty-four hours varied from 19·2 to 40·3, gave an average of uric acid 7·94 grains; whilst fifteen days, when the alkalinity was from 19·1 down to 1·4, gave an average of uric acid 8·08 grains—a fact which would have shown that the alkali had exercised no action on the calculus, in case the determinations of the uric acid could be depended upon, and in case the alkaline treatment did not cause a diminution of the uric acid secreted. The latter point could only be ascertained by a course of experiments in cases free from calculus; the former point the author proceeded to investigate. He found that the quantity of uric acid precipitated from the urine was diminished by dilution, and augmented by concentration previous to the addition of the hydrochloric acid. In forty comparative experiments, the two extremes of excess in the concentrated over the natural urine were 1·08 and 4·13 grains, in the last fifteen of which the urine was reduced to a standard volume of 6 or 3 fluid-ounces, according as half or quarter of the urine was employed; the average difference was 3·03; in the former twenty-five, reduced to the above proportions, the average excess in the weight of the precipitates was 3·09 grains. The determinations were further improved by the adoption of the following method:—a fourth of the urine of twenty-four hours was evaporated to 3 fluid-ounces; it was treated with a mixture of hydrochloric acid and alcohol in equal parts, each being 2·5 per cent. of the quantity of urine employed; the precipitate was washed with alcohol (methylated spirit), and then with equal parts of acetic acid and water. The colouring-matter and phosphates &c. were thus removed, and the uric acid was of a light colour and completely, though confusedly, crystalline.

The advantage which this method possesses over those heretofore in use is shown in the experiment which follows:—In urine having an acidity of 5 grains per pint, the nitric-acid method gave 1·16 grain of impure uric acid; the ordinary hydrochloric-acid method 5·53 grains, the method above described 9·90 grains of uric acid. The proportion of alcohol to the hydrochloric acid was then increased to the bulk of the evaporate. The urine voided in twenty-four hours (35 fluid-ounces), of which the acidity =15·7 grains of carbonate of potash, was neutralized and divided into 3 parts; No. 1 (11·7 fluid-ounces) was evaporated to 1·5 fluid-ounce; an equal bulk of alcohol was added with 2·3 drachms of hydrochloric acid. To No. 2, 17·5 grains of carbonate of potash were added, and it was then treated like No. 1. No. 3 was treated like No. 2, but with the addition of 3 grains of uric acid dissolved in carbonate of potash. The three precipitates were severally washed, first with alcohol, and lastly with equal proportions of acetic acid and water. The result was follows:—

	No. 1.	No. 2.	No. 3.
Uric acid	6·97	6·51	9·62 − 3 = 6·62 grains.

The urine of twenty-four hours (35·5 fluid-ozs.), of which the acidity = 10 grains of carbonate of potash per pint, was neutralized and divided into four parts. No. 1 was treated in all respects like No. 1 of the above series. No. 2 was similarly treated with the addition of 30 grains per pint of carbonate of potash neutralized. No. 3 was treated like No. 2, with the addition of 2 grains of uric acid dissolved in carbonate of potash. No. 4 was evaporated only to 3 fluid-ounces; the alcohol added was only 1·7 fluid drachm; in other respects it was treated like No. 2;

* The details here mentioned are to be found in the 'Medical Times and Gazette' (vol. ii. p. 482).

but the precipitate of uric acid being more coloured than in Nos. 1, 2, and 3, it was further washed with boiling alcohol, which removed 0·14 grain of colouring-matter, and still left it darker than the others, retaining, that is, more of the colouring-matter. The weight of uric acid obtained in the four experiments was as follows:—

	No. 1.	No. 2.	No. 3.	No. 4.
Uric acid	7·44	7·80	9·50−2=7·50	7·30 grains.

Two further experiments were made, in both of which the proportion of one grain only of uric acid was superadded to the urine of twenty-four hours, the process employed being the same in other respects as that of No. 1 in the preceding experiments. The results were as follow:—

1. Uric acid without addition=7·96 grains.
   „ „ with addition of one grain=8·74, or−1=7·74 grains.
2. Uric acid without addition=7·67 grains.
   „ „ with addition of one grain=8·42, or−1=7·42 grains.

In the first of these two last experiments the alcoholic acid was *decanted* from the precipitate previous to filtration after standing for only *nineteen* hours, and an interval considerably less would probably suffice. The uniformity of these results deserve to be remarked.

On the whole it appears that the best process for determining the quantity of uric acid in urine is the following:—To neutralize a third or fourth part of the urine of twenty-four hours, if alkaline with hydrochloric acid, or of acid with carbonate of potash, to reduce this to 1·5 fluid-ounce, to treat it with 3 drachms of hydrochloric acid, combined with 1·5 fluid-ounce of alcohol, to decant when the liquid is clear, to wash the deposit first with alcohol, and when that dissolves no more, with equal parts of acetic acid and water; and it also appears that the amount of alkalinity in the urine, after being neutralized, does not effect the precipitate or detract from the accuracy of the determination. It may also be concluded that notwithstanding the variability of the quantity of uric acid in different states of the system, if under uniform conditions of health and diet, experiments be first made, in the manner described, on the natural urine, a sufficiently exact average determination may be made of the normal quantity of uric acid antecedent to the alkaline treatment, and that if the alkaline treatment subsequently furnishes a grain or two more of uric acid, this may be relied upon as evidence that the uric-acid calculus in the bladder is undergoing solution.

Though the foregoing researches have failed to realize the expectation of testing by analysis the effect of the solvent treatment on vesical calculus, a fact observed during the whole course of that treatment, and not afterwards, appeared to indicate that a solvent action was really going on. This fact consisted in a small but constant amount of deposit, in which fragmentary particles of uric acid were discerned by the microscope enveloped in mucus, resembling, in the opinion of Mr. Spencer Wells, as well as of the author and his assistant *, the detritus left by the incomplete action of carbonate of potash on uric-acid calculi, and such as might have been washed out of the bladder in consequence of partial solution. That no such solution should have been brought into evidence by the many determinations of uric acid, however imperfect, here described, if it cannot be fully accounted for by that imperfection, may possibly be due to a physiological effect of the alkaline treatment in preventing the formation of uric acid, which may have counterbalanced the excess expected from solution of the calculus. To ascertain these points, as has been stated above, two sets of experiments are required, one in a case in which calculus is *present*, and one in which it is *absent*, in both of which the process for determining the quantity of uric acid here recommended may be of use.

The author stated his conviction, from his own experience of the effects of citrate of potash not exceeding 300 grains taken in twenty-four hours, and producing an alkalinity equalling from 20 to 35 grains of carbonate of potash continued during three months, that no disadvantage to health need be feared from

* The author's laboratory assistant, Mr. William P. Horn, executed the experiments detailed in this paper with great precision.

such a course; and this is the experience of a man eighty years of age, who has been for some years an invalid. Neither during or since the treatment has any irritation of the bladder &c. been felt, and the urine has been for many months perfectly clear and free from mucus; it has never been ammoniacal when voided, and has contained no albumen. The calculus was judged to be uric from the previous passage of crystals of uric acid. Since the treatment no uric acid has appeared in it, except once recently, and 25 grains of citrate of potash are found sufficient to prevent its recurrence.

There is one prominent chemical fact attending these experiments which remains to be noticed, viz. a great diminution in the quantity of the mineral acids subsequent to the alkaline treatment; whilst from 120 to 150 grains of citrate of potash were required for neutrality in August 1868, in March and April 1869 from 30 to 60 grains sufficed for the same purpose. Dr. Thudichum's analysis in September 1868 gave—of sulphuric acid 51·1, of phosphoric 45·7 grains. The analysis made in the author's laboratory in March 1869 gave, sulphuric acid 25·9, of phosphoric 34·2 grains,—a difference scarcely to be accounted for without reference to the alkaline treatment undergone in the first three months of the interval; and it is worthy of remark that a similar reduction seems to have taken place in the amount of uric acid.

On the Physiology of Sleep and of Chloroform Anæsthesia. *By* Charles Kidd, *M.D., M.R.C.S.E., &c.*

In further continuation of previous researches as to the clinical value and peculiarities of chloroform, ether, and other anæsthetics, the author invited discussion on some conflicting opinions and ideas amongst physiologists, as to the precise nature of anæsthesia itself, particularly under nitrous protoxide, contrasted with chloral and chloroform; the relation of sleep to anæsthesia; the exact physiology of sleep, so intimately bound up with medical treatment, in mania, fever, delirium tremens, puerperal convulsions, and other diseases, where chloroform is sometimes inadmissible, but at other times of great value, as in the "shock" of large surgical or mechanical injuries to limbs, according as the practitioner has to treat pain and irritation, or, on the other hand, exhaustion and inflammation.

Two, if not three forms of accident, as seen in hospital practice, as contradistinguished from the simple suffocation of animals in experiments on the methylene series, were explained; the chief one, sudden failure, not of the heart as popularly believed, but of the laryngeal recurrent nerve and others distributed to the larynx, causing spasm, or sudden apnœa. Deaths have occurred from the use of "ether mixtures," and while every precaution was taken; and while using the "Clover-apparatus," supposed to be safe; but in a vast number of cases, by proper precaution at the moment, and notably by use of electricity, the danger may be warded off. Fatal accidents, in fact, are most common, not in the deep narcotism of chloroform, but in the early excitement stage when reflex action is still active, and chiefly hitherto in healthy active adults for trivial small operations, rather than in old unhealthy subjects with fatty heart or in large operations.

Again, connected not indirectly with the nature of anæsthesia, is the nature of ordinary "sleep," the latter a state of rest of the active molecular work previously going on, with a restoration of the power. Can this condition depend on venous congestion of the choroid plexus and such vascular parts, or on the opposite state of the brain vessels? Facts abound on each side, yet the question is undecided, though at the threshold of a world of phenomena and accurate treatment in fevers, delirium tremens, mania, bad surgical accidents, with delirium, &c. Nearly all our recent vast improvements in surgery, ovariotomy, especially large amputations, Cæsarean section, are due to chloroform, and probably better views as to "shock," and how sleep is to be obtained, and rest for the nervous system; chloroform in puerperal convulsions, in tedious cases requiring "version," not only gives rest to the nervous system, but is a directly curative agent, as well as taking away pain. The author next illustrated various half-cleared up points as to sleep and anæsthesia, by what has been learned during the year of the extraordinary action of the nitrous protoxide, or "laughing gas," in London hospital practice. This "gas," at first condemned from mere experiments on rabbits as the most deadly of all the anæsthetics, proves to be in man the least deadly. In one hundred thousand cases there has been perhaps no death due to the gas itself. One or two accidents have been noted in dental practice from foreign bodies, loose teeth, or the cork used to keep the jaws asunder slipping into the relaxed glottis. This gas neither enters into combination with the blood, as ether for instance, nor does it produce change in the blood as carbonic oxide, nor is it changed itself; it is, in a word, quite passive, and offers to the notice of physiologists, the author believes, a passive agent, taking the place of atmospheric air in the lungs.

As to the physiology of common "sleep," opposite instances were cited of sleep from venous congestion, and sleep from vascular anæmia. In sleep the pupils are contracted in children and fontanelles depressed. The ophthalmoscope, too, bears out Mr. Durham's theory of anæmia; or, is it because we sleep, the brain becomes anæmic (independent of vaso-motor or ganglionic action, as urged by Mr. Moore)? Sleep is the chief remedy in delirium tremens; and here digitalis is superior to chloral as a remedy.

Even the spectroscope can detect no change in the blood when the nitrous oxide is inhaled—indeed there is not sufficient time in the forty or fifty seconds during which the gas begins to act before sudden asphyxia takes place, for the complex changes to occur supposed by Dr. Marcet and others; even the same ten gallons of gas thus unchanged may be inhaled over and over again by the same patient with like results of complete insensibility, going off almost in a moment when the inhalation is stopped, and atmospheric air allowed into the lung. The author in previous memoirs in the 'Transactions,' from observation in London hospitals in over 20,000 cases of chloroform administration, papers read at Newcastle, Oxford, &c., was led to doubt that the principle on which the Clover apparatus, that of cardiac syncope, is constructed is always true, so that patients die of cardiac exhaustion in every instance; he thinks now, if any fact or suggestion were wanting to complete the proof, it is this cardiac exhaustion under this gas far greater than under chloroform, and yet the patients invariably recover in three to four minutes; the pulse under chloroform never sinks, it rises; the pulse under this gas gradually sinks till it is almost imperceptible.

The instantaneousness of the insensibility and the waking up are not unlike the falling asleep under ordinary sleep; deficient oxidation runs parallel with the sleep, but the change is a "vital" one; oxidation alone will no more explain it than explain a fit of chorea or epilepsy. The microscopic examination goes deeper, and shows the blood-corpuscles and brain, or grey matter (protagon), altered by one set of anæsthetics but not by others; the author, in fine, concludes that deaths from chloroform are more frequent from emotion or fright on the part of the patient than cardiac exhaustion from deficient oxidation.

Experiments with methylene on animals, or chloral or ether "mixtures," so strongly recommended from theoretic ideas by the Royal Medical and Chirurgical Society (though previously abandoned in Austria, where they had been enforced by government authority), experiments with the nitrous oxide, on the supposition that it is more dangerous than terchloride of carbon, with voltaic narcotism, or with some patent mixture or ether, are experiments that frighten patients and lessen their faith in simple chloroform, and things that cause confusion, founded on the theory of deficient oxidation alone, and have only retarded the progress of anæsthetics; nor is a fatty heart one of the chief sources of danger, at least as far as is shown by 300 cases of deaths from chloroform collected by the author from journals,—mostly cases of healthy adult men attacked with sudden apnœa from alarm or fright at viewing the preparation of knives, saws, &c. for the operation, the tears and grief of friends, &c., or of men who were bad subjects for operation, with healthy heart, from the presence of delirium tremens, want of sleep, want of food, &c. The Association would now confer a great benefit on the public if these 300 or 350 cases were carefully tabulated, and the deductions as to age, sex, disease, character of accident (apnœa or asphyxia), post-mortem result, &c. were marked out. Electricity to the diaphragm has proved in many late chloroform cases most valuable, since the idea of apnœa, in place of fatty heart, has impressed itself on the minds of practical men. Even in the asphyxia or apnœa of other accidents, such as drowning, suffocation in coal mines, &c., the artificial stimulus to respiration (electricity), not to the heart, but to the phrenic nerves, has astonished good observers in Germany, America, Australia, &c.

Further Observations on Dendroidal Forms assumed by Minerals. *By* J. D. Heaton, *M.D.*

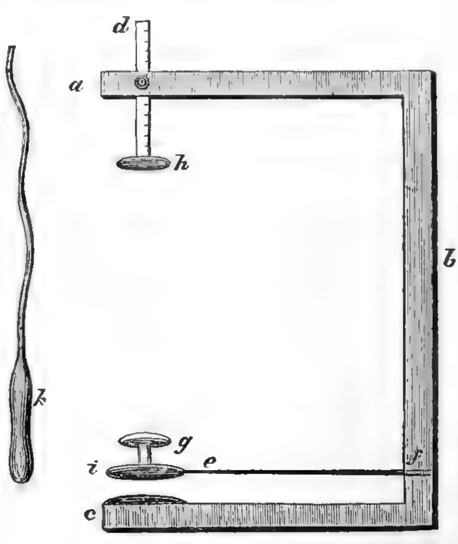
In this communication attention was drawn to the peculiarities of the dendroidal forms developed upon some purely mineral crystals when immersed in weak solutions of silicate of soda, and some additions were made to the observations upon this subject read at the Meeting of the Association at Dundee in 1867. It was then pointed out that when crystals of sulphate of iron, sulphate of copper, or some other mineral salts are immersed in a dilute solution of silicate of soda, in the course of a few hours branches shoot perpendicularly upwards in the liquid, presenting a remarkable resemblance to the branches of some vegetation. These branches are straighter in a rather stronger solution, more contorted, and sometimes distinctly spiral, when the solution is somewhat weaker; but results are only attainable within certain limits of dilution, of the solution ordinarily supplied for commercial purposes, about one part in eight being most efficient. The trunks of these mineral vegetations occasionally ramify and subdivide, and sometimes parallel branches, after growing side by side for a time, will approximate and again anastomose into a single trunk. At the base those developed on sulphate of iron may have a diameter of one-sixteenth or one-twentieth of an inch; as they elongate they gradually narrow to that of a fine hair. They have a definite limit of growth, restricted to a height of from four to six inches. Those developed on sulphate of copper are shorter and more delicate than those on sulphate of iron. When the power of growth fails they terminate in fine needle-shaped extremities. The author had stated at Dundee his opinion that the terminations of branches still in process of elongation presented pointed extremities, which were carried forward as growth proceeds, necessarily implying an interstitial mode of increase. But having since made an arrangement by which branches may be observed microscopically in the act of growth, he must now correct that statement. No change of size or form can be observed in a branch subsequent to its first development; but as a branch elongates, it narrows as the power of growth fails, and when the needle-shaped point is formed, there is no more elongation. The growing-point of an elongating branch, as seen under the microscope, appears enveloped in a slight cloudiness in the liquid medium, which is gradually lifted up and precedes the extremity of the elongating branch, whose gradual and continuous development presents a very curious appearance. The branches are delicate tubes, having thin semitransparent walls; they fall in pieces when taken out of their native fluid. Under a high power of the microscope their walls present a finely granular structure, but no trace of crystalline form. Both the silica of the solution and the constituents of the crystal on which the branches grow enter into their formation. What is the nature of the force which determines the assumption of dendroidal forms and a tubular structure by these strictly mineral formations, and their upright growth, in opposition to the tendencies of gravitation, like the ascending axis of a plant? It is neither simple aggregation, not is it crystallization. It presents certainly, in its results, a remarkable resemblance to that force by which is effected the growth of living tissues under the influence of vitality, and upon which it may serve to throw some light. And thus these dead structures, assuming the forms, and increasing so much after the manner, of living tissues, seem to effect one slight gap (amongst others) in that wall of separation by which it has hitherto generally been held that the mineral world is absolutely divided from the world of organization, but which now seems at various points to be giving way. In connexion with this subject, the author noticed a communication by Mr. W. C. Roberts to the 'Journal of the Chemical Society' upon the occurrence of organic forms in colloid silica, as obtained by Graham's process of dialysis. These specimens have all the appearance of microscopic fungi, presenting radiating fibres composed of elongated cells, with occasional clusters of cells having the appearance of fructification, very much resembling common mildew. The Rev. Mr. Berkeley, the eminent mycologist, has seen them, and recognizes their fungoid character, and even their specific peculiarities.

Description of an Apparatus for Measuring and Recording the Respiratory and Cardiac Movements of the Chest. By J. Burdon Sanderson, *M.D., F.R.S.*

The purposes which this instrument is intended to answer are (1) to measure accurately any given diameter of the chest, (2) to determine the extent of those rhythmical variations of that diameter which are due to breathing and to the movements of the heart, and (3) to record the results mechanically on a cylinder revolving at a known rate by clockwork.

To accomplish these objects various methods have been employed by physiologists. The most accurate is that contrived by M. Marey. The subject of observation is placed on a chair, against the back of which he is directed to lean. The measuring-apparatus is supported on a table at a short distance from the front of the chest. Its construction is such that the variations of distance between the anterior surface of the chest and the instrument (*i. e.* the table on which it rests) are transmitted to a lever, by which they are inscribed on the recording-cylinder. The instrument which has been recently introduced and exhibited in London by Dr. Hawksley is constructed on the same principle. Both methods are subject to a fundamental objection, namely that the curve inscribed on the cylinder expresses, not the variations of the diameter of the chest, but the variations of distance between the surface of the chest and the table. If it were possible to render the spinal column of the subject of observation absolutely immoveable the objection would be groundless, for the two variations referred to would be the same; but, practically, any such fixation of the spinal column is impossible. Irregular contractions of the muscles of the back occur constantly, and are of such extent that no method of measurement in which they are disregarded can pretend to accuracy. If it be alleged that they are so trivial as not materially to impair the general accuracy of the tracing, I reply that, although they are in themselves inconsiderable, they are enormous in proportion to the extent of the rhythmical movements to be measured. Some of these movements do not exceed $\frac{1}{100}$ of an inch; consequently an accidental jerk, even if it amounted to only half that distance, would entirely vitiate the result.

In the instrument exhibited to the Section this error is entirely avoided. It consists of two parts, viz. (1) a light frame of wrought iron which is applied to the chest, and (2) the apparatus by which the movements are transmitted to the recording-cylinder. The construction can be understood by referring to the sketch in the margin. The letters *a b c* indicate the frame of wrought iron; *d* is a rod of brass which is graduated, and slides through a socket in the arm *a*, terminating in a knob covered with wash-leather, *h*. *e* is a steel spring which is fixed to the frame *a b c* at *f*, in such a position that it is parallel to the arm *c*. The end of the spring bears on its inner surface a button, similar in form and size to *h*, and on its outer surface a circular plate, *i*. A similar plate is screwed on to the inner surface of the arm *c* in such a position that the two disks face each other. Between the two disks is placed, when the instrument is in use, a disk-shaped bag (*k*) of vulcanized caoutchouc, the mouth of which com-



municates with a long flexible tube; the opposite end of the tube is in connexion with the drum of Marey's cardiograph. The effect of this arrangement is, that when the frame is adapted to any diameter of the chest—as, *e. g.*, the antero-posterior—in such a manner that while the button *h* is applied to the spine, the button *g* is pressed by the spring against the sternum, all, even the most minute, variations of the particular diameter investigated are inscribed on the cylinder. The tracing so obtained presents characters, as regards sharpness and regularity of contour, which to the eye accustomed to the examination of kymographic tracings, appear exceedingly satisfactory.

The author claims for this instrument the following advantages, viz. (1) that it affords to the physiologist a means of recording the rhythmical movements of the chest, either in man or animals, with greater accuracy than is possible by any method previously employed, and (2) that from its simplicity it is applicable to the purposes of clinical observation. Here, as in every case in which instruments of exactitude are employed, especially for the investigation of the functions of respiration, the fact that the patient is conscious that he is under observation is apt to interfere with the accuracy of the result. This difficulty cannot be entirely overcome. In consequence of it a large proportion of observations made on patients are rendered valueless. Its existence affords, however, no excuse for contenting ourselves with clumsy instruments and inexact methods of research. It rather points to the necessity of improving and simplifying these methods and instruments to the utmost, and of acquiring the greatest attainable skill in their use. At the same time it is to be borne in mind that neither instruments nor skill will be of much service unless the observer is possessed of that tact in the management of patients by which alone disturbing emotions can be calmed and controlled.

On the Physiological Action of Hydrate of Chloral. *By* Benjamin W. Richardson, *M.D., F.R.S.*

[For Abstract of this Paper, see Appendix.]

On the Moral Imbecility of Habitual Criminals, exemplified by Cranial Measurements. *By* Dr. Wilson.

Ethnology, etc.

On Stone Implements from Rangoon. *By* Vice-Admiral Sir E. Belcher, *K.C.B., F.R.A.S.*

Notes on Mosquito and Wulwa Dialects. *By* C. Carter Blake, *D.Sc., F.G.S., and* R. S. Charnock, *Ph.D., F.S.A.*

The authors entered into a minute comparison of the elements contained in Mr. Collinson's 'Vocabularies of Mosquito Dialects,' and pointed out the large proportion of words which occurred in them that were derived from Spanish or other European sources. They contrasted the dialects of the Mosquito shore with those of the Wulwas, and gave long vocabularies, showing the proportion of words in common, and the range of linguistic variation observable in the very limited area of Eastern Nicaragua and Mosquito.

On the Origin of the Tasmanians, Geologically considered. *By* James Bonwick, *F.R.G.S.*

The author called attention to the fact that Aborigines, evidently allied to the Tasmanians, existed in the North Pacific, in New Guinea, New Caledonia, New Hebrides, the Peninsula of Malaya, Cochin China, India, Madagascar, and most probably the Pre-Maori inhabitants of New Zealand. Most of these, the Tasmanians especially, were ignorant of the art of navigation, and knew not the construction of boats. Unless, therefore, the Polygenistic idea be received, that they grew where they were found, they must have been at one period geographically connected. Their migration could only have taken place on land.

A great number of interesting particulars, from such authorities as Dr. Hooker, Dr. Owen, Prof. Huxley, &c., were adduced to show the plausibility of the theory of the existence of a former southern continent. The remarkable relation of flora between Australia and South Africa, and Australia (with Tasmania) and New Zealand, went to prove the position. Geology established the opinion of previous connexion of a number of the islands with the continent of New Holland. At the time of the gradual submergence of the old southern continent, many of these ancient races had reached to the outside limits, and were thus preserved.

The author contended for the high antiquity of man, in order to reconcile the difficulties affecting the origin of the Tasmanians, as well as to support the doctrine of the unity of the human species. On botanical and geological grounds, the inhabited land of the Tasmanians was conjectured to have been part of a great continent at a time when most parts of Europe and Asia were beneath the ocean.

On the Primitive Status of Man. By W. C. Dendy.

On Human Remains in the Gravel of Leicestershire. By Francis Drake, *F.G.S., F.R.G.S.*

On a Crannoge in Wales. By the Rev. Edgar N. Dumbleton.

In the Lake of Llangorse, Brecknockshire, is an island about 90 yards in circumference, and situated about 120 yards from the northern shore. Until two years ago no idea was entertained that this had anything remarkable about it.

The angular appearance of the stones exposed at the margin first suggested the thought that this island was no part of the natural structure of the lake-basin, and subsequent investigation has shown that the whole material has been conveyed from the main land and heaped within flat piles. Of these about fifty may be counted about the edge of the Crannoge. They are from 4 to 5 feet in length, of oak, and are well shaped, and pointed with a sharp metal instrument; the cuts are plainly visible, and resemble those made by an adze. The material of the island is—first, faggot wood and reeds, then loose mould, with but few stones, in which is a considerable layer of charcoal, at about one foot from the level of the lake; nearer the surface the stones are more frequent; the whole does not exceed 5 feet above the surface of the water.

In all parts of the island, and at all levels, are found large quantities of bones, as well as in the shallow water all round; very many of these are broken or split into fragments. A package of these bones was sent to Professor Rolleston, who pronounced them to exhibit two varieties of horse, also the remains of the ox, the sheep, and pig. Other specimens of bones found on the island were shown at the Meeting, and were asserted to be those of the wild boar, red deer, and *Bos longifrons*.

Very little in the way of human implements has been found. One stone and a bone appeared to have been shaped for use, and some fragments of leather, pierced to admit sewing material, came to light. That there have been wooden structures about and upon this island appears evident, the remains being plentiful, both about the edge and under the water.

On the Age of the Human Remains in the Cave of Cro-Magnon in the Valley of the Vezère. Dr. P. M. Duncan, *F.R.S.*

On the Discovery of Flint Implements of Palæolithic Type in the Gravel of the Thames Valley at Acton and Ealing. By Colonel A. Lane Fox.

During the first six months of the present year (1869) the author devoted some time to an examination of the gravels, brick-earth, and surface-soils on the northern side of the Thames valley, between Shepherd's Bush and Ealing.

In the nearly flat portion of the valley adjoining the river which lies between Hammersmith, Shepherd's Bush, and Acton, the surface of which averages 5 to 10 feet above high-water mark, several cuttings were being made in the brick-earth, which here lies to a thickness of 10 to 12 feet upon the gravel.

The workmen had the appearance of flint flakes and implements explained to them, by showing them specimens from other localities, and rewards were offered to induce them to preserve any similar implements they might find during the excavations, but no trace of the fabrication of flint implements was found in the area above specified. This would tend to give some confirmation to the conjecture that this portion of the bottom of the valley may have been excavated by the river more recently than the Palæolithic period.

At Acton the Uxbridge road passes over the natural slope which bounds the plain on the north, and which rises from 10 to 40 and 80 feet above high-water mark.

The upper portion of this slope near Acton is capped with gravel, which overlies the London Clay, and varies from 6 to 12 feet in thickness. In Acton village it is 18 feet thick, and it was shown, by a cutting made for a sewer in the direction of the Great Western Railway Station, that it thins out northward. It is very variously stratified, in alternate layers of subangular gravel and yellow and white sand, with red and yellow stains. In some places the sand and gravel lie in horizontal bands, of greater or less thickness, above each other; in others the strata are very much contorted and undulating, thinning out in various directions, and sometimes turning up almost perpendicularly, indicating probably the existence of floods or currents, or winding watercourses at the time when the river ran at this higher level. The gravel consists chiefly of subangular flints, mixed with rounded quartz and quartzite pebbles. No trace of freshwater shells or of animal remains have yet been found in this drift-gravel.

This is the first patch of gravel as we go westward from London which lies so high above the river, all the high ground to the north in the direction of Willesden, and to the north-east in the direction of Hampstead and Highgate being composed of the London Clay, whilst to the south and south-east, as already mentioned, the gravel and brick-earth is at a much lower level. The position on the sides of the valley corresponds so exactly to that in which implements have been found in the valleys of the Somme, the Ouse, and elsewhere, that the author determined to make a close examination of the cuttings that were being made for the erection of new buildings, and for that purpose paid almost daily visits to the place for some months. The result has been to bring to light several implements of the antique form, usually found in drift-gravel, and others of more modern type.

To the east of the East Acton Station, on the Willesden and Kew line, the gravel had been disturbed at some former period. Some cuttings were being made for the foundations of buildings at about 40 feet above high-water mark. All the worked flints found here were of surface type, consisting of numerous small flakes, one or two small scrapers, a chipped knife or spear-head, and, lastly, a chipped celt, without any trace of grinding, corresponding in form to those, a large hoard of which were lately discovered by the author at Cissbury in Sussex, and have been described in the 'Archæologia.' This class of implement may probably be regarded as forming an intermediate link between the Palæolithic and Neolithic types.

To the west of the Station the gravel was undisturbed, and stratified in the manner already described; the surface rises to 60 and 80 feet above high-water mark. It was in this gravel that the implements of Palæolithic type were discovered. They consist of numerous flakes, of larger size than those found at the lower level to the east of the Station, one or two cores from which flakes had been detached; but these were not in sufficient number to denote that the fabrication of flints to any great extent had been conducted here—two large and roughly made scrapers and five implements. One implement of oval type was found under 7 feet of stratified sand and gravel, resting on the clay beneath, another of pointed type was found in the middle of the gravel, about 10 feet from the surface, and beneath a layer of sand 8 feet in thickness. Three other implements of similar forms were found on the roads in the neighbourhood, in gravel that had been excavated from the same locality, and from Mill Hill, half a mile to the westward; and one well-formed flake was found in a cutting in Acton village, as much as 18 feet from the surface. Although the author did not succeed in himself finding any of these implements *in situ*, he took all the steps necessary to ascertain the correctness of the reports given him by the workmen, and he has no reason to doubt the accuracy of the positions here given. The majority of the flakes appeared to have been rubbed and chipped by use, leaving concave scallops on the edges of the flint. All the implements and flakes were of the ochreous colour of the gravel, and they appeared by their edges to have been much rolled in the gravel. The author also found two very well-formed implements at Ealing Dean, at a spot the height of which is given as 92 feet above mean water-mark in the Ordnance 6-inch map. (All these implements were exhibited at the Meeting of the Association.)

The value of the discovery consists in its extending our knowledge of the distribution of these implements higher up the main valley of the Thames than they have been found hitherto. It is well known that implements of Palæolithic type have been found near Reculvers, at about 50 feet above the sea-level. The earliest recorded discovery of a Drift implement was that found at the commencement of the last century, near Gray's Inn Lane, at a height of probably from 50 to 60 feet; and Mr. Evans has lately discovered one at a higher level near Highbury.

Though evidently of much less common occurrence in the Thames valley than in those of the Somme, the Ouse, and other rivers in which they have been found, there appears to be no reason to doubt that they are as widely distributed, and that they occupy corresponding positions to those which have been found in the above-named rivers.

On Man and the Animals, being a Counter Theory to Mr. Darwin's as to the Origin of Species. By ARCHDEACON FREEMAN.

On the Brain of a Negro. By R. GARNER, *F.R.C.S., F.L.S.*

The author, in a previous paper read at the British Association, described his method of making casts of the brain, first hardening them in a solution of corrosive sublimate, about 1 oz. to 1 pint of water at 60° F., that is of the specific gravity of the brain itself, 1·038. The Negro, of whose brain a cast was shown, though by no means of quite black skin, was apparently of pure blood, judging from the shape of his head and face, and woolly hair. He was a tall man, and when able to follow his employment, acted as cook on board a ship, and in private families. He was intelligent, and apparently had been placed in more favourable circumstances for mental development than the generality of his race.

The Negro skull is generally thick and heavy, as was the case here; the parietals are not unfrequently cut off from joining the sphenoidal wings in the temples, and there appear to be one or two other little imperfections, so called. The brain is commonly long and narrow, but high, as it was in the instance in question. According to Morton the Negro's brain, compared with the Englishman's in weight, is only as 82 to 96. But the brain of the Negro in question weighed 49 oz., the full weight of the Englishman's; and, generally speaking, the convolutions may be called rich, more so than those of the ordinary Englishman, and more so than those of an Englishman's brain exhibited, though the latter was of course wider or brachycephalic. This Englishman was well known to the author. He could read, write, and sum well, was quite of average intelligence, but self-indulgent in regard to drink, and choleric, and had been a soldier and servant. If mere name were anything he ought to be of our noblest blood, but probably he had no such claim.

The prognathousness of the Negro, to whatever due, is attended with a long brain, but whether he is the better or the worse for this, or whether any other uncommon shape of brain has very much effect on the faculties, or what, is difficult to say. The Negro's prognathousness seems to affect his voice, which is commonly rather guttural than sonorous. The brains of imbeciles have commonly all the convolutions, though of course less developed, and the author doubts whether the performance of any particular faculty can be attributed to any particular convolution; language, for instance, as distinguished from its merely lingual and oral portion, requires the development of the convolutions in general, and not of the external temporal gyri in particular. Wideness of skull, as seen in most of the dominant races, the author would set down rather to bodily conformation than to the reason the phrenologist would give. The Negro brain is well developed as regards the posterior lobe, whether this be a perfection or the reverse; probably it is less a character of the brain of the Quadrumana, than of them *and* Bimana, smooth in monkeys, with gyri in man.

The brain in the Negro in question is more developed than that figured so well by Calori. The lobules of the orbit are certainly simple, but the frontal convolutions are rather rich, the temporal lobes deep and long, the fissure of Rolando not situated so far back as in many Europeans, but this is due rather to a fulness of the convolutions behind (where, at the summit of the brain, they are rich and extend as far back as the post-parietal lobe, cuneus, and annectent gyri) than to the poverty of those before.

The sulci were in places an inch deep; the grey matter looked dusky, but there was no dark pigment in the arachnoid as we see in some animals. The author thinks that it is a misnomer to call the fissure of Rolando the *coronal fissure*, there being another sufficiently well marked under the coronal suture, the direction of which the first does not follow.

Though our prepossessions may be that the Negro is in his place as the labourer of the hot regions of the earth, servant and not master, and that he is not of the most highly organized race of man, yet the cast seems to show that he may be very capable of improvement though still retaining his peculiar characteristics, but to what extent and in what direction has not perhaps been fairly tried, and not set about in the right way.

The author anticipates that light will be thrown on the brain by a more precise indication of the course of its formative fibres, respecting which no two authorities agree. The mere topography of the organ has now been sufficiently made out, it remains to connect it with fibrillation and formation.

The cast of an old man's brain, æt. 97, which was exhibited, exemplified how much the gyri shrink in old age, whilst the sulci enlarge, corresponding atrophy occurring in all the other organs of the body; whilst the brain of the deceased consumptive retains all the plumpness of the healthy organ.

In judging of the brain from its size, several qualifications must be made, the size of the individual for instance. Unless we make such a qualification we might conclude that the elephant is wiser than man, or the Chinese giant than all other men, as he can get on no other man's hat.

On the Paucity of Aboriginal Monuments in Canada.
By Sir Duncan Gibb, *Bart., M.D., F.G.S.*

The ordinary sepulchral remains commonly found in various parts of the country with flint implements, pottery, &c., were excluded in this inquiry. It was confined to true Aboriginal monuments built of stone, such as are met with in Central America and Peru. Their scarcity and almost complete absence he attributed to the peculiar character of the climate, which would be unfavourable to their preservation, unless constantly looked after as in modern times. The mounds existing in the heart of the country north of Lake Ontario, though often filled with broken granite, were not regular buildings, and the frost and ice exerted no destructive influence upon them. He anticipated the discovery some day of traces of the ancient inhabitants in the great caverns north of Flamborough, and possibly in similar caverns which he conjectured would be found in the island of Anticosti, composed of similar rocks belonging to the Middle Silurian formation.

On an Obstacle to European Longevity beyond 70 years.
By Sir Duncan Gibb, *Bart., M.D., F.G.S.*

The author had previously drawn attention to the position of the leaf-shaped cartilage at the root of the tongue, known as the epiglottis, in 5000 people of all ages, and in 11 per cent. it was found to be drooping or pendent in place of being vertical. He discovered the important fact that in all persons over 70 its position was vertical, without a single exception—a circumstance of the highest importance bearing upon the attainment of old age amongst Europeans. In a number of instances, where the age varied from 70 to 95, in all was this cartilage vertical. Many of these he cited as examples, such as the well-known statesmen, Lord Palmerston, Lord Lyndhurst, Lord Campbell, and Lord Brougham. He also gave some among old ladies still alive at ages from 76 to 92, whose epiglottis was vertical. But the most remarakable was that of a gentleman still alive, 102 years old, in whom it occupied the same position. His facts clearly demonstrated that longevity beyond 70 could not be attained with a pendent epiglottis. The author summed up his views in the following conclusions:—1. As a rule persons with a pendent epiglottis do not attain a longevity beyond 70. Possibly a few may overstep it, but such examples are exceptional. 2. With pendency of the epiglottis life verges to a close at or about 70, and the limit of old age is reached. 3. A vertical epiglottis, on the other hand, allows of the attainment of fourscore years and upwards, all other things being equal, and affords the best chance of reaching the extremest limit of longevity. Lastly, pendency of the epiglottis is an obstacle to longevity certainly beyond the age of 70 years, and it is a peculiarity that occurs in 11 per cent. of all ages amongst Europeans.

On a Cause of Diminished Longevity among the Jews. By Sir Duncan Gibb, *Bart., M.D., F.G.S.*

The author stated that a considerable portion of the Jewish race possesses a physiognomy to which he gave the name of sanguineo-oleaginous expression, characterized by varying degrees of flushed face, sleepy aspect, greasy look, guttural or husky voice, and fulness of body. The best examples of the class are to be seen in the furniture auction-rooms of the metropolis. With this expression is usually associated pendency of the epiglottis. As a rule longevity is rare among such persons, for they are liable to those diseases of a congestive character which influence the heart, brain, and liver. The cause of all this is eating food, especially fish cooked in oil, which tends to the destructive formative processes in the system, and induces premature old age, although the individual may appear to be the personification of comparatively good health. The extensive use of oil in the south of Europe has the same effect in giving rise to congestive diseases and diminished longevity. Pendency of the epiglottis, associated with the sanguineo-oleaginous expression, is of serious import. The persistent use of oil, therefore, as an article of diet, is pernicious, unless in persons of spare habit of body, delicate constitution, and liability to disease wherein its employment would prove useful.

On the Method of forming the Flint Flakes used by the early inhabitants of Devon, in Prehistoric Times. By Townshend M. Hall, *F.G.S. &c.*

The flint flakes and chippings found distributed throughout the soil in several parts of North Devon, and those associated with the submerged forest at Northam, occur so abundantly that the question has sometimes been raised, whether or not they may have been naturally formed, or whether they may not be the results of some unknown kind of accidental fracture.

In about ten different localities flint cores have been found buried with the flakes; and from a careful observation of them it appears that they are of great importance in deciding this point; for whilst a flake may possibly in some cases be caused by an accidental blow, the cores show unmistakable evidence of design. They show also that, owing to the extreme scarcity of flint all through the northern parts of Devon and Cornwall, the early inhabitants appear to have adopted in these districts a somewhat peculiar method of forming the flint flakes, which were probably used by them as knives and scrapers for domestic purposes, or as darts and arrowheads for war and the chase.

This method, the author stated, differed considerably from that which prevailed in flint-producing countries, and it seemed as if the value of the material was such as to induce the makers of these flint tools to adopt a plan by which the maximum number were obtained with a minimum amount of waste.

All the flint flakes and cores from the ten different stations, ranging along the coast from Croyde to Bude, show a singular uniformity in their design, and the method by which they were formed appears to have been as follows. A nodule having been selected, a flat surface or base was first formed by striking off one end, as near the point as possible. If the flint was cherty, or showed an uneven and hackly fracture, it seems to have been rejected in this first stage of its manufacture; but if, on the other hand, it split with a smooth conchoidal fracture, a series of blows were administered from the flat surface, at intervals round the margin, so as to peel off the rough coating of the nodule on three sides. The second series of blows produced the largest flakes, and a third or even a fourth set of flakes could be obtained in this manner before the core was used up.

This peculiarity was noticed by the author about two years ago, in the course of a communication to the Society of Antiquaries, and a subsequent examination of many hundred flakes and cores has served to prove that the same process was in use throughout the whole of this district.

The largest flakes hitherto found in North Devon are about three inches in length, but between these and the smallest, which measure not more than three-quarters of an inch, there are innumerable gradations in size. The results of the principal excavations which have been made at Croyde and Northam, show that the average proportion of cores to flakes is about 14 per cent.

On the Esquimaux considered in their relationship to Man's Antiquity. By W. S. Hall.

On the Circassians or White Khazars. By* H. H. Howorth.

The author detailed the history of the Circassians and Kabardiens from the 12th century downwards. Before the arrival of the Turks, Comans, &c. the chief race in the plains of the Kuban and the Crimea were the Khazars, a race well known to the Byzantines and Arabians. When the name Khazar disappears, that of Circassian appears, and from a comparison of the language, customs, and traditions of both races, the author proved them to be one race under two names, and that the Circassians are the descendants of the White Khazars.

On a Frontier of Ethnology and Geology. By* H. H. Howorth.

The Isothermals in Europe are twisted far to the north of the normal course they follow in Asia and America. This twisting has not always existed, as is proved by the fauna and flora of prehistoric times, and by the remarks of the Greek and Roman geographers on the climate of Central Europe. Their gradual movement, synchronous with the gradual pushing back of the limit of the fauna and flora of prehistoric times towards Siberia, the author correlated with the gradual intrusion of the Iranian race of men, with its associated animals and plants, into Europe, and the gradual displacement of the Ugrians; the Ugrian being as much a palæontological witness to such a condition of things as we find in Siberia, or as existed in prehistoric times, as the musk sheep or the reindeer. The first intrusion of the Iranians into Europe, which the author could not date before the 12th century B.C., marked the beginning of a new geologic period. The climactic changes incident to it seem to be caused solely by the presence of the Gulf-stream, so that if we can date the first giving way of the Ugrians, we may possibly also date the first advent of the Gulf-stream.

On the so-called "Petrified Human Eyes," from the Graves of the Dead, Arica, Peru. By the Rev. A. Hume, *D.C.L., F.S.A., &c.*

A very large portion of the Republic of Peru, on the west coast of South America, lies in a district where rain is unknown; and in several important respects,

* This paper will be printed at length in the 'Journal of the Ethnological Society of London.'

especially in the periodical overflow of many of its rivers, it resembles Egypt. Starting from Arica on the coast, in lat. 18° 27′·5, the railroad passes over 39 miles, to the town of Tacna, which is on the high road to the Cordilleras and Bolivia. This is now a tree-less waste of sand, which sparkles with myriads of hexagonal crystals of salt; indeed scarcely a blade of grass is to be seen. Yet it was formerly known as "the *Forest* of San Juan de Dios;" and no doubt trees were abundant, where now the traveller sees the mirage every day of the year.

At various times there have been found near the mummified bodies, in the graves at Arica, small hemispherical objects of amber-looking matter; and occasionally they have been found in the eye-holes of the skulls. These objects have naturally been supposed to be *human eyes*; but as they have become completely solidified or hardened, they have been called incorrectly "*petrified* human eyes."

Such being the simple facts of the case, I give the only theories which are known on the subject, in the hope of eliciting some final decision, on the best evidence, as to what the objects really are.

1st. *That they are bonâ fide human eyes.*

2nd. *That they are the eyes of fishes.* Dr. MacDowell of Taboga, near Panama, says, "The substance is evidently organic, but in no other way has it any affinity with the human eye. With the difference that the striated lines run transverse instead of radial, it exactly resembles the eye of the shark. I lately made a dissection of one of these eyes, and hardened the lens in acetic acid, and it assumed almost the exact appearance. I feel sure that they are the eyes of some similar animal; but it is a question for the microscope and for comparative anatomy."

3rd. That they are the crystalline lenses of a Cephalopod, as shown on the authority of Professors Clift and Owen, and Mr. Bowman.

4th. *That they are vegetable matter, not animal.*

Extract of a Letter from Dr. C, M. Tidy, of Cambridge Heath, Hackney:—

"When I received the eye, I showed it to my colleague, Dr. Letheby, as well as to the Professor of Comparative Anatomy at our hospital. We were all agreed in this—that it was not a human eye, nor was it the eye of an animal at all. Dr. Letheby's impression at once was (and I perfectly agree with him) that it is a resinoid exudation from some tree; and this I proved further by analysis. The form is at once explained by this, the concentric laminæ also; and the various colours that are apparent may be explained by the length of time that elapsed between the exudation of one lamina and another, and the amount of oxidation it would undergo. I have myself no hesitation in stating that it is a *vegetable* and not an *animal* substance."

To the last of these theories there is the obvious objection, that no such dripping of gum is known, and in a district almost wholly destitute of vegetation there is no tree to yield it. The second and third are open to a moral objection, viz. that the pagan Indian always regarded the future life as the repetition of this one, with slight varieties; and why should he represent a foreign body as performing the functions of a natural part? The living would not attach to the dead the teeth of oxen or the leg of a mule. The opinion that they are human eyes is less extensively and less confidently held than formerly; but the whole subject still requires a more thorough investigation.

Notes on the Race Elements of the Irish People.
By G. Henry Kinahan, *M.R.I.A. &c.*

The author called attention to the various and numerous different races that from the earliest period up to the reign of William III. came in masses into Ireland. He took Co. Galway as an example, as it is believed to be one of the most Irish parts of Ireland, and showed that nearly all the families in it are of foreign extraction. He pointed out that in the hills of West Galway (Varconnaught), although the worst land in Ireland, nearly all the inhabitants are of English descent, their ancestors being brought in at a comparatively recent date by the Martins, &c., to regenerate the country; the country, however, conquered, as their descendants became so degenerate that the famous Colonel Martin had to get a law passed to prevent them ploughing with the horses harnessed by their tails.

The author stated that he believed no real type-Celt can now be found, as people having Celtic names are exactly similar to those of foreign origin in complexion, form, stature, &c.; but he is inclined to believe that the nearest approach to the true Celt will be found in some of the hill-countries, such as Slieve Phelin at the junction of the counties of Tipperary and Limerick, or the Burren in county of Clare, &c.

On the Natives of Vancouver's Island. By Dr. Richard King.

Notes on the Builders and the purposes of Megalithic Monuments. By A. L. Lewis, *F.A.S.L.*

An almost unbroken chain of megalithic (Druidic) monuments extends from India, through Persia and Asia Minor, the Mediterranean coasts and France, to Britain and Scandinavia, those in India being still in use, and the whole having throughout such a resemblance as could not possibly be accidental. This circumstance, with others, such as obscure but identical superstitions, traditions, &c. existing throughout this chain, induces the belief that these monuments were constructed under a common influence of some kind. The consideration of a variety of facts leads to the conclusion that in Europe they were constructed by the Celts under Druidic influence, but whether that influence was derived from India, or whether India has been subjected to a Celtic influence of some sort, or whether both India and Celtica have been influenced from some common source, is at present uncertain.

From the peculiar construction of the monuments, and from the uses to which similar monuments are still put in India, it would seem that the alignments and circles were used primarily as places of sacrifice, the dolmens or table-stones, of which there are two classes, as places of sacrifice on the one hand, and places of sepulture on the other, and the menhirs or single pillars as landmarks, commemorative pillars, tombstones, and possibly also, in some cases, as places of worship or sacrifice.

On the Origin of Civilization and the Primitive Condition of Man.—Part II. *By* Sir John Lubbock, *Bart., F.R.S., V.P. Ethn. Soc., &c. &c.*

At the Dundee Meeting of the British Association I had the honour of reading a paper "On the Origin of Civilization and the Primitive Condition of Man." The views therein advocated met with little opposition at the time. The then Presidents of the Ethnological and Anthropological Societies both expressed their concurrence in the conclusions to which I arrived; and the memoir was ordered to be printed *in extenso*. It has, however, subsequently been attacked at some length by the Duke of Argyll*. As the Duke has in some cases strangely misunderstood me, and in others (I am sure unintentionally) misrepresented my views, and as the subject is one of great interest and importance, I am anxious, with the permission of the Meeting, to make some remarks in reply to his Grace's criticisms, as well as to bring forward some additional arguments. The Duke has divided his work into four chapters:—I. Introduction; II. The Origin of Man; III. and IV. His Primitive Condition.

I did not in my first memoir, nor do I now, propose to, discuss the subjects dealt with in the first half of the Duke's "Speculations." In using the expression "First men or first beings worthy to be so-called," I did not intend to express any opinion, but merely to indicate the alternative. I wish distinctly to point this out, because the Duke so frequently quotes the expression, from which he draws an erroneous conclusion. I am, however, glad to find that he is not himself sufficiently satisfied with his arguments to dispense with an appeal to the wishes and failing of his readers. I must also observe that in attacking Prof. Huxley for proposing to unite the Bimana and Quadrumana in one Order Primates, the Duke uses a dangerous argument; for if, on account of his great mental superiority over the Quadrumana, Man forms an Order or even Class by himself, it will be im-

* Good Words: March, April, May, and June, 1868. Also since republished in a separate form.

possible any longer to regard all men as belonging to one species or even to one genus.

The Duke is in error when he supposes that "mental powers and instincts" afford tests of easy application in other parts of the animal kingdom. On the contrary, genera with the most different mental powers and instincts are placed, not only in the same Order, but even in the same family. Thus our most learned hymenopterologist, Mr. Frederick Smith, classes the Hive-bee, the Humble-bee, and the parasitic Apathus, in the same subfamily of Apidæ. It seems to me, therefore, illogical to separate man zoologically from the other primates on the ground of his mental superiority, and yet to maintain the specific unity of the human race notwithstanding the mental differences between different races of men.

I did not, however, nor do I now, propose to discuss the origin of man, and pass on therefore at once to the Duke's third chapter; and here I congratulate myself at the outset that the result of my paper has been to satisfy him that "Whately's argument *, though strong at some points, is at others open to assault, and that, as a whole, the subject now requires to be differently handled, and regarded from a different point of view." "I do not, therefore," he adds in a subsequent page †, "agree with the late Archbishop of Dublin, that we are entitled to assume it as a fact that, as regards the mechanical arts, no savage race has ever raised itself." These are, indeed, important admissions; in fact the Duke, while supporting Whately's conclusions, altogether abandons the arguments by which Whately was convinced, and which he regarded as telling most strongly in their favour.

I feel, however, less satisfaction on this account than would otherwise have been the case, because it seems to me that though the Duke acknowledges the Archbishop's argument to be untenable, he practically reproduces it with but a slight alteration, and somewhat protected by obscurity. The Duke considers that "man had instincts which afforded all that was necessary as a starting-ground." He admits, however, that monkeys use stones to break nuts; he might have added that they throw sticks at intruders. But he says, "between these rudiments of intellectual perception and the next step (that of adapting and fashioning an instrument for a particular purpose) there is a gulf in which lies the whole immeasureable distance between man and brutes." Yet in the very same page he adds the following sentence:—"The wielding of a stick is, in all probability, an act equally of primitive intuition, and from this to throwing of a stick, and the use of javelins, is an easy and natural transition." These two passages seem to me irreconcileable.

He continues as follows:—"Simple as these acts are, they involve both physical and mental powers which are capable of all the developments which we see in the most advanced industrial arts. These acts involve the instinctive idea of the constancy of natural causes and the capacity of thought, which gives men the conviction that what has happened under given conditions will, under the same conditions, always occur again." Certainly I should never have supposed that any one who had studied the lower races of men would have considered that when one savage knocked another down he thereby demonstrated his appreciation "of the constancy of natural causes," or gave any evidence of "capacity for thought."

The Duke blames the Archbishop of Dublin for not having defined the terms "civilization" and "barbarism." It seems to me that Whately illustrated his meaning better by examples than he could have done by any definition. The Duke does not appear to have felt any practical difficulty from the omission; and it is remarkable that after all he himself omits to define the terms, thus being himself guilty of the very fault for which he blames Whately. In truth it would be impossible in a few words to define the complex organization which we call civilization, or to state in a few words how a civilized differs from a barbarous people. On the other hand, to define civilization as it should be, is surely as yet impossible, since we are far indeed from having solved the problem, how we may best avail ourselves of our opportunities, and enjoy the beautiful world in which we live.

As regards barbarism, the Duke observes, "All I desire to point out here is, that there is no necessary connexion between a state of mere childhood in respect to knowledge and a state of utter barbarism, words which, if they have any de-

* 'Good Words,' 1868, p. 156. † Ibid. June, p. 386.

finite meaning at all, imply the lowest moral as well as the lowest intellectual condition." To every proposition in this remarkable sentence I entirely demur. There is, I think, a very intimate connexion between knowledge and civilization. Knowledge and barbarism cannot coexist, knowledge and civilization are inseparable.

Again, the words "utter barbarism" have certainly a very definite signification, but as certainly, I think, not that which the Duke attributes to them. The lowest moral and the lowest intellectual condition are not only, in my opinion, not inseparable, they are not even compatible. Morality implies responsibility, and consequently intelligence; the lower animals are neither moral nor immoral; the lower races of men may be, and are, vicious; but allowances must be made for them; on the contrary (*corruptio optimi pessima est*), the higher the mental power, the more splendid the intellectual endowment, the deeper is the moral degradation of him who wastes the one and abuses the other.

Travellers who have lived much among savages differ greatly from the Duke in his estimate of their moral condition. Thus, Mr. Wallace, our latest and one of our best travellers, says*, "I have lived with communities of savages in South America and in the East, who have no laws or law courts but the public opinion of the villagers freely expressed. Each man scrupulously respects the rights of his fellow, and any infraction of those rights rarely or never takes place. In such a community all are nearly equal; there are none of those wide distinctions of education and ignorance, wealth and poverty, master and servant, which are the product of our civilization; there is none of those widespread division of labour which, while it increases wealth, produces also conflicting interests; there is not that severe competition and struggle for existence or for wealth which the dense population of civilized countries inevitably creates. All incitements to great crimes are thus wanting, and petty ones are thus repressed, partly by the influence of public opinion, but chiefly by that natural sense of justice and of his neighbour's right, which seems to be in some degree inherent in every race of man. Now, although we have progressed vastly beyond the savage state in intellectual achievements, we have not advanced equally in morals."

As regards the Bushmen, Le Vaillant says:—"For myself, who, far from fearing the Houzouanas, had felt pleasure from their society, and entertained an affection for them, I once more confess that I did not part from them without regret; that I found them an active, laborious, and intelligent race of men, ever ready to oblige in spite of obstacles, and superior to other savages both in courage and ability . . . . They inspired me," he adds, "with more love and esteem than any other tribe in Africa; with whom I would have undertaken, without fear, to traverse the whole of that quarter of the globe had my good fortune permitted me to know them sooner; and if ever circumstances allow me to resume the project, which it has been so painful to me to relinquish, they are the only ones that shall be my companions in the enterprise, and to them alone will I direct my steps without delay."

Speaking of the South Australians, Major Mitchell says:—"My experience enables me to speak in the most favourable terms of the Aborigines" †.

The Flatheads of Oregon are described by those who have the best opportunities of knowing them, collectively as well as individually, as moral and honest in all their dealings; brave in the field, amenable to their chiefs, fond of cleanliness, and decided enemies of theft and falsehood of every description. They are also free from backbiting and laziness, which are so common among other tribes‡.

Lafitau §, also, speaking of the American savages, observes that, "ces peuples, sans avoir de loix écrites, ne laissent pas d'avoir une justice rigoureuse dans le fonds, et de se tenir en respect les uns les autres, par la crainte qui oblige les particuliers à veiller sur leur propre conduite, pour ne pas troubles l'ordre et la tranquillité publique; ce qui est le but de tout bon gouvernement."

It may be said that these are exceptional cases, still they are enough for my purpose, and on the whole, the fair inference seems to be that savages are more

* Malay Archipelago, vol. ii. p. 460.

† Stephens's 'South Australia,' p. 73. See also p. 80.

‡ Dunn's 'Oregon,' p. 311.

§ Mœurs des Sauvages Américains, vol. i. p. 501.

innocent, and yet more criminal than civilized races; they are by no means in the lowest possible moral condition, nor do they rise to the higher virtues.

In my previous paper I laid much stress on the fact that even in the most civilized nations we find traces of early barbarism. The Duke maintains, on the contrary, that these traces afford no proof, or even presumption, that barbarism was the primeval condition of man; he urges that all such customs may have been, not primeval, but medieval; and he continues—"Yet this assumption runs through all Sir J. Lubbock's arguments. Wherever a brutal or savage custom prevails, it is regarded as a sample of the original condition of mankind. And this in the teeth of facts which prove that many of such customs not only may have been, but must have been, the result of corruption."

Fortunately, it is unnecessary for me to defend myself against this criticism, because in the very next sentence the Duke directly contradicts himself, and shows that I have not done that of which he accuses me. He continues his argument thus:—"Take cannibalism as one of these. Sir J. Lubbock seems to admit that this loathsome practice was not primeval." Thus, by way of proof that I regard all brutal customs as primeval, he states, and correctly states, that I do not regard cannibalism as primeval.

The Duke refers particularly to the practice of Bride-catching, which he states "cannot possibly have been primeval." He omits, however, to explain why not; and, of course, assuming the word "primeval" to cover a period of some length. Mr. M'Lennan has, I think, brought forward strong reasons for considering Bride-catching to have been a primeval custom. As the Duke correctly observes, I laid some stress on this custom, and am sorry that his Grace here meets me with a mere contradiction, instead of an argument. It may perhaps, however, be as well to state emphatically that all brutal customs are not, in my opinion, primeval. Human sacrifices, for instance, were, I think, certainly not so.

My argument, however, was that there is a definite sequence of habits and ideas; that certain customs (some brutal, others not so) which we find lingering on in civilized communities, are a page of past history, and tell a tale of former barbarism, rather on account of their simplicity than of their brutality, though many of them are brutal enough.

No one surely would go back from letter-writing to the use of the quippu or hieroglyphics; no one would abandon the fire-drill and obtain fire by hand-friction.

Believing that the primitive condition of man was one of civilization, the Duke accounts for the existence of savages by the remark that they are "mere outcasts of the human race," descendants of weak tribes which were "driven to the woods and rocks." But until the historical period these "mere outcasts" occupied almost the whole of North and South America, all Northern Europe, the greater part of Africa, the great continent of Australia, a large part of Asia, and the beautiful islands of the Pacific. Moreover, until modified by man the great continents were either in the condition of open plains, such as heaths, downs, prairies, and tundras, or they were mere "woods and rocks." Now everything tends to show that mere woods and rocks exercised on the whole a favourable influence. Inhabitants of great plains rarely rose beyond the pastoral stage. In America the most advanced civilization was attained, not by the occupants of the fertile valleys, not along the banks of the Mississippi or the Amazon, but among the rocks and the woods of Mexico and Peru.

Scotland itself is a brilliant proof that woods and rocks are compatible with a high state of civilization. My idea of the manner in which, and the causes owing to which, man spread over the earth, is very different from that of the Duke. He evidently supposes that new countries have been occupied by weaker races, driven there by more powerful tribes. This I believe to be an entirely erroneous notion. Take for instance our own island. We are sometimes told that the Celts were driven by the Saxons into Wales and Cornwall. On the contrary, however, we know that Wales and Cornwall were both occupied long before the Saxons landed on our shores. The Celts were not driven away at all, but either destroyed or absorbed.

The gradual extension of the human race has not in my opinion been effected by force acting on any given race from without, but by internal necessity, and the pressure of population; by peaceful, not by hostile force; by prosperity, not by misfortune. I believe that of old, as now, founders of new colonies were men of energy and enterprise; animated by hope and courage, not by fear and despair; that they were, in short, anything but mere outcasts of the human race.

The Duke relies a good deal on the case of America. "Is it not true," he asks, "that the lowest and rudest tribes in the population of the globe have been found at the furthest extremities of its great continents, and in the distant islands which would be the last refuge of the victims of violence and misfortune? 'The New World' is the continent which presents the most uninterrupted stretch of habitable land from the highest northern to the lowest southern latitude. On the extreme north we have the Esquimaux, or Inuit race, maintaining human life under conditions of extremest hardship, even amid the perpetual ice of the Polar Seas. And what a life it is! Watching at the blow-hole of a seal for many hours, in a temperature of 75° below freezing-point, is the constant work of the Inuit hunter. And when at last his prey is struck, it is his luxury to feast upon the raw blood and blubber. To civilized man it is hardly possible to conceive a life so wretched, and in many respects so brutal as the life led by this race during the long lasting night of the arctic winter."

To this question I confidently reply, No, it is not true; it is not true as a general proposition that the lowest races are found furthest from the centres of continents; it is not true in the particular case of America. The natives of Brazil, possessing a country of almost unrivalled fertility, surrounded by the most luxuriant vegetation, watered by magnificent rivers, and abounding in animal life, were yet unquestionably lower than the Esquimaux *, whom the Duke pities and despises so much †. More, indeed, I think than the case requires. Our own sportsmen willingly undergo great hardships in pursuit of game; and hunting in reality possesses a keen zest which it can never attain when it is a mere sport.

"When we rise," says Mr. Hill ‡, "twice or thrice a day from a full meal, we cannot be in a right frame either of body or mind for the proper enjoyments of the chase. Our sluggish spirits then wants the true incentive to action, which should be hunger, with the hope before us of filling a craving stomach. I could remember once before being for a long time dependent upon the gun for food, and feeling a touch of the charm of a savage life (for every condition of humanity has its good as well as its evil), but never till now did I fully comprehend the attachment of the sensitive, not drowsy Indian."

Esquimaux life, indeed, as painted by our Arctic voyagers, is by no means so miserable as the Duke supposes. Capt. Parry, for instance, gives the following picture of an Esquimaux hut. "In the few opportunities we had in putting their hospitality to the test we had every reason to be pleased with them. Both as to food and accommodation, the best they had were always at our service; and their attention, both in kind and degree, was everything that hospitality and even good breeding could dictate. The kindly offices of drying and mending our clothes, cooking our provisions and thawing snow for our drink, were performed by the women with an obliging cheerfulness which we shall not easily forget, and which demanded its due share of our admiration and esteem. While thus their guest I have passed an evening not only with comfort, but with extreme gratification; for with the women working and singing, their husbands quietly mending their lines, the children playing before the door, and the pot boiling over the blaze of a cheerful lamp, one might well forget for the time that an Esquimaux hut was the scene of this domestic comfort and tranquillity; and I can safely affirm with Cartwright that, while thus lodged beneath their roof, I know no people whom I would more confidently trust, as respects either my person or my property, than the Esquimaux." Dr. Rae §, who had ample means of judging, tells us that the Eastern Esquimaux "are sober, steady, and faithful. . . . . Provident of their own property and

* See Martius, p. 77. Dr. Rae ranks the Esquimaux above the Red Indians (Trans. Ethn. Soc. 1866).

† When the Duke states that "neither an agricultural nor pastoral life is possible on the borders of a frozen sea," he forgot for the moment the inhabitants of Lapland and of Siberia.

‡ Travels in Siberia, vol. ii. p. 288.

§ Trans. Ethn. Soc. 1866. p. 138.

careful of that of others when under their charge. . . . . Socially they are a lively, cheerful, and chatty people, fond of associating with each other and with strangers, with whom they soon become on friendly terms, if kindly treated. . . In their domestic relations they are exemplary. The man is an obedient son, a good husband, and a kind father. . . . . The children when young are docile. . . . . The girls have their dolls, in making dresses and shoes for which they amuse and employ themselves. The boys have miniature bows, arrows, and spears. . . . When grown up they are dutiful and kind to their parents. . . . . Orphan children are readily adopted and well cared for until they are able to provide for themselves." He concludes by saying, "the more I saw of the Esquimaux the higher was the opinion I formed of them."

Again, Hooper* thus describes a visit to an Asiatic Esquimaux belonging to the Tuski:—"Upon reaching Mooldooyah's habitation, we found Captain Moore installed at his ease, with every provision made for comfort and convenience. Water and venison were suspended over the lamps in preparation for dinner; skins nicely arranged for couches, and the hangings raised to admit the cool air; our baggage was bestowed around us with care and in quiet, and we were free to take our own way of enjoying such unobtrusive hospitality, without a crowd of eager gazers watching us like lions at feed; nor were we troubled by importunate begging, such as detracted from the dignity of Metra's station, which was undoubtedly high in the tribe."

I know no sufficient reason for supposing that the Esquimaux were ever more advanced than they are now. The Duke indeed considers that before they were "driven by wars and migrations" (a somewhat curious expression) they "may have been nomads living on their flocks and herds;" and he states broadly that "the rigours of the region they now inhabit have reduced this people to the condition in which we now see them;" a conclusion for which I know no reason, particularly as the Tinné and other Indians living to the south of the Esquimaux are ruder and more barbarous.

It is my belief that the great continents were already occupied by a widespread, though sparse population, when man was no more advanced than the lowest savages of to-day; and although I am far from believing that the various degrees of civilization which now occur can be altogether accounted for by the external circumstances as they at present exist, still these circumstances seem to me to throw much light on the very different amount of progress which has been attained by different races.

In referring to the backwardness of the aboriginal Australians, I had observed that New Holland contained "neither cereals nor any animals which could be domesticated with advantage," upon which the Duke remarks that "Sir John Lubbock urges in reply to Whately that the low condition of Australian savages affords no proof whatever that they could not raise themselves, because the materials of improvement are wanting in that country, which affords no cereals, nor animals capable of useful domestication. But Sir J. Lubbock does not perceive that the same argument which shows how improvement could not possibly be attained, shows also how degradation could not possibly be avoided. If with the few resources of the country it was impossible for savages to rise, it follows that with those same resources it would be impossible for a half-civilized race not to fall. And as in this case again, unless we are to suppose a separate Adam and Eve for Van Diemen's Land, its natives must originally have come from countries where both corn and cattle were to be had, it follows that the low condition of these natives is much more likely to have been the result of degradation than of primeval barbarism."

But my argument was that a half-civilized race would have brought other resources with them. The dog was, I think, certainly introduced into that country by man, who would have brought with him other animals also if he had possessed any. The same argument applies to plants; the Polynesians carried with them the Sweet Potato and the Yam, as well as the dog, from island to island; and even if the first settlers in Australia happened to have been without them, and without the means of acquiring them, they would certainly have found some

* The Tents of the Tuski, *cit.* p. 102.

native plants which would have been worth the trouble of cultivation, if they had attained to the agricultural stage.

This argument applies with even more force to pottery; if the first settlers in Australia were acquainted with this art, I can see no reason why they should suddenly and completely have lost it.

The Duke, indeed, appears to maintain that though the natives of Van Diemen's Land (whom he evidently regards as belonging to the same race as the Australians and Polynesians, from both of which they are entirely distinct) "must originally have come from countries where both corn and cattle were to be had," still "degradation could not possibly be avoided." This seems to be the natural inference from the Duke's language, and suggests a very gloomy feature for our Australian fellow-countrymen. The position is, however, so manifestly untenable, when once put into plain language, that I think it unnecessary to dwell longer on this part of the subject. Even the Duke himself will hardly maintain that our colonists must fall back because the natives did not improve. Yet he extends and generalizes this argument in a subsequent paragraph, saying, "there is hardly a single fact quoted by Sir J. Lubbock in favour of his own theory, which when viewed in connexion with the same undisputable principles, does not tell against that theory rather than in its favour." So far from being "indisputable," the principle that when savages remained savages, civilized settlers must descend to the same level, appears to me entirely erroneous. On reading the above passage, however, I passed on with much interest to see which of my facts I had so strangely misread.

The great majority of facts connected with savage life have no perceptible bearing on the question, and I must therefore have been not only very stupid, but also singularly unfortunate, if of all those quoted by me in support of my argument there was "hardly a single one," which read aright was not merely irrelevant, but actually told against me. In support of his statement the Duke gives three illustrations, but it is remarkable that not one of these three cases was referred to by me in the present discussion, or in favour of my theory. If all the facts on which I relied told against me, it is curious that the Duke should not give an instance. The three illustrations which he quotes from my 'Prehistoric Times' seem to me irrelevant, but as the Duke thinks otherwise, and some may agree with him, it will be worth while to see how he uses them, and whether they give any real support to his argument. As already mentioned they are three in number.

"Sir J. Lubbock," he says, "reminds us that in a cave on the north-west coast, tolerable figures of sharks, porpoises, turtles, lizards, canoes, and some quadrupeds &c. were found, and yet that the present natives of the country where they were found were utterly incapable of realizing the most vivid artistic representations, and ascribe the drawings in the cave to diabolical agency."

This does not prove much, because the Australian tribes differ much in their artistic condition; some of them still make rude drawings like those above described.

Secondly, he says, "Sir J. Lubbock quotes the testimony of Cook, in respect to the Tasmanians, that they had no canoes. Yet their ancestors could not have reached the island by walking on the sea."

This argument would equally prove that the kangaroos and Echidnas must have had civilized ancestors; it would have been equally impossible for "*their* ancestors to have reached the island by walking on the sea." The Duke, though admitting the antiquity of man, does not I think appreciate the geological changes which have taken place during the human period.

The only other case which he quotes is that of the highland Eskimo, who had no weapons nor any idea of war. The Duke's comment is as follows. "No wonder, poor people! They had been driven into regions where no stronger race could desire to follow them. But that the fathers had once known what war and violence meant, there is no more conclusive proof than the dwelling-place of their children."

It is perhaps natural that the head of a great Highland Clan should regard with pity a people who, having "once known what war and violence meant," have no longer any neighbours to pillage or to fight, but a lowlander can hardly be expected seriously to regard such a change as one calculated to excite pity, or as any evidence of degradation. In my first paper I deduced an argument, the condition of religion among the different races of man, a part of the subject which has since been admirably dealt with by Mr. Tylor in a lecture at the Royal Institution. The use of flint for sacrificial purposes long after the introduction of metal, seemed to me a good case of what Mr. Tylor has aptly called "Survival." So also is the method of obtaining fire. The Brahman will not use ordinary fire for sacred purposes, he does not even obtain a fresh spark from flint and steel, but reverts, or rather continues the old way of obtaining it by friction with a wooden drill, one Brahman pulling the thong backwards and forwards while another watches to catch the sacred spark.

I also referred to the non-existence of religion among certain savage races, and as the Duke correctly observes, I argued that this was probably their primitive condition, because it is difficult to believe that a people which had once possessed a religion would ever entirely lose it*.

This argument filled the Duke with "astonishment." Surely, he says, "if there is one fact more certain than another in respect to the nature of Man, it is that he is capable of losing religous knowledge, of ceasing to believe in religious truth, and of falling away from religious duty. If by 'religion' is meant the existence merely of some impressions of powers invisible and supernatural, even this, we know, can not only be lost, but be scornfully disavowed by men who are highly civilized."

Yet in the very same page, with that curious tendency to self-contradiction, of which I have already given several instances, the Duke goes on to say "the most cruel and savage customs in the world are the direct effect of its 'religions.' And if men could drop religions when they would, or if they could even form the wish to get rid of those which sit like a nightmare on their life, there would be many more nations without a 'religion' than there are found to be. But religions can neither be put on nor cast off like garments, according to their utility, or according to their beauty, or according to their power of comforting."

With this I entirely agree. Man can no more voluntarily abandon or change the articles of his religious creed than he can make one hair black or white, or add one cubit to his stature. I do not deny that there may be exceptional cases of intellectual men entirely devoid of religion; but if the Duke means to say that men who are highly civilized habitually or frequently lose and scornfully disavow religion, I can only say that I should adopt such an opinion with difficulty and regret. There is, so far as I know, no evidence on record which would justify such an opinion, and as far as my private experience goes, I at least have met with no such tendency.

It is indeed true that from the times of Socrates down to those of Luther, and perhaps later, men in advance of their age have disavowed particular religions, and particular myths; but the Duke of Argyll would, I am sure, not confuse a desire for reformation with the scornful disavowal of religion as a whole. Some philosophers may object to prayers for rain, but they are foremost in denouncing the folly of witchcraft; they may regard matter as aboriginal, but they would never suppose with the Redskin that land was created while water existed from the beginning; nor would any one now suppose with the South-Sea Islanders that the Peerage were immortal, but not Commoners. If, indeed, there is "one fact more certain than another in respect to the nature of man," I should have considered it to be the gradual diffusion of religious light, and of nobler conceptions as to the nature of God.

The lowest savages have no idea of a Deity at all. Those slightly more advanced regard him as an enemy to be dreaded, but who may be resisted with a fair prospect of success; who may be cheated by the cunning and defied by the strong. Thus the natives of the Nicobar islands endeavour to terrify their deity by scarecrows, and the Negro beats his fetish if his prayers are not granted. As tribes advance in civilization, their deities advance in dignity, but their power is still limited; one governs the sea, another the land; one reigns over the plains, another among the mountains. The most powerful are vindictive, cruel, and unjust. They require humiliating ceremonies and bloody sacrifices. But few races have arrived at the conception of an omnipotent and beneficent deity.

Perhaps the lowest form of religion may be considered to be that presented by

* It is hardly necessary to explain to anyone that I did not intend to question the possibility of a change in, but a total loss of religion.

the Australians, which consists of a mere unreasoning belief in the existence of mysterious beings. The native who has in his sleep a nightmare, or a dream, does not doubt the reality of that which passes, and as the beings by whom he is visited in his sleep are unseen by his friends and relations, he regards them as invisible.

In Fetichism this feeling is more methodized. The Negro, by means of witchcraft, endeavours to make a slave of his deity. Thus Fetichism is almost the opposite of Religion; it stands towards it in the same relation as Alchemy to Chemistry, or Astrology to Astronomy; and shows how fundamentally our idea of a deity differs from that which presents itself to the savage. The Negro does not hesitate to punish a refractory fetish, and hides it in his waistcloth if he does not wish it to know what is going on. Aladdin's lamp is, in fact, a well-known illustration of a fetish.

A further stage is that in which the superiority of the higher deities is more fully recognized. Everything is worshipped indiscriminately—animals, plants, and even inanimate objects. In endeavouring to account for the worship of animals, we must remember that names are very frequently taken from them. The children and followers of a man called the Bear or the Lion would make that a tribal name. Hence the animal itself would be first respected, at last worshipped. This form of religion can be shown to have existed, at one time or another, almost all over the world.

"The Totem," says Schoolcraft, "is a symbol of the name of the progenitor,—generally some quadruped, or bird, or other object in the animal kingdom, which stands, if we may so express it, as the surname of the family. It is always some animated object, and seldom or never derived from the inanimate class of nature. Its significant importance is derived from the fact that individuals unhesitatingly trace their lineage from it. By whatever names they may be called during their lifetime, it is the Totem, and not their personal name, that is recorded on the tomb or 'adjedating' that marks the place of burial. Families are thus traced when expanded into bands or tribes, multiplication of which, in North America, has been very great, and has decreased, in like ratio, the labours of the ethnologist." Totemism, however, is by no means confined to America. In Central India "the Moondah 'Enidhi,' or Oraon 'Minijrar,' or Eel tribe, will not kill or eat that fish. The Hawk, Crow, or Heron tribes will not kill or eat those birds. Livingstone, quoted in Latham, tells us that the subtribes of Bitshuanas (or Bechuanas) are similarly named after certain animals, and a tribe never eats the animal from which it is named, using the term 'ila,' hate or dread, in reference to killing it"*.

Traces, indeed, of Totemism, more or less distinct, are widely distributed, and often connected with marriage prohibitions.

As regards inanimate objects, we must remember that the savage accounts for all action and movement by life; hence a watch is to him alive. This being taken in conjunction with the feeling that anything unusual is "great medicine," leads to the worship of any remarkable inanimate object. Mr. Fergusson has recently attempted to show the special prevalence of Tree and Serpent worship. He might, I believe, have made out as strong a case for some other objects. It seems clear that the objects worshipped in this stage are neither to be regarded as emblems, nor are they personified. Inanimate objects have spirits as well as men; hence when the wives and slaves are sacrificed, the weapons also are broken in the grave, so that the spirits of the latter, as well as of the former, may accompany their master to the other world.

The gradually increasing power of chiefs and priests led to Anthropomorphism with its sacrifices, temples, and priests, &c. To this stage belongs idolatry, which must by no means be regarded as the lowest state of religion. Solomon†, indeed, long ago pointed out how it was connected with monarchical power:—

"Whom men could not honour in presence, because they dwelt far off, they took the counterfeit of his visage from far, and made an express image of a king, whom they honoured, to the end that by this, their forwardness, they might flatter him that was absent, as if he were present.

"Also the singular diligence of the artificer did help to set forward the ignorant to more superstition.

* Trans. Ethnological Soc. N. S. vol. vi. p. 36. † Wisdom, xiv. 17.

"For he, peradventure willing to please one in authority, forced all his skill to make the resemblance of the best fashion.

"And so the multitude, allured by the grace of the work, took him now for a God, which a little before was but honoured as a man.'

The worship of principles may be regarded as a still further stage in the natural development of religion.

It is important to observe that each stage of religion is superimposed on the preceding, and that bygone beliefs linger on among the children and the ignorant. Thus witchcraft is still believed in by the ignorant, and fairy tales flourish in the nursery.

It certainly appears to me that the gradual development of religious ideas among the lower races of men is a fair argument in opposition to the view that savages are degenerate descendants of civilized ancestors. Archbishop Whately would admit the connexion between these different phases of religious belief, but I think he would find it very difficult to show any process of natural degradation and decay which could explain the quaint errors and opinions of the lower races of men, or to account for the lingering belief in witchcraft, and other similar absurdities in civilized races, excepting by some such train of reasoning as that which I have endeavoured to sketch.

There is another case in this memoir wherein the Duke, although generally a fair opponent, brings forward an unsupportable accusation. He criticises severely the "Four Ages," generally admitted by archæologists, especially referring to the terms "Palæolithic" and "Neolithic," which are used to denote the two earlier.

I have no wish to take to myself in particular the blame which the Duke impartially extends to archæologists in general, but having suggested the two terms in question, I will simply place side by side the passage in which they first appeared, and the Duke's criticism, and confidently ask whether there is any foundation for the sweeping accusation made by the noble Duke.

The Duke says, "For here I must observe that Archæologists are using language on this subject which, if not positively erroneous, requires, at least, more rigorous definitions and limitations of meaning than they are disposed to attend to. They talk of an Old Stone Age (Palæolithic), and of a Newer Stone Age (Neolithic), and of a Bronze Age, and of an Iron Age. Now, there is no proof whatever that such Ages ever existed in the world. It may be true, and it probably is true, that most nations in the progress of the Arts have passed through the stages of using stone for implements before they were acquainted with the use of metals. Even this, however, may not be true of all nations. In Africa there appears to be no traces of any time when the natives were not acquainted with the use of iron; and I am informed by Sir Samuel Baker that iron ore is so common in Africa, and of a kind so easily reducible by heat, and its use might well be discovered by the rudest tribes, who were in the habit of lighting fires. Then again it is to be remembered that there are some countries in the world where stone is as rare and difficult to get as metals. The great alluvial plains of Mesopotamia are a case in point. Ac-

My words, in proposing the terms, were as follows:—

"From the careful study of the remains which have come down to us, it would appear that the prehistoric Archæology may be divided into four great epochs.

"Firstly. That of Drift; when man shared the possession of Europe with the Mammoth, the Cave-bear, the woolly-haired rhinoceros and other extinct animals. This we may call the "Palæolithic" period.

"Secondly. The later or polished Stone Age; a period characterized by beautiful weapons and instruments made of flint and other kinds of stone, in which, however, we find no trace of the knowledge of any metal, excepting gold, which seems to have been sometimes used for ornaments. This we may call the Neolithic period.

"Thirdly. The Bronze Age, in which bronze was used for arms and cutting instruments of all kinds.

"Fourthly. The Iron Age, in which that metal had superseded bronze for arms, axes, knives, &c.; bronze, however, still being in common use for ornaments, and frequently also for the handles of swords and other arms, but never for the blades.

"Stone weapons, however, of many

cordingly, we know from the remains of the First Chaldean Monarchy that a very high civilization in the arts of agriculture and of commerce coexisted with the use of stone implements of a very rude character. This fact proves that rude stone implements are not necessarily any proof whatever of a really barbarous condition. And even if it were true that the use of stone has in all cases preceded the use of metals, it is quite certain that the same Age, which was an Age of Stone in one part of the world was an Age of Metal in the other. As regards the Eskimo and the South-Sea Islanders we are now, or were very recently, living in a Stone Age."

kinds were still in use during the age of Bronze, and even during that of Iron. So that the mere presence of a few stone implements is not in itself sufficient evidence that any given 'find' belongs to the Stone Age.

"In order to prevent misapprehension, it may be as well to state at once, that I only apply this classification to Europe, though in all probability it might also be extended to the neighbouring parts of Asia and Africa. As regards other civilized countries, China and Japan for instance, we, as yet, know nothing of their Prehistoric Archæology. It is evident, also, that some nations, such as the Fuegians, Andamaners, &c., are even now only in an age of Stone."

I cannot, of course, on this occasion repeat the arguments adduced in my first memoir; I will, however, now bring forward one or two additional ones in support of my view. There is a considerable body of evidence tending to show that the offspring produced by crossing different varieties tends to revert to the type from which these varieties are descended. Thus Tegetmeier states that "a cross between two non-sitting varieties (of the common fowl) almost invariably produces a mongrel that becomes broody, and sits with remarkable steadiness." Mr. Darwin gives several cases in which such hybrids or mongrels are singularly wild and untameable, the mule being a familiar instance. Messrs. Boitard and Corbié state that, when they crossed certain breeds of pigeons, they invariably got some young ones coloured like the wild *C. livia*. Mr. Darwin repeated these experiments, and found the statement fully confirmed.

So again the same is the case with fowls. Tens of thousands of the Black Spanish and the white silk fowls might be bred without a single red feather appearing, yet Mr. Darwin found that on crossing them he immediately obtained specimens with red feathers. Similar results have been obtained with ducks, rabbits, and cattle. Mules also have not unfrequently barred legs. It is unnecessary to give these cases in detail, because Mr. Darwin's work on 'Animals and Plants under Domestication' is in the hands of every naturalist.

Applying the same test to man, Mr. Darwin observes that crossed races of men are singularly savage and degraded. "Many years ago," he says, "I was struck by the fact that in South America men of complicated descent between Negroes, Indians, and Spaniards seldom had, whatever the cause might be, a good expression. Livingstone remarks that 'it is unaccountable why half-castes are so much more cruel than the Portuguese, but such is undoubtedly the case.' An inhabitant remarked to Livingstone, 'God made white men, and God made black men, but the devil made half-castes!' When two races, both low in the scale, are crossed, the progeny seems to be eminently bad. Thus the noble-hearted Humboldt, who felt none of that prejudice against the inferior races now so current in England, speaks in strong terms of the bad and savage disposition of Zambas, or half-castes between Indians and Negroes, and this conclusion has been arrived at by various observers. From these facts we may perhaps infer that the degraded state of so many half-castes is in part due to reversion to a primitive and savage condition, induced by the act of crossing, as to well as the unfavourable moral conditions under which they generally exist."

I confess, however, that I am not sure how far this may not be accounted for by the unfortunate circumstances in which half-breeds are generally placed. The half-breeds between the Hudson's Bay Company's servants and the native women, being well treated and looked after, appear to be a creditable and well-behaved race*.

* Dunn's 'Oregon Territory,' p. 147.

I would also call particular attention to the remarkable similarity between the mental characteristics of savages and those of children.

"The Abipones," says Dobritzhoffer*, "when they are unable to comprehend anything at first sight, soon grow weary of examining it, and cry 'orqueenàm'? what is it after all? Sometimes the Guaranies, when completely puzzled, knit their brows and cry 'tupâ oiquaà,' God knows what it is. Since they possess such small reasoning powers, and have so little inclination to exert them, it is no wonder that they are neither able nor willing to argue one thing from another." Richardson says of the Dogrib Indians, "that however high the reward they expected to receive on reaching their destination, they could not be depended on to carry letters. A slight difficulty, the prospect of a banquet on venison, or a sudden impulse to visit some friend, were sufficient to turn them aside for an indefinite length of time"†.

Le Vaillant‡ also observes of the Namaquas, that they closely resembled children in their great curiosity.

M. Bourien§, speaking of the wild tribes in the Malayan Peninsula, says that an "inconstant humour, fickle and erratic, together with a mixture of fear, timidity, and diffidence, lies at the bottom of their character, they seem always to think that they would be better in any other place than in the one they occupy at the time. Like children, their actions seem to be rarely guided by reflection, and they almost always act impulsively."

The tears of the South-Sea Islanders, "like those of children, were always ready to express any passion that was strongly excited, and, like those of children, they also appeared to be forgotten as soon as shed"‖.

At Tahiti Captain Cook mentions that Oberea, the Queen, and Tootathah, one of the principal chiefs, amused themselves with two large dolls. D'Urville tells us that a New Zealand chief, Tauvarya by name, "cried like a child because the sailors spoilt his favourite cloak by powdering it with flour"¶.

Williams** mentions that in Fiji not only the women, but even the men give vent to their feelings by crying. Burton even says that among East Africans the men cried more frequently than the women††.

Not only do savages closely resemble children in their general character, but a curious similarity exists between them in many small points. For instance, the tendency to reduplication, which is so characteristic of children, prevails remarkably also amongst savages.

The first 1000 words in Richardson's dictionary (down to allege), contain only three, namely, adscititious, adventitious, agitator, and even in these it is reduced to a minimum. There is not a single word like *ahi ahi*, evening; *ake ake*, eternal; *aki aki*, a bird; *aniwaniwa*, the rainbow; *anga anga*, agreement; *angi angi*, aboard; *aro aro*, in front; *aruaru*, to woo; *ati ati*, to drive out; *awa awa*, a valley; or *awanga wanga*, hope, words of a class which abound in savage languages.

The first 1000 words in a French dictionary I found to contain only two reduplications, namely, anana and assassin, both of which are derived from a lower race, and cannot, strictly speaking, be regarded as French.

Again, 1000 German words, taking for variety the letters C and D, contain six cases, namely, *Cacadu* (Cockatoo), *cacao*, *cocon* (cocoon), *cocosbaum*, a cocao tree, *cocos nuss*, cocao nut, and *dagegen*, of which again all but the last are foreign.

Lastly, the first 1000 Greek words contained only two reduplications, one of which is αβαρβαρος.

For comparison with the above I have examined the vocabularies of seventeen savage races, and the results are given in the following Table:—

For African languages I have examined the Beetjuan and Bosjesman dialects, given by Lichtenstein in his Travels in Southern Africa; the Namaqua Hottentot, as given by Tindall in his 'Grammar and Vocabulary of the Namaqua Hottentot;' the Ne-

* Vol. ii. p. 59.
† Arctic Expedition, vol. ii. p. 23.
‡ Travels in Africa, 1776, vol. iii. p. 12.
§ Trans. Ethn. Soc. N. S. vol. iii. p. 78.
‖ Cook's First Voyage, p. 103.
¶ Vol. ii. p. 398. See also 'Yates's New Zealand,' p. 101.
** Fiji and the Fijians, vol. ii. p. 121.
†† Lake Regions, p. 332.

pongwe of the Gaboon, from the Grammar of the Mpongwe language, published by Snowden and Prall of New York; and lastly, the Fulup and Mbofon languages from Koelle's 'Polyglotta Africana.' For America, the Ojibwa Vocabulary, given in Schoolcraft's 'Indian Tribes;' the Darien Vocabulary, from the 6th vol. N. S. of the Ethnological Society's Transactions; and the Tupy Vocabulary, given in A. Goncaloes Dias's 'Diccionario da Lingua Tupy chamada lingui geral dos indigenas do Brazil.' To these I have added the languages spoken on Brumer Island, at Redscar Bay, Kowrarega, and at the Louisiade, as collected by M'Gillivray in the 'Voyage of the Rattlesnake;' and the dialects of Erroob and Lewis Murray Island, from Jukes's 'Voyage of the Fly.' Lastly, for Polynesia, the Tongan Dictionary, given by Mariner, and that of New Zealand by Dieffenbach.

The result is, that while in the four European languages we get about two reduplications in 1000 words, in the savage ones the number varies from 38 to 170, being from 20 to 80 times as many in proportion.

In the Polynesian and Fiji Islands they are particularly numerous; thus, in Fiji, such names as *Somosomo, Raki raki, Ravirari, Lumaluma* are numerous. Perhaps the most familiar New Zealand words are *meremere, patoo patoo*, and *kivi kivi*. So generally, however, is reduplication a characteristic of savage tongues, that it even gave rise to the term "barbarous."

The love of pets is very strongly developed among savages. Many instances have been given by Mr. Galton in his Memoir on the "Domestication of Animals"*. Among minor indications may be mentioned the use of the rattle. Originally a sacred and mysterious instrument, as it is still among some of the Siberian Redskin and Brazilian† tribes, it has with us degenerated into a child's toy.

Thus Dobritzhoffer tells us, the Abipones at a certain season of the year worshipped the Pleiades. The ceremony consisted in a feast accompanied with dancing and music, accompanied with praises of the stars, during which the principal priestess, "who conducts the festive ceremonies, dances at intervals, rattling a gourd full of hardish fruit-seeds to musical time, and whirling round to the right with one foot, and to the left with another, without ever removing from one spot, or in the least varying her motions"‡.

Spix and Martius § thus describes a Coroado chief:—"In the middle of the assembly, and nearest to the pot, stood the chief, who, by his strength, cunning, and courage, had obtained some command over them, and had received from Marlier the title of Captain. In his right hand he held the maracá, the above-mentioned castanet, which they call gringerina, and rattled with it, beating time with his right foot."

"The Congo Negroes had a great wooden rattle, upon which they took their oaths"‖.

The rattle also is very important among the Indians of North America¶. When any person is sick, the sorcerer or medicine man brings his sacred rattle and shakes it over him. This, says Prescott, "is the principal catholicon for all diseases." Catlin** also describes the "rattle" as being of great importance. Some tribes have a sacred drum, closely resembling that of the Lapps††. When an Indian is ill, the magician, says Carver‡‡, "sits by the patient day and night, rattling in his ears a gourd-shell filled with dried beans, called a chichiconé." Klemm§§ also remarks on the great importance attached to the rattle throughout America, and Staad even thought that it was worshipped as a divinity‖‖. Schoolcraft¶¶ also gives a figure of Oshkabaiwis, the Redskin medical chief, "holding in his hand the

* Trans. Ethn. Soc. vol. iii. p. 122.

† Martius, Von dem Rectszustande und. Ur. Brasiliens, p. 34.

‡ Dobritzhoffer, vol. ii. p. 65. See also p. 72.

§ Travels in Brazil. London, 1824, vol. ii. p. 234.

‖ Astley's Coll. of Voyages, vol. iii. p. 233.

¶ Prescott in Schoolcraft's 'Indian Tribes,' vol. ii. pp. 179, 180.

** American Indians, vol. i. pp. 39, 40, 163, &c.

†† Catlin, *l. c.* p. 40.

‡‡ Travels, p. 385.

§§ Culturgéchichte, vol. ii. p. 172.

‖‖ Mœurs des Sauvages Américains, vol. ii. p. 297.

¶¶ Indian Tribes, pt. iii. pp. 490–493.

magic rattle," which is indeed the usual emblem of authority in the American pictographs. I know no case of a savage infant using the rattle as a plaything.

Tossing halfpence, as dice, again, which used to be a sacred and solemn mode of consulting the oracles, is now a mere game for children.

So again the doll is a hybrid between the baby and the fetish, and exhibiting the contradictory characters of its parents, becomes singularly unintelligible to grown-up people.

Mr. Tylor has pointed out other illustrations of this argument, and I would refer those who feel interested in this part of the subject to his excellent works.

Dancing is another case in point. With us it is a mere amusement. Among savages it is an important and, in some cases, religious ceremony. "If," says Robertson*, "any intercourse be necessary between two American tribes, the ambassadors of the one approach in a solemn dance, and present the calumet or emblem of peace; the sachems of the other receive it with the same ceremony. If war is denounced against an enemy, it is by a dance, expressive of the resentment which they feel, and of the vengeance which they meditate. If the wrath of their gods is to be appeased, or their beneficence to be celebrated, if they rejoice at the birth of a child, or mourn the death of a friend, they have dances appropriated to each of these situations, and suited to the different sentiments with which they are then animated. If a person is indisposed, a dance is prescribed as the most effectual means of restoring him to health; and if he himself cannot endure the fatigue of such an exercise, the physician or conjuror performs it in his name, as if the virtue of his activity could be transferred to his patient."

But it is unnecessary to multiply illustrations. Every one who has read much on the subject will admit the remarkable similarity which exists between savages and children. It explains the capricious treatment which so many white men have received from savage potentates; how they have been alternately petted and illtreated, at one time loaded with the best of everything, at another neglected or put to death.

This close resemblance existing in ideas, language, habits, and character between savages and children, though generally admitted, has usually been disposed of in a passing sentence, and regarded rather as a curious accident than as an important truth. Yet from several points of view it possesses a high interest. Better understood, it might have saved us many national misfortunes, from the loss of Captain Cook down to the Abyssinian war. It has also a direct bearing on the present discussion.

The opinion is rapidly gaining ground among naturalists, that the development of the individual is an epitome of that of the species, a conclusion which, if fully borne out, will evidently prove most instructive. Already many facts are on record which render it, to say the least, highly probable.

Birds of the same genus, or of closely allied genera, which, when mature, differ much in colour, are often very similar when young. The young of the Lion and the Puma are often striped, and fœtal whales have teeth.

Leidy has shown that the milk-teeth of the genus *Equus* resemble the permanent teeth of *Anchitherium*, while the milk-teeth of *Anchitherium* again approximate to the dental system of *Merychippus*†. Rutimeyer, while calling attention to this interesting observation, adds that the milk-teeth of *Equus caballus* in the same way, and still more those of *E. fossilis*, resemble the permanent teeth of *Hipparion*‡.

Agassiz, according to Darwin, regards it as a "law of nature," that the young states of each species and group resembles older forms of the same group; and Darwin himself says§, that "in two or more groups of animals, however much they may at first differ from each other in structure and habits, if they pass through closely similar embryonic stages, we may feel almost assured that they have descended from the same parent form, and are therefore closely related."

So also Mr. Herbert Spencer says||, "Each organism exhibits, within a short

* Robertson's America, bk. iv. p. 133.
† Proc. Acad. Nat. Soc. Philadelphia, 1858, p. 26.
‡ Beitrage zur kenntniss der fossilen Pferde. Basle, 1863.
§ Origin of Species, 4th edition, p. 532.
|| Principles of Biology, vol. i. p. 349.

space of time, a series of changes which, when supposed to occupy a period indefinitely great, and to go on in various ways instead of one way, give us a tolerably clear conception of organic evolution in general."

It may be said that this argument involves the acceptance of the Darwinian hypothesis; this would, however, be a mistake; the objection might indeed be tenable if men belonged to different species, but it cannot fairly be urged by those who regard all mankind as descended from common ancestors; and, in fact, it is strongly held by Agassiz, one of Darwin's most uncompromising opponents.

Regarded from this point of view, the similarity existing between savages and children assumes a singular importance, and becomes almost conclusive as regards the question now at issue.

The Duke ends his work with the expression of a belief that man, "even in his most civilized condition, is capable of degradation, that his knowledge may decay, and that his religion may be lost." Far more noble, as it seems to me, are the concluding passages of Lord Dunraven's opening address to the Cambrian Archæological Association,—"that if we look back through the entire period of the past history of man, as exhibited in the result of archæological investigation, we can scarcely fail to perceive that the whole exhibits one grand scheme of progression, which, notwithstanding partial periods of decline, has for its end the ever-increasing civilization of man, and the gradual development of his higher faculties, and for its object the continual manipulation of the design, the power, the wisdom, and the goodness of Almighty God."

I confess therefore that, after giving the arguments of the Duke of Argyll my most attentive and candid consideration, I see no reason to adopt his melancholy conclusion, but I remain persuaded that the past history of man has, on the whole, been one of progress, and that, in looking forward to the future, we are justified in doing so with confidence and with hope.

Philosophical Objection to Darwinism or Evolution.
By the Rev. J. M'Cann, *D.D.*

The Difficulties of Darwinism. By the Rev. F. O. Morris.

On the occasional definition of the Convolutions of the Brain on the exterior of the Skull. By T. S. Prideaux.

[For Abstract of this Paper see Appendix.]

On the Races of Morocco. By J. Stirling.

Notes on an Inscribed Rock. By Ralph Tate, *F.G.S.*

Initial Life. By C. Staniland Wake, *F.A.S.L.*

The object of the paper was to show, by various experiments with the tissue, seeds, and pollen of plants, that the germs of the Infusoria, supposed by heterogenists to be spontaneously generated in infusions of organic substances, are present in these substances before infusion. These experiments show also that Infusoria are developed from the fungus which is produced from milk-globules placed in water, as also from the contents of the pollen-cell, proving that decomposition is not necessary to such development. The conclusion enunciated in the paper is that infusorial germs are essential to the development of all plants, and that the final product of these germs, whether it shall be animal or vegetable, depends on the conditions under which they are brought to maturity.

Race affinities of the Madecasees. By Staniland Wake, *F.A.S.L.*

The object of the paper was to show, by a comparison of the physical characters, the customs, and the language of the Madecasees (including the Hovas) with those of peoples living on the margin of the Indian Ocean, that the former are more closely related to the peoples of South Africa than to the Malays or Polynesians; but that the Madecasees are allied to all the aboriginal peoples of the tropics, Madagascar having probably been the centre of primitive civilization.

GEOGRAPHY.

Address by Sir Bartle Frere, *President of the Section.*

In opening the proceedings of this Section I have no intention to attempt any systematic summary of the progress, present state, or prospects of geographical science generally. Such an effort would be impertinent in the presence of some of the great geographers whom we see around us; and considering that the comprehensive and exhaustive annual address of Sir Roderick Murchison for the past year is in the hands of so many of our members and visitors, it would be superfluous were I to essay even a sketch of the progress of geographical science since the British Association last met at Norwich.

My object will be simply to state the proposed course of our proceedings in this Section of the Association, and to inform you very briefly, and by way of introduction only, on what particular points we may expect to hear from the Members or from visitors who honour us with their presence, information which may be either new in itself or may form the basis of useful discussion by those present, whether they come in the character of masters or disciples of the science.

Polar discovery seems, by universal consent, to have a sort of precedence in all classification of recent geographical inquiry, and in this branch we cannot expect much that is new to be laid before our present Meeting.

We are now in the midst of the very brief season during which an Arctic summer allows the navigator, for a few weeks only, any chance of making fresh discoveries, and we cannot, for some time longer, hear what measure of success may have attended attempts like that of Mr. Lamont, to extend our knowledge of the regions adjacent to the North Pole, and especially to solve the present great Arctic problem as to the existence of an open Polar basin. We must not expect too much. The point has been passed at which skill and well-directed energy could command important results in the way of discoveries in those seas. Each fresh addition to our knowledge of the distribution of land and water in those ice-bound regions has generally left the difficulties of further discovery greater than before; and while the precautions to be taken, and the energy to be applied must be quite as great as in the days of Baffin or Parry, the results must depend more than ever on a favourable season, a lucky lane in the ice, or on what a sportsman would call a judicious cast in critical cases of doubt.

We may, however, hope to hear something of interest to geographers with regard to the prospects of Antarctic discovery in connexion with the preparations for observing the coming transit of Venus.

Geographers and astronomers will sympathize less than other taxpayers with the Chancellor of the Exchequer when he finds even the heavenly bodies moving for a parliamentary grant. We may wonder, with Mr. Lowe, that Venus cannot arrange a transit without an application to the British Treasury; but we may hope that Parliament, when the application does come before them, will not be less liberal than they were exactly a century ago (in the days of Cook), and that they will regard the investigation as one of really national importance. We may further trust that there will not be wanting a Hooker or a Darwin to record the discoveries of our philosophers in the Antarctic regions. They will be most important in a scientific point of view, even though they may lack the novelty and thrilling incidents which make the voyages of the 'Erebus' and 'Terror' almost as exciting as the most sensational of modern works of fiction.

Directly we leave the immediate neighbourhood of the Polar seas we come to regions where the restless activity of geographical discoverers is at work filling up the vast spaces of *terra incognita* which still exist on our best maps. We may not this year hope to hear statements of such importance as at former Meetings, when Livingstone, Speke, Baker, or Palgrave enchained the attention of the Association with their narratives of their then recent discoveries. Still I believe there are gentlemen present who will satisfy you that the spirit of research is not less active now than in former years, and that every season brings additions to our stock of geographical knowledge which, in the aggregate, are of vast importance.

There are amongst us, I am glad to hear, more than one geographer who will represent that vast Russian Empire, whose territories extend in so many directions into regions comparatively unknown, and whose Government has long been so honourably distinguished by the aid it has afforded to geographical science. It may I believe be truly said that along the line of thousands of leagues which form the southern boundary of the Russian Empire in Asia, there are scarcely a hundred miles regarding which our knowledge is as complete as could be desired; and almost every Government official employed on the frontier, and every trader who crosses it, has the means of adding important information to our stock of ascertained geographical facts.

An increasing share of public attention has of late been directed to those regions where the southern frontier line of the Russian Empire approaches the northern limits of our own Indian Empire.

The vast space which intervenes between our two empires, differing, as it does, so widely, both in physical aspect and in political condition, from these ocean-washed shores of Europe, is a region not unblessed by nature. History assures us that it is little changed in anything, save in political condition, since it was a nursery of great nations, and the cradle, not only of kings and founders of empires, but of trains of thought and of vast systems of moral and political philosophy which have overspread and largely influenced the richer regions of the south and west. What has inflicted on countries once so famous such a curse that the solitary traveller who passes through them, as Vámbéry did, in disguise, is welcomed among us as one just escaped from almost certain death, who has during his whole sojourn carried his life in his hand? Surely we must rejoice that the thoughts of two great civilized neighbouring nations are at length earnestly directed to this vast region; that we no longer regard our neighbours to the north and west of our Indian frontier with studied aversion and distrust, as nations of born men-stealers and man-slayers, all intercourse with whom must be discouraged and prohibited as the only condition on which we can hope to avoid being drawn into desolating wars or embarrassing political alliances.

I believe that nothing but good can result from the attention of the great statesmen of Russia and of England being directed to the condition of the countries which intervene between our empires in Asia. As far as we are ourselves concerned, I feel sure that the cause of peace and good neighbourhood could not be in better hands than those of the able and enlightened nobleman who now rules over India as Viceroy; and geographers may, I think, rest assured that it will not be Lord Mayo's fault if he fails to secure that condition of permanent good neighbourhood which both empires most earnestly desire. It is the best guarantee for progress in geographical science as in all those other branches of knowledge and civilization which flourish best in peace, and languish, or maintain but a fevered existence, in time of war or political disturbance.

We shall have among us Mr. Douglas Forsyth, honourably distinguished among those who, like Capt. Montgomery and his fellow-labourers, have led the way in geographical discovery to the north of India, and contributed to lift the veil which has for so many generations separated the inhabitants of Tartary and Thibet from those of India. He will give you, I hope, much interesting information regarding the trade-routes towards Thibet and Eastern Chinese Tartary, and will satisfy you that he is actuated by no motive more dangerous to us or our neighbours than a sincere desire to extend the peaceful domain of commerce, and, as a handmaid thereto, to aid the cause of geographical discovery.

He will tell you how much has been accomplished since Humboldt, but a few years ago, pointed to a correct knowledge of those regions as among the great desiderata of geographical science. He will give you the latest intelligence of those enterprising travellers, Messrs. Shaw and Hayward, the former of whom is at Yarkand, well treated, and apparently a special favourite with both rulers and people. Times are indeed changed since Adolphe Schlagintweit, only a few years ago, became a martyr to his zeal for science, and was put to death at Kashgar, almost all his valuable papers and observations being, it is to be feared, irretrievably lost.

Mr. Trelawney Saunders will read a paper in which he has combined some of the latest information acquired by Capt. Montgomery, and his intelligent and enterprising assistants, the Pundits, and applied it to illustrate the general geography of the Himalayan range. Much as has been written about that vast chain, it can hardly be said that even professed geographers have any adequate conception of the bulk and importance of that great mountain-mass. Its length may be said to be still almost a matter of conjecture, for its eastern and western terminations have both still to be defined. Its breadth, as Capt. Montgomery, who may be said first to have spanned it, tells us is more than 400 miles at its narrowest, or about eight times the average width of the Alps, with a summit-ridge the passes over which average about 15,000 feet in height. Probably many scores of peaks may be enumerated higher than Mont Blanc. Considering how long it has taken geographers in Europe to trace out the yet unexhausted wonders of our own Alpine ranges, it is clear that the Himalayan range and its offshoots may afford ample ground for the most energetic of explorers for many generations to come.

I trust some of our visitors may be able to give us late and detailed accounts of what Mr. Cooper has done and proposes to do towards exploring the almost unknown region which he has already so vigorously attacked from various directions. Though he has not hitherto succeeded in traversing the inhospitable countries between Bengal and China, the energy and judgment with which he has repeated and varied his efforts must, sooner or later, lead to important discoveries; and I trust that his repeated disappointments may find compensation in the ultimate solution of what may be regarded at present as the great geographical problem of that part of Asia.

The Association will recollect that the latest intelligence regarding the course of the Sanpoo, the great river which runs so far from W. to E. in a course nearly parallel to the general direction of the main Himalayan range, has revived a former discussion as to whether that river is the upper stream of the Barrumpootra or of the Irrawaddy. The supposition that it was identical with the Irrawaddy has long been considered as set at rest, and some of our best authorities, such as Drs. Hooker, Thomson, and Campbell, would, I believe, scout the notion that there was any present doubt on the subject. Still it is certain that some Chinese and Thibetan informants have assured later travellers that the Sanpoo is the upper stream of the Irrawaddy, and we are almost destitute of any accurate data regarding the course of the Barrumpootra much higher up than Sudiya. It is clear, then, that there is need of further inquiry before the question can be said to be finally set at rest, and the little we know of the rivers further down, between Burma and China, tends to show that it would be unsafe to dogmatize too confidently as to the impossibility of any theory, however improbable it may *primâ facie* appear to be.

Thus, unless there be a misprint in the published accounts of Capt. Sladen's expedition, he ascertained Mourein, one of the furthest points reached near the Burmese and Chinese frontier, to be 8000 feet above the sea, an elevation hitherto, I believe, quite unsuspected. It is true that the somewhat doubtful course of the four great rivers, the Irrawaddy, the Salween, Cambogia River, and the Yang-tse-Kiang, which are represented on our latest maps as running for so many hundred miles, in courses nearly parallel, and frequently less than sixty miles apart, would indicate streams flowing in deep gorges, like the upper course of many of the rivers which have their source in the Himalaya, separated probably by very lofty mountain-ranges; but hitherto the data for mapping out the course of these rivers have been little better than conjectural. We may hope that future attempts to penetrate in this direction from Burma will meet with better success than that of Capt. Sladen, who has, however, brought back information of considerable value, and may aid future explorers to renew their attempts, with better prospect of a complete and successful result.

The glory of being the first in modern days actually to traverse the almost unknown region between the Indo-Chinese races and China proper, has been reserved for our neighbours the French. The Fellows of the Geographical Society will recollect the admirable summary of the results of the great French expedition, which was given by the President in his last Anniversary Address, wherein Sir Roderick Murchison described the general course of a journey almost unparalleled in modern days—a journey of 6200 miles from the tidal waters of the Cambogia River to Shanghai, 2480 miles of the distance having been traversed on foot—the whole distance, with very few exceptions, being almost entirely new to modern European travellers.

I am not sure whether we are likely to hear from any of our visitors any details of this expedition beyond what has been already published in the French geographical periodicals; but we cannot doubt that whenever the scientific results of such a journey are published, they will prove of surpassing interest. A country so rich and varied in soil, with a rainfall probably, in parts, exceeding that of almost any known portion of the globe, and a great variety of temperature, which has been hitherto almost cut off from civilized Europe, while it approximates geographically to some of the most interesting regions of India and the Eastern Archipelago, must possess a fauna and flora of great novelty and interest.

Nor can it be doubted that all these attempts to traverse the regions which separate India from China have a political and social aspect of the highest importance.

It is clear that the time has arrived in China when we may witness one of those great social movements which in all ages have so powerfully affected the destinies of nations, and the geographical distribution of races. A vast surplus population, pressed at home by over-competition in the race for life, wells over, as it were, and seeks in other lands the means of supporting existence which have become difficult of attainment in their native country. The pressure from within, in the case of China, has been increased by the existence of artificial barriers, in the shape of legislative obstacles to the free movement of the population, and when these are removed or disregarded, the human tide will pour outwards with a force of which emigration from Europe to our own oclonies can give us but a faint idea. The Chinese labourers, who meet but a doubtful welcome, or are repelled from Australia and America, would be hailed as benefactors much nearer their own homes, in almost any of the rich but thinly-inhabited countries between Assam and Saigoon; and the first Chinese who succeeds in passing overland from China to India and back, may be the herald of an immigration calculated to change the face and the destiny of that vast rich, but almost uninhabited region, which has for so many ages proved an almost impassable barrier between India proper and China.

Before turning from this part of Asia, I would remind you of a fact new, I believe, in the annals of geographical discovery, and not often observable in the history of parliamentary interpellations, that two of the best *résumées* of the present state of our geographical knowledge of Central Asia and the Indo-Chinese frontier, are to be found in the answers given, in his place in parliament, by Mr. Grant Duff, a Member of the Council of the Royal Geographical Society, to questions addressed during the last session to him, in his capacity as Under Secretary of State for India.

I may also mention, as a proof of the extent to which purely European ideas are penetrating to those remote regions, that I have seen a translation of a letter, addressed by a friendly Indian potentate to the Grand Llama of Thibet, remonstrating with him on the illtreatment of certain Roman Catholic missionaries and their converts, on the ground that the sufferings of the converts had formed the subject of comments in some of the Indian journals; and the writer of the letter felt assured that evil would result to his friend the Grand Llama if he suffered public attention in Europe, with the ways and inhabitants of which the writer had intimate personal acquaintance, to be thus attracted to the inhospitable proceedings of the Grand Llama's subordinates.

Africa.—It is a great disappointment that another year should have passed without revealing, as far as I am aware, a single new fact which would throw light on the fate of Livingstone. The additional information we have received since last the Association met, is purely negative, and adds literally nothing to what was then laid before you in the masterly sketch of Livingstone's ascertained progress, contained in Capt. Richards's address. We still only know that up to December 14th, 1867, he was alive and well and in good spirits, at a place south-west of Lake Tanganyika. Further than this all is conjecture. Whether we may hear of him in the Nile Basin from Sir Samuel Baker's expedition, or on the west coast, must for the present be pure subject of speculation. Most fervently do I join in Sir Roderick Murchison's hopes that we may yet welcome him back among us during the course of the coming year. It was my privilege to see much of him in Bombay after he had taken leave of his friends in England, and before he arrived at Zanzibar, at the outset of his last expedition, and on this, as on former occasions, I was at a loss which to admire most, his unconquerable courage and perseverance, his patience and forbearance, or the grand simplicity of his character. I never met a man of such lofty aims and of such genuine humility; but what is more to the purpose, as a ground of our present hopes, I never met a man of such sagacity and unfailing resources in overcoming difficulties of every kind; and if his health is spared him, I feel every confidence that he will vanquish every obstacle, and ultimately succeed in whatever he may have undertaken.

There can be little doubt that great results may be looked for from the Egyptian expedition up the Nile, under Sir Samuel Baker, which is so totally unlike in its conception and objects anything of modern days, and for any parallel to which in its difficulties and in the important results it may produce, we must go back to the days of our earliest English, Spanish, and Portuguese discoverers.

I am assured that Sir Samuel's hopes point to passing next Christmas on Lake Albert Nyanza, and if he does that he will have achieved more than, with such a great expedition, could be expected even from his skill, energy, and enterprise.

Mr. Blanford, who remained in Abyssinia after Lord Napier's expedition left, writes to me that he will be present, if his brief time in England permits, and he will doubtless have much of interest to tell us regarding the geography as well as the geology and natural history of those regions which he has made his special study.

Further south we may hear something of Mr. Erskine's explorations on the Lower Limpopo, and in other parts of the regions adjoining the Natal colony, to which recent rumours of gold and diamond mines discovered have attracted so much attention. Whatever the value of these gold-fields, it is certain that geographical discovery is likely to benefit by the search; and if, in the course of their wanderings, the explorers should find coal-seams such as Dr. Livingstone found on the Zambesi, the discovery may be more important to the future of that part of Africa than if they rediscovered the Ophir of Solomon.

In West Africa Mr. Winwood Reade, under the auspices of the Royal Geographical Society, and Mr. A. Swanzy, one of those liberal merchants to whom geographical discovery on that coast owes so much, is on his way to the sources of the Niger.

Mr. Stirling will give you an account of his visit to the holy city of Faz, which has been long kept so sacred from the foot of any but Mahomedans, that I believe few European travellers in modern days, except Lord St. Maur, have visited it.

We cannot turn from Africa without a passing tribute to the great French engineer who has reversed the geological revolutions of ages before the birth of history, and restored Africa to that insular position which the vast continent probably occupied in the geography of times preceding the early dawn of authentic history. It is difficult to speak without exaggeration of a work which is destined to have such important results on the commerce and intercourse of the East and West, and M. Lesseps's great work itself may seem to belong of right to another Section of this Association. But geographers must recollect how much of our geographical discovery is due to the closing of this ancient route to the East. Had the action of the Moslem powers not interfered with the Genoese and Venetian trade with the East, the discoveries of Columbus and Vasco de Gama and Magellan, and even those of Hudson, Baffin, and Frobisher, might have been delayed for generations; and now, such are the insatiable demands of commerce, no sooner has the genius and energy of M. Lesseps removed one great barrier to this ancient trade-route, than mercantile men turn their attention to others still shorter, and investigate the long-forgotten geography of those lines by which the commerce of the Persian Gulf and India used to reach Tyre and Palestine *viâ* Tadmor and the valleys of the Tigris and Euphrates.

Colonel Pelly, well remembered by geographers as a daring traveller, writes, in a letter only just received, of the sudden growth of commerce which has sprung up in the Persian Gulf. Bahrein, once an important emporium of Arabian commerce, has long been known to us, till within these few years, as little better than a nest of pirates and slave-dealers; but the chief who, till quite lately, strenuously opposed everything in the shape of legitimate foreign commerce, is now in treaty with two steamer companies to visit his port regularly, and there is talk even there of agricultural companies to cultivate the lower plains of the Euphrates valley, and of railways to connect the Persian Gulf with the Mediterranean.

In South America Mr. Chandless is carrying out, single-handed, and, I believe, entirely at his own expense, his wonderful surveys of the tributaries of the Amazon. I trust Mr. Bates will give us some account of labours, with the value of which, as well as with the difficulty attending them, no man is better acquainted than our indefatigable Secretary.

In North America the great Pacific Railway, which has just been opened, must exercise a very important influence in making us better acquainted with the little-known regions which for hundreds of miles lie on both sides of its course.

There may be among us this day men who, within the last month, have looked on the waters of the Pacific from the shores of British Columbia or California, have since traversed the whole width of the American continent, and have seen, within the space of a few days' travel, every variety of country, from the wilds of the Rocky Mountains and the abode of the grisly bear and the bison, to the most civilized cities of the western world.

From Australia we have nothing very striking to relate, though we have among us some of the most distinguished of Australian explorers. I know of no great expedition on foot from which we are likely to derive any sudden and important addition to our knowledge of the vast regions still unexplored on that continent. But the ever-active population of Australia is always at work, pushing forward exploring expeditions on a smaller scale, and the aggregate of their annual discoveries is very considerable, often bringing to light districts of great future value to the colonists.

The death of the last native Tasmanian, which has been lately reported, has a melancholy interest in the history of the geographical distribution of the human race, and I may be permitted to mention it, though ethnology has been this year transferred to another Section.

Turning from the land to the sea, we find almost every month adding to our knowledge of the depth and conditions under which animal life is sustained in the great ocean-beds. The extraordinary results obtained by Dr. Carpenter and his companions in their examination of the deep-sea soundings of our own Northern Ocean will be fresh in the recollection of Members, and I trust we may at this Meeting hear some of the details of their labours during the present season.

The laying of the French electric telegraph line also, cannot fail to have furnished many new facts regarding the ocean-bed which that cable (at present, I believe, the longest in the world) passes over; and there are other examinations of ocean-beds in the eastern seas, connected with the contemplated laying of the cable to India from Suez, which cannot fail to be new and interesting, and regarding which our indefatigable Member, Capt. Sherard Osborn, if he is present, would be able to enlighten us.

Information of this kind is likely, as ocean electric cables multiply, to increase in value. When first such cables were laid, it was usual to select comparatively shallow portions of the ocean-bed for the cable to traverse, and the deep ocean-valleys and hollows were, as far as possible, avoided. But experience shows that in the deepest water the cable is safest from injury, especially in latitudes where there is risk of icebergs, which may ground and destroy the cable. Hence our Electric Telegraph Cable companies are likely to become valuable allies to geographical exploration in all that relates to our deepest ocean cavities.

Geographers are aware that from the earliest days of the Electric Telegraph Company, the Indian records have contained a vast amount of important geographical information. No one knows better than our Member, Sir Andrew Waugh, who was for so many years at the head of the Grand Trigonometrical Survey of India, how valuable and accurate, how varied and extensive were the stores of information, bearing on every portion of Indian geography, which had been accumulated during the last two centuries of our connexion with India and China. But most of this information was very difficult of access to geographers, and they will be glad to know that, since the last Meeting of the Association, a separate geographical department has been formed at the India Office, under the general direction of Mr. Clements Markham, the able Hon. Secretary of the Royal Geographical Society, and that an excellent map-room has been arranged and placed under the special charge of Mr. Trelawney Saunders, so well and favourably known to all practical geographers, while arrangements have been made for the more rapid printing and publication in India, under the care of Cols. Thuillier and Walker, of the Royal Engineers, of those series of maps for which, during so many years, we have been indebted to the conscientious accuracy of Mr. Walker, who may, I believe, now be called almost the Nestor of our English map compilers.

As connected with this subject may be mentioned arrangements for compiling a complete and trustworthy Gazeteer for India, and for systematic ethnological inquiry, which has now such important bearing on political and historical geography in India as well as in other parts of the world. I may be excused for here dilating on a reform which is not only in itself important to geographers, but which originated with your member, Sir Stafford Northcote, while Secretary of State for India.

Colonel Strange will, I hope, be able to give you some account of another reform, which I have the authority of Sir Edward Sabine for saying is likely to have very important bearing on the accuracy of all instrumental observations connected with our Eastern Empire.

Here in Devon, where so many of our great English discoverers are claimed as among the numbers of our western worthies, I may be excused for alluding to the prizes which (at the suggestion, I believe, of Mr. Francis Galton) were offered by the Royal Geographical Society for proficiency in geography among the scholars still in *statu pupillari*. I believe the conditions of the prizes are as yet but imperfectly known, and we may hope that in future our great public schools will send us more competitors in what surely ought to be considered a necessary branch of a liberal education.

Every practical geographer knows how trying it is to come across some uneducated seaman, who has voyaged in regions almost unknown to civilized man, and who, for lack of educated powers of observation, has been able to make no use of his rare advantages. But the disappointment is a thousand times greater when he who has missed such opportunities is a man of fortune, and, in the ordinary sense of the word, of high education aud accomplishments. I have known two instances of such men who, in pursuit of game, traversed regions of Africa absolutely unknown to modern geographers; in one case the knowledge thus acquired was not absolutely lost, for the sportsman fortunately communicated his observations to a scientific friend, who at once recognized their value. In the other case the sportsman could only satisfy the man of science that an unparalleled opportunity had been irretrievably lost.

I hope, from time to time, as they come forward to address you, to have the opportunity of introducing to you some of the eminent foreigners who have come to England for the special purpose of being present at this Meeting of the Association. M. Khanikof has on previous occasions attended Meetings of the British Association, and is already personally known to many Members, and he will, I trust, favour his old friends with some notes on those remote regions, with the exploration of which his name is inseparably connected. But there are two names on the list of our visitors which will have been recognized with special interest by geographers of every nation, and ensure to the gentlemen who bear them a special welcome.

M. Pierre de Tchihatchef has been so lately eulogized by his friend and admirer, the President of our own Royal Geographical Society, and in such felicitous terms, that I cannot do better than refer our visitors and members to what Sir Roderick Murchison says of the labours of our illustrious guest in his last Annual Address. I am happy to be able to inform you that M. Tchihatchef proposes to favour us with an address on the geography of Central Asia, and I feel assured that the interest of the subject will render us all anxious to hear him, apart from the privilege of discussing the subject with one who, on all topics connected with the geography of Central Asia, is allowed by the great geographers of France and England to be one of the highest geographical authorities of our age.

Another equally distinguished guest is the Commandatore Negri Christoforo, who, as members are aware, is the President, and I believe I may say the founder of the Italian Geographical Society. I cannot better state to you his claims to a warm welcome among us than by describing him as the "Murchison of Italy." After slumbering for ages, the spirit of geographical discovery seems once more revived in the native land of Marco Polo and Columbus, and we may look for the most important results from the labours of the Society of which the Commandatore is, at any rate, the foster parent.

I have been commissioned by Sir Roderick to state how deeply he regrets that he has been prevented being present this day to offer to these distinguished foreigners the expression of that hearty appreciation and welcome which would come most fitly from the President of our Royal Geographical Society; and you will all join with me in my regret, that our venerated friend and leader is not here himself to give to that welcome the personal weight which it would derive alike from his official position and from his scientific standing among the first of living European geographers.

On a Canal to unite the Upper Nile and Red Sea.
By Dr. C. Beke, *F.R.G.S.*

On the Distribution of Heat on the Sea-surface throughout the Globe.
By Vice-Admiral Sir Edward Belcher, *K.C.B., F.R.G.S.*

On the Geography of the Frankincense Plant. *By* Dr. Birdwood.

Notes on a Journey in Northern Abyssinia. *By* W. T. Blanford.

Subsequently to the departure of the British troops Mr. Blanford made a journey in Northern Abyssinia to the Anseba Valley and the Bogos Country, in company with Mr. Werner Munzinger and two other gentlemen. The great mass of the Abyssinian highlands, 7000 to 8000 feet in elevation, terminates a little north of the parallel of Zulla. From the northern side of the plateau two considerable streams arise, the Anseba and the Barka, which afterwards unite and fall into the Red Sea south of Suakin. Both are dry except in the rainy season, when they are frequently impassable. The country drained by them is of a general level of 3000 to 5000 feet, and is inhabited by tribes of Bedawins, some of whom, the Bogos being the principal, still remain Christian. The party first marched due west about thirty miles to Ailat, a village lying in a plain at the foot of the hills, abounding in lions and leopards. From this place they proceeded to Asus, and thence to Kenzal and the Lebka Valley. The road, like all the passes leading to the Abyssinian highlands, lay up the bed of a torrent—a gradual slope of 1000 feet in twenty miles. At Kokai, some forty miles up the valley, the passage was sudden from a perfectly desert region to hills covered with bushes and rich valleys clothed with fine trees; this abrupt transition was to be explained by the upper part lying within the sharply-limited area of the Abyssinian rains. At Kokai they found a large encampment of the Az Temeriam, with immense herds of camels. These people, and all others of the Habab and Shoho tribes, live a curious nomade life. During the cold weather, from November to April or May, they inhabit the lowlands near the Red Sea, which at that time, in consequence of the winter rain, afford pasturage for their animals. When grass and water fail here, they move with their herds to the highlands, and remain there from June to November. The wild elephants migrate like the people, and for the same reason. On the 13th of July the party marched from Kokai to Bedjuk in the Anseba Valley, and remained till the 8th of Augus, collecting specimens of animals which exist there in great numbers and variety. Lions were numerous and very noisy, and two specimens were obtained of a rhinoceros, allied to the *R. bicornis* of South Africa. In the valley Christian tribes live on perfectly friendly terms with others who are Mohammedans in religion. During their stay the weather was very pleasant, always fine in the morning, with occasional showers in the afternoon. Owing to the continuance of the rains they were unable to return down the valley, and made a detour to the north from Kelamet through Rairo, and thence to Ain, and across the desert by the direct route to Massowa.

On a Recent Visit to the Suez Canal. By Captain C. Dodd.

Notes on the Runn of Cutch. By Captain C. Dodd.

On Extraordinary Agitations of the Sea. By R. Edmonds.

On the Supposed Influence of the Gulf-stream on the Climate of North-West Europe. By A. G. Findlay, *F.R.G.S.*

The author referred to a former communication to the British Association at Liverpool in 1853, where it was shown more clearly than had been before done, that a continuous series of current-streams could be traced all over the globe, and that by analogy these circulations extended from the surface to the bed of the ocean, a process by which the universally uniform character of sea-water was maintained. Our knowledge of deep-sea temperatures, and of the depth of the ocean, was then comparatively limited, and the opinion that at that time might be entertained, that the Gulf-stream had sufficient depth and velocity to reach our shores as a continuous stream of *warm water*, has been since proved to be fallacious.

First, the *volume* of the Gulf-stream is very much less than was formerly believed. We have now a tolerably exact knowledge of its dimensions as derived from the surveys made in the summer months between 1855 and 1866, by the officers of the U.S. Coast Survey. The term "Gulf-stream" is here confined to the current between the Florida Strait and the Nantucket Banks, an excellent history of which was published at Bremen in 1868 by M. Kohl.

In estimating the volume of the stream theoretically we meet with a difficulty at the outset. It is derived from an area of not less than 5,400,000 square miles of the equatorial portion of the Atlantic, drifting westward at a rate of from fifteen to twenty-two miles per day. The whole of this tropically-heated water is apparently represented by the outlet of the comparatively puny Gulf-stream, not more than 1200 feet deep and less than one sixteen-hundredth part of the breadth of its parent source.

Its dimensions in the Strait of Florida have been ascertained in sections, from its entrance between the Dry Tortugas and the Havana, and its outlet on the Narrows off Cape Florida. In the first section (1858) it is ninety-eight miles wide, but the stream occupies only the southern moiety of the channel. Between the Sand Key and Havana (1866) the distance is $82\frac{1}{2}$ miles, of which the Gulf-stream occupies only forty miles, and it was not more than 1200 feet deep, not reaching to the summit of a submarine ridge discovered here, on the summit of which the temperature was only 60° Fahr., while at the bottom it was only 45°. Passing over the other sections, that of the Narrows between Cape Florida and the Bemini Isles was chosen as an index of the whole. It was examined in 1855 by Commander Craven, U.S.N., and proved to be the narrowest, and also the *shallowest* part of its course. The maximum depth is only from 300 to 370 fathoms, and the temperature at the bottom was only 49°, so that warm water did not extend much beyond one-third of the entire depth. The Gulf-stream at its outset is then not more than $39\frac{1}{2}$ miles wide, and 1200 feet deep.

The velocity has been much exaggerated. From all attainable data the author computes the mean annual rate to be 65·4 miles per day, more in summer, less in winter. As this rate decreases with the depth, the mean velocity of the whole mass does not exceed 49·4 miles per day. As the sectional area of the stream is not more than 6·64 square miles, there are not more than from 294 to 333 cubic miles of water per day passing over a given line in the Gulf of Florida.

From the entrance of the Gulf to the Narrows, the distance is 330 miles. To the northward of this, it appears as the innermost of a series of warm bands, alternating with cold ones flowing in an opposite direction, and having the cold Arctic current also flowing southwards, between the stream and the coast. In ten days it arrives off Cape Hatteras, with a loss of only 3° of its initial temperature; in twenty days it is off Nantucket, being 14° or 15° cooler still; it is this rapid course and preservation of its original warmth thus far which has made it so remarkable in all ages, but beyond this it rapidly loses its characteristics. After fifty days it is off the banks of Newfoundland, and its warmth is lowered to 51° in summer. In January it is down to 30°. The distance thus travelled is about 3500 miles; its velocity is not more than one-third of its commencement, and it has lost all the extra warmth it possessed at the outset; for the volume of water above 70° in the Narrows will not form a film more than 60 feet thick off Newfoundland.

The second point insisted on was that it is here more than neutralized, as a *warm* current, by the ice-bearing Arctic current flowing southwards into its northern edge, bringing a volume of cold water equal fully to one-half the entire stream flowing eastward, and penetrating, as a cold-water gulf, shown by the isotherms, from 150 to 200 miles southward of its general limit. It was therefore urged that the Gulf-stream is here so thinned out and cooled down, and further neutralized by the Arctic current, that it could no longer be recognized as a heat-bearing stream, and as such ceased to exist. The southern and warmer portion of the stream passes onwards, also eastward, until it is finally lost on the general drifts about the Azores.

The third point proposed was, that the warm N.E. stream flowing past the British Isles cannot be taken as the Gulf-stream; it has a distinct origin, and should have a distinct designation. It is true that there is a continuous stream from the West Indies, past the Banks of Newfoundfand, but not throughout a warm stream; for the temperature rises considerably, from 20° to 27°, to the eastward of the Banks. How can this be the Gulf-stream? the warmth must be derived from more southern sources. The evidences of this easterly drift (the cocoa-nuts, tropical seeds, &c.) pass onwards to the coast of Norway, to Iceland, &c. It will take a floating body fully 150 days to reach Cornwall from the banks of Newfoundland, and perhaps double that period to reach the North Cape or Iceland. The area claimed to be influenced by the stream, or raised in its temperature, is fully 1,500,000 square miles to the northward of the 50° parallel. The known bulk of the Gulf-stream proper (and it receives no accessions) will only give *six inches* per diem over this area, and this too after an interval varying from one to two years from the time it left the Gulf of Florida.

The origin of the warm ocean temperature in high latitudes was attributed by the author to the prevalent S.W. winds, which, passing over a higher sea temperature, and also driving the water from that direction, brought to North-Western Europe the climatorial attributes of much more southern regions on the eastern side of the Atlanic, and that this N.E. current, which has only of late years been called the Gulf-stream, should possess a specific term.

On Trade Routes between Northern India and Central Asia. *By* T. D. Forsyth.

The author stated that he had devoted his time and energies as a public servant in India in applying geographical knowledge to the purposes of material progress. In his capacity of practical geographer he had had occasion to point out an error into which most scientific geographers had fallen, namely, that of assuming that the mighty Himalayas presented a grand impassable bulwark, and that the mountains of the Kuen Luen rose like a wall 17,000 feet high, with scarcely a crest or depression throughout their entire extent. There were two great outlets for trade from Northern India: one, the route of a very large commerce, crosses the Indus at different points between Kurrachee and Peshawur, and threading the various passes of Bolan, Goleri, Kyber, &c., finds its way into Affghanistan, Balkh, Bokhara, Kokan, and Western Turkistan; the other crosses the Himalayan passes, and enters Eastern Turkistan or Chinese Tartary, a region containing several ancient and renowned cities, such as Yarkund, Yangihissar, Khoten, &c. It was this latter outlet which had been most studied by the author. Between the years 1750 and 1862 the Chinese held military possession of all Eastern Turkistan; in the last-mentioned year the Tungâni insurrection against their rule commenced, and the Chinese were finally expelled in 1864. One of the leaders in the revolt was Yakoob Beg, who took the Chinese fort of Kashgar, and is known by the title of Koosh Begi, or Commander-in-Chief. This man now holds the chief power in the country, and is a brave, energetic, liberal-minded man, with whom and his subjects the author contended it was for the advantage of India to establish commercial relations. During the period of Chinese domination all trade over the passes north of Cashmere to Eastern Turkistan was extremely hazardous. The physical difficulties opposed to extensive communication had recently been found not so great as was supposed. Formerly the route over the Karakorum pass was the one chiefly used; by this traders had to march five or six days consecutively without obtaining one blade of grass or one atom of fuel; but by a new route further to the east, which the author had lately endeavoured to establish, namely, the Changchenmo, fuel and grass could be found at nearly every stage. After this route had been explored by Mr. Johnson and Dr. Cayley, and declared by them to be perfectly practicable, it was still difficult to induce the native traders in Cashmere to try the road. The author, however, whilst at Ladack, succeeded in prevailing upon the Vakeel of the Koosh Begi to return by the new route last year, and was gratified to learn that he had accomplished the journey with the utmost ease. Since then Mr. Shaw, an English tea-planter, had succeeded in reaching Yarkund by this route. Four passes have to be crossed between the plains of Hindostan and Leh; but only the lowest, the Rotang, is spoken of by traders with anything like fear, owing to the severity of its ascents and to the danger from sudden storms, caused by the proximity to the monsoons of the plains. Atmospheric influences and deficiency of fuel apart, there would be little physical difficulty in laying a railroad from Tso Moreri Lake to Yarkund.

On the Existence of Sir Walter Raleigh's El Dorado. *By* Dr. C. Le Neve Foster.

The author advanced his own experience as acquired in a recent journey to the Caratal gold-mines of the Orinoco, as confirming the veracity of Sir Walter Raleigh, so coarsely impugned by the historian Hume, who says, "On his return Raleigh published an account of the country full of the grossest and most palpable lies that were ever attempted to be imposed on the credulity of mankind." Schomburgk, in defending Raleigh's statements, had, in his time, no positive evidence of the existence of gold in Venezuelan Guiana. The gold-mines which the author visited last year were discovered in 1849 by Dr. Louis Plassard, in the bed of the Yuruari, near the old Spanish Mission of Tupuquen. The Yuruari falls into the Yuruan, a tributary of the Cuyuni, which enters British Guiana, and eventually pours its waters into the Essequibo. In 1857 people began to flock to the place, and washed for gold in the river-bed, establishing the settlement of Caratal. The author had given the geological details of these mines in a paper recently read before the Geological Society. He maintained that the present Caratal gold-field was the one of which Raleigh heard such wonderful accounts. The "white spar" in Raleigh's detailed description was undoubtedly quartz; for spar is the name still used for quartz in Devon and Cornwall, and the author had himself seen outcrops of lode in Caratal where gold was visible in blocks of quartz rising up from the surface. There could be no mistake, also, in identifying the locality,—"the Caroli," mentioned by Raleigh as the Caroni; for he mentions the falls, which are close to the point where the Caroni joins the Orinoco. The other details of locality and distance in Raleigh's account were shown by the author to agree closely with the facts that have now come to light.

On the Runn of Cutch and the Countries between Rajpootana and Sind. By Sir Bartle Frere.

The author stated that little had been recorded regarding this singular tract of country, which he had visited in the exercise of his official duties. It formed a great belt, presenting extraordinary physical features, lying between India Proper and the Indus. It had neither mountain-ranges nor river-systems; nor could it be called a plain, for it is ridged into sand-hills; nor desert, for it is everywhere inhabited, in parts supporting a considerable fixed population and numerous herds of cattle. The term "Pampas," or "Savannah," would imperfectly describe it. The length of the district, N.E. to S.W.—from the point where numerous streams, descending from the lower ranges of the Himalayas, between the Sutlej and the Jumna, flow towards it and lose themselves in its sands, to the hills of Cutch,—was about 600 miles, its breadth was about 150 miles; the total area was somewhat larger than that of Great Britain. The north-easterly part was termed the "Thurr,"—a plain diversified by sand-hills or ridges and waves of sand, varying from 60 to 200 feet in height, not uniform in direction and not lying in the direction of the wind. The appearance of this country was most singular, reminding the traveller of the ocean, with billows formed of sand. Next to this was the "Put," alluvial plains formed of hard soil and adapted to cultivation. Throughout the "Put" could be seen traces of ancient canals and ruins of cities. Lastly, the portion nearer the Indian Ocean and separated from it by the crescent-shaped, elevated territory of Cutch was the "Runn." This was neither a morass nor a swamp, but a vast level plain, with a surface so firm that the feet of camels traversing it scarcely left an imprint on the soil. Its length was about 150 miles, but if outlying areas were included, it would be 300 miles, to the shores of the Cambay Gulf. The Runn was nearly a dead level, rising slightly in its centre; heavy rains covered it only transiently with a thin film of water which found no drainage-outlet, but remained until it evaporated, and became salt through the intensely saline nature of the surface. It was totally destitute of landmarks, and travellers guided themselves only by the stars; and, on approaching Cutch, by a fire, kindled on the top of a hill, the lighting and care of which was the self-imposed duty of a faqueer living near the spot. Notwithstanding all precautions, however, travellers were sometimes lost on the plain and perished miserably. The whole country was subject to earthquakes, most of which were only slight vibrations, and it was to the action of these vibrations that the author ascribed the peculiar configuration of the country. Sometimes small crateriform pits would be formed in the sandy soil, which subsequently became obliterated, the sandy particles rearranging themselves and the perfectly level surface again resumed. The more elevated district around showed evidences of severer shocks, and the remains of ruined cities—some, as Brahminabad, being of great extent—testified to their violence. To these shocks were due the elevated ridges which constituted so singular a feature; these, in the opinion of the author, being folds produced by earthquake-waves that had not again subsided like other parts of the surface. The Runn is periodically inundated by the waters of the Indian Ocean, at the height of the south-west monsoon and at high tides; several rivers also discharge themselves into it on the eastern side, but the water reaches the depth of only a few feet. During the dry season the effects of mirage were most extraordinary, the skeletons of camels perished in the traversal presenting a deceptive resemblance to a magnificent city with its palaces and towers. This frequent phenomenon had given rise to a myth related by the inhabitants, to the effect that a pious king once obtained, as the result of his prayers, the favour of the translation of his city to heaven, but on the discovery, after the upward journey was commenced, of a jackass concealed in the buildings, the favour was revoked, and the proud city remained ever afterwards fixed in mid-heavens.

On the best Route to the North Pole. By Captain R. V. Hamilton, *R.N.*

On the Latitude of Samarcand. By M. Nicholas de Khanikof.

Twenty-six years ago (September 1841) the author visited Samarcand, being, after his companion, Lehmann, the first European who had seen the famous capital of Tamerlane since 1404, when, in the same month of September, Gonzales Clavijo, envoy of Henry the Eighth, of Castille, entered the city. Exhausted by the heat and covered with dust, M. de Khanikof reached the summit of an elevation, on the road from Bokhara, where he first beheld the place he had been permitted to visit, as member of a mining commission, invited by the Khan of Bokhara. M. de Khanikof was not able himself to fix the longitude or latitude of Samarcand; but M. Struve, who visited Samarcand on a scientific mission in 1868, has verified the latitude of the city at 39° 38′ 45″, and the longitude 64° 38′ 12″ east of Paris.

Erskine's Discovery of the Mouth of the Limpopo. By R. J. Mann.

On the Straits of Magellan and the Passages leading Northward to the Gulf of Peñas. By Captain R. C. Mayne, *R.N.*

The whole distance through the Straits of Magellan is about 300 miles, and the width of the passage varies from 2 miles to 15 or 20. The eastern and western portions are strongly contrasted in scenery and climate; on the east we have low prairie land, perfectly bare of trees, with a clear bright sky, and hard, fresh wind; on the west rise, almost perpendicularly from the sea, lofty mountains clothed with the evergreen beech, which produce torrents of rain, varied by hail and snow in their seasons. From the western end of the Straits is a passage leading northward among numberless islands for 360 miles, and ending in the Gulf of Peñas. In this part it is scarcely too much to say that the rain never ceases for twenty-four hours together; the channel is much narrower than the Straits, and lofty mountains close it in on each side, so that the sun scarcely ever penetrates into its recesses. During the recent naval survey, in which Capt. Mayne was engaged, the ship's crew passed three months without being once able to dry their clothes, except by the engine fires. When, however, the mists do clear away from the mountain-tops the scenery is grand beyond description. Dreary as is this passage it is of great commercial importance, enabling the largest steam-vessels to get northward to finer latitudes, without encountering the high seas of the open Pacific, and to reach Valparaiso without the strain to the ship and machinery which the outer passage so frequently involves. Between the date when the celebrated survey of the 'Beagle,' under Capt. FitzRoy terminated, in 1836, and the present day, a new era has commenced in the navigation of the southern extremity of America. All vessels of war, and a great proportion of merchant vessels, are now steamers, and the Straits of Magellan offer immense advantages to them over the stormy passage round Cape Horn. Many vessels which now pass into the Pacific are 300 to 400 feet long, drawing 25 or 26 feet of water: the surveys of thirty or forty years ago, therefore, which provided only for vessels 100 feet in length, drawing 14 or 15 feet of water, were no longer applicable. In those days, moreover, harbours were sought for and surveyed, into and out of which vessels could work under sail; with the monster steamers of the present day such harbours were not required, and the recent survey had to provide for the new conditions of navigation. In 1867 Capt. Mayne went through the Straits in H.M.S. 'Zealous,' an iron-clad of 4000 tons, and in that year thirty-eight steamers, in all, passed. At the present time a monthly line of large steamers runs from Liverpool to Valparaiso by this route, accomplishing the distance in forty-two days, or quicker than the overland route *viâ* Panama. The work of the Survey, which Capt. Mayne commanded, in the 'Nassau,' commenced in December 1866, and ended May 1869. The surveying parties frequently met with Patagonians in the eastern part of the Straits. They were clad in their usual long robes of guanaco skins, which make them look so much taller than they really are. Their chief Casimiro spoke Spanish, and at the first meeting requested the Captain to give him two bottles of rum, not, as he explained, for the tribe, but as a gift from chief to chief. Capt. Mayne took the trouble to measure several of the men; he found one who was 6 ft. 10½ ins. high, and several reached 6 ft. 4 ins., but the average of those met with was 5 ft. 10 ins. or 5 ft. 11 ins., which is some 4 or 5 inches taller than the middle height of Englishmen. The women are nearly as tall in proportion. Tall as the Patagonians are, their costume adds greatly to their apparent size; their robes of guanaco skin being as deceptive an addition to their stature as a woman's dress would be to a man of our own race. Their habit of standing on the cliffs, beside their diminutive houses, to gaze on passing ships, further explains the exaggerated accounts of the early voyagers. The Patagonians are entirely confined to the eastern portion of the Straits, never going further west than the Chilian settlement of Punta Arena; they have no canoes, and much dislike going afloat. Wonderful is the difference between them and the natives of the mountainous and wooded country further west, and even those of the eastern part of the southern islands, from whom they are separated only by a narrow strait. These are the Fuegians; those of this race who live on the east being finer physically than their western relatives, probably owing to a more abundant diet of guanaco meat; but both sections, unlike the Patagonians, are untrustworthy. The western Fuegians extend even up the western channels and inhabit both sides of the Strait. They differ in almost every respect from the Patagonians, being usually small, badly shaped, and ugly in features; but they have one advantage, in their dislike of wine and spirits. Capt. Mayne often tried them, and could never get them to taste a second time, whereas any Patagonian would drink as much as he could get. Among the ethnological points the expedition was asked to notice was, whether these people ever smiled. Not only did they frequently smile, but they laughed outright whenever anything amused them. But mimicking was their peculiar *forte*; they would repeat whatever was said to them, and hum tunes after the men, though whistling rather bothered them. They were much amused at the officers walking up and down the deck two and two, and frequently joined hands and walked after them, looking over their shoulders to hit the right time of turning. Sometimes their mimickry was rather annoying, as when they repeated the remark, "Why have not these people left the ship?" at times when they had stayed too long aboard. The new Chilian settlement in the Straits, at Punta Arena, now numbers 800 souls, and signs of civilization are rapidly rising around it. Coal having been found in the neighbourhood, it promises soon to become a coaling-station for steamers, and will take away all trade from the Falkland Islands, which lie too far to windward of the Straits to be of importance in the new era of navigation of the Cape, which has now set in. During the survey, the 'Nassau' entered a small bay in an island called Sta. Magdalena, 12 miles from Punta Arena, which had never before been visited. The vessel was immediately surrounded by hundreds of seals, plunging about the ship in the utmost astonishment at this invasion of their haunts, and the cliffs were covered with thousands of penguins, looking on in an absurdly sedate manner. None of these and other animals which swarmed around the bay were afraid of the approach of man, whom they had not yet learnt to consider as their enemy, and the penguins in particular, when the cliffs were climbed, swarmed round and attempted to peck the legs of their visitors.

Scheme for a Scientific Exploration of Australia. *By* Dr. G. Neumayer.

On the Kitai and Kara Kitai. *By* Dr. Gustav Oppert.

The author described the Kitai, a people who once ruled over Central Asia and China, but whose descendants now live in an humble condition in the Russian Government of Derbend, near the Caspian and in the Siberian district of Ili, or Kuldja. They are a very industrious race, living in Derbend mostly as husbandmen, and in Kuldja as clever artisans. The author went into some details to establish the identity of Yelintashe with Prester John of medieval writers.

On the Encroachment of the Sea on Exmouth Warren. By G. Peacock.

According to the author, the Warren, or natural barrier of the harbour at the mouth of the Exe, is gradually wasting away by the action of the sea, combined with causes which, he believed, might have been prevented. The "Exe Bight" runs the danger of being no longer a harbour, but of becoming converted into a dangerous bay of shoals.

On the Influence of Atmospheric Pressure on the Displacement of the Ocean. By T. Wyatt Reid.

Account of Mr. Cooper's Attempt to reach India from Western China. By Trelawney W. Saunders.

In February 1868 Mr. T. T. Cooper ascended the Yang-tsze-Kiang, with the intention of passing, if possible, through the little-known country which separates the western frontier of China Proper into British India. At Suchan, where the river Min joins the Yang-tsze, he proceeded by the former river to Ching-tu, the chief town of the province of Sze-chuen, and from thence proceeded, through Ta-tsien and Litang, to Batang, a Chinese post on the frontiers of Sze-chuen, and bordering on Thibet, a vast highland country, stretching along the whole of the northern frontier of India, and subject to the imperial sway of the Chinese. From Batang he expected to reach India either by way of Lassa, or by a direct route to Sudiya, in the British province of Assam. Between Batang and Assam lies a mountainous country, not more than 200 miles in width, with villages at intervals. The Thibetan authorities refused Mr. Cooper permission to proceed by way of Lassa, or even to enter their country. The resolute traveller thereupon directed his utmost efforts to get across the short distance of 200 miles, which separated him from Assam, but he found himself completely foiled by the vigilance of the authorities. After waiting ten days, he was obliged to attempt the Yunan route for Burmah. He crossed on his way the Kin-char-Kiang, six miles south-west of Batang, on the 3rd of June; and travelling two days, came in sight of the range of mountains forming the "boundary of the kingdom of Lassa." He was here again stopped by a party of armed Lamas, and was obliged to turn south. In this direction he travelled for about twelve miles, and struck the east foot of the snowy range, forming the east bank of the Lan-tsan-Kiang. Deserted by his guides, he lost his way, and reached the Thibetan village of Tsung Tsar. He next crossed a pass in the snowy range, and reached the village of Tong. On the 10th of June he arrived at Artenze, the first Chinese military station, on the borders of Yunan. On the 12th he struck the left bank of the Lan-tsan-Kiang, and reached the village of Coneah, the head man of which took it for granted that the traveller had come from Assam. At the Ludzu village of Wharfoopin he found the people were chiefly Christians, connected with the Catholic mission of Succoo, distant about eight miles, on the right bank of the Lan-tsan-Kiang. Leaving this place, in two days he reached the residence of a Yertzu chief. His next stopping-place was at the house of a Mooquor chief, who talked quite familiarly of Assam, and showed the traveller his gold-mines and gold-washings on the banks of the Lan-tsan-Kiang. Two days thence he arrived at the Chinese imperial city of Wussee-foo, the General at which place gave him a pass to Talifoo; but ultimately he was obliged to return to Wesee, and thence to Permootan, in Thibet; and being again foiled in an attempt to get to Lassa, he returned to Hankow *viâ* Kia-ting-foo, on the Min river. The author explained that Mr. Cooper in his report contributed but little to our knowledge of the geography of the new countries he traversed. His track could only be made out in a general way; but it seems not improbable that the place he calls Wusee might be the Chusi of Lieut. Wilcox; and if so, Mr. Cooper must have reached the very threshold of British Assam without knowing it, in a valley descending immediately into the Brahmaputra. His narrative, chiefly relating to his personal adventures with the obstructive or hostile people, seldom contains any graphic description of the country. Mr. Cooper's failure in his laudable purpose to initiate communication between two friendly empires of such vast populations, was one of a series of such failures, dating from the first quarter of the present century, when British officers, having penetrated the Himalayas, naturally attempted to extend their explorations further into Central Asia. From these cases it may be concluded that, if British intercourse is to be extended from India into the Chinese Empire, it can only be done by a fresh treaty between the two supreme governments.

The Himalayas and Central Asia. *By* Trelawney W. Saunders.

Peruvian Explorations and Settlements on the Upper Amazons. *By* Francis F. Searle.

Yquitos, a small town on the upper part of the Amazons, or Marañon, has recently sprung into importance as the site of a Peruvian Government station. It is situated on the left bank of the Marañon, below its junction with the Ucayali, and at the mouth of a small affluent, the Itaia. The place was fixed upon in 1862, as affording the best station for a factory and floating dock, and the steamers 'Morona' and 'Pastáza,' of 500 tons burthen each, proceeded thither from England, in September, to commence the works. A difficulty was encountered at the outset by the Brazilian authorities disputing the right of foreign vessels laden with cargo and flying the pennant of men-of-war to ascend the Amazons. The 'Morona' was fired at from the fort at Obydos, and subsequently ran aground, when all the crew were taken prisoners; but the right of free passage being afterwards conceded, two more steamers were sent up in 1865, with a floating-dock, and the materials for constructing two smaller steamers, for river exploration. The author was sent in charge of this portion of the expedition, and stated that one of the vessels, of 750 tons burthen, safely ascended to Yquitos, a distance of 2400 miles from the mouth of the river. Other vessels, and numerous mechanics with machinery, soon after arrived from England, and the settlement was soon in full working order. The larger steamers were then used as passenger and cargo vessels, running monthly between Tabatinga, on the Brazilian frontier, and the little town of Yurimaguas, on the river Huallaga; the smaller steamers, at the same time, were despatched up the various tributary streams, most of which were hitherto unknown, except by name, to examine their capabilities for navigation and commerce. One of the principal objects of the Peruvian Government was to ascertain the practicability of navigating the Ucayali and its affluents to within a moderate distance of Lima, and of establishing a port at some point to which a road might be made from Lima, with a view to its becoming an outlet to the Atlantic for the trade of the rich provinces of Central and Southern Peru. In pursuance of this grand idea, the 'Putomayo' steamer was sent up the Ucayali in June 1866. Passing with facility up this great stream and one of its western tributaries, the Pachitea, the expedition encountered a ferocious tribe of Indians, called Cachibos, and two of the officers, Tabara and West, were enticed ashore and treacherously slain. Foiled for a time in the attempt to ascend the stream, the vessel returned to Yquitos, and a larger expedition was despatched, in December of the same year (1866) in three steamers. On arriving at Chunta Isla, on the Pachitea, the scene of the treacherous onslaught of the Cachibos, a severe lesson was taught the savages. A party of soldiers was landed in the forest, together with a number of friendly Conibo Indians to act as guides; and the secret path to the hostile villages being tracked in the silence of night, the Cachibos were surprised and shot down without mercy. In the centre of a village was found a kind of altar, on which human sacrifices had been offered, and one of the women who were captured wore a necklace of human teeth, which she stated had belonged to one of the officers, who had been roasted and eaten. This done, the three steamers proceeded further up the river; the two smaller succeeded in reaching the port of Mayro, the nearest practicable point to Lima, from which the Prefect of Loreto and his staff passed by land to the capital. One of the vessels remained in the Pachitea for several months, and received on board the Hydrographic Commission sent across the Andes from Lima, who afterwards descended the river, to survey the boundaries between Brazil and Peru. The same Commission also ascended the Ucayali, with the view of exploring the River Tambo, but were not able to reach far up that river, owing to the strength of the current being too great for the capabilities of the steamer. The Commission had arrived at the conclusion that the Ucayali must be considered the upper stream of the Amazons, and not the upper Marañon or Tunguragua, as hitherto supposed. The distance from the port of Mayro, to which the smaller steamers of the expedition ascended, to the mouth of the Amazons, is about 3300 miles. The present population of Yquitos is about 1000, of whom 72 are English. The Peruvian Government offered grants of land in this new and fertile country to immigrants; and the author concluded his paper by stating his conviction that no other tropical country offered so healthy a climate and so many advantages to European emigrants.

A Visit to the Holy City of Fas, in Marocco. By J. Stirling.

Fas, usually misspelt Fez, is one of the three or four capitals of Marocco, and has rarely been visited by Europeans. It is termed "holy" probably because it was once a substitute for Mecca as a place of pilgrimage for the Moors, during a period when a journey to Arabia was rendered impracticable. The author visited the city in the suite of Sir J. Drummond Hay, the British Minister, on his official mission in November 1867. It is a fortified place, situated at the eastern extremity of a fine plain, sloping towards the great and fertile valleys watered by the Sebu river, into whose stream flow the waters of a river which passes through the centre of the city. This river forms an interesting feature of the place, supplying, as it does, abundant water for domestic purposes, and numerous fountains, public and private, besides irrigating the gardens outside the walls. There were no means of ascertaining with accuracy the population of the city; the author estimated it at somewhat less than 100,000. There are numerous hotels, picturesque mosques, and *Medresāt*, or colleges, the latter containing libraries and apartments for the students; but the range of studies is limited to the Koran and its commentaries, grammar, logic, and geometry. The official interview took place in the open court of the palace, the Sultan mounted on a white horse, according to ancient Arabian etiquette.

On a small Altazimuth Instrument for the Use of Explorers. By Lieut.-Colonel A. Strange, *F.R.S., F.R.A.S.*

On Central Asia. By Pierre de Tchihatchef.

I beg leave to submit to your kind attention a few remarks in reference to a publication which is about to be issued, and which recommends itself by the name of the author and the importance of its subject: I mean the intended publication of a new, completed, and corrected edition of Baron Humboldt's 'Asie centrale,' a celebrated work published in the year 1843, which was entirely exhausted even before the death of the great German philosopher. This fact alone would certainly be sufficient to justify the enterprise: but a peculiar circumstance conveys to it an additional interest and renders it still more desirable; it is the discovery of an autograph letter in French, written in the year 1854, addressed by Baron Humboldt to M. Gide, his publisher and intimate friend,—a letter which has been found among the valuable papers of this gentleman recently deceased, and after whose death all those papers, as well as the exclusive property of the works of Baron von Humboldt, written in French and published in Paris, have been acquired by M. Guérin, one of the chief and ablest publishers in France. In this letter, which Baron von Humboldt designates as his last will, entrusted to a dear friend ("c'est mon testament déposé entre les mains d'un ami qui m'est cher"), the illustrious philosopher entreats most warmly M. Gide to undertake a new edition of the 'Asie centrale,' which Baron von Humboldt declares to be the most important of all his writings ("le plus important de tous mes ouvrages"), and which, therefore, he wishes to be raised to the level of the numerous discoveries made in geography, natural history, and the physical sciences during the twenty-six years elapsed since its publication. But, what is still more interesting, he gives in this letter a sketch of the principal additions and corrections his work is to receive, and among which the following *desiderata* play the chief part:—a new delineation of the mountainous ranges of Central Asia in conformity with the numerous and important materials acquired since the year 1843, particularly in reference to the Thian-chan and to the orography of the vast and complicated Himalayan regions; further, a summary of the results of the recent explorations of the Lac Aral and the Caspian Sea, of the hydrographical system of the Jaxartes and the Oxus, of the northern extremities of the Oural Mountains, &c.; finally, a complete official account of the annual produce of the auriferous deposits in Russia since the year 1854 until the present day, and a survey of all the meteorological and magnetic observations collected during this time in the Caucasian regions, in Siberia, and in the Turkestan. It is evident that the additions and modifications by which Baron von Humboldt intended to complete, enrich, and adorn his celebrated work could not have been carried out without the assistance of many fellow-labourers, however great may have been the universal knowledge of this extraordinary man. No doubt, we must regret that death prevented him from accomplishing a task which he seems to have considered as the last and most brilliant crown of his long and laborious life; but whatever may have been the amount of additional glory it could have given him, all his disciples, friends, and admirers are bound to consider the expression of his last and most cherished wishes as a kind of sacred legacy imposed upon them; and this was precisely the feeling which decided me to yield to the appeal M. Guérin addressed to me, in order to work out a new edition of the 'Asie centrale' according to the instructions left by its illustrious author. In spite of the various occupations which absorb all my time, particularly at the present moment, when I am preparing myself for a new expedition in the East, I have decided to perform this rather difficult task to the best of my abilities, and I hope that in the course of the next winter the three volumes of the 'Asie centrale' will be published, accompanied by a fourth supplementary one, which will contain all the important additions and modifications desired by the author, and, moreover, a new map of Central Asia, quite different from that which appeared in 1843, at the end of the third volume of the work.

Now, before I conclude this little bibliographical information, which I hope will be received with interest by many persons who compose this distinguished assembly, let me add that, independently of the great name of Humboldt, a special work on Central Asia has, now-a-days, a peculiar importance and a striking opportuneness, for it will at last dispel for ever the threatening clouds which, during so many years, were gathering on those regions, as gloomy forebodings of a dreadful tempest. The truth is, that as long as our knowledge of Central Asia was scanty and vague, this mysterious country must have appeared, not only to the ignorant crowd, but also to many of the most enlightened and sagacious statesmen, as the natural battle-field where, sooner or later, England and Russia had to meet in an exterminating, dogged struggle. The danger seemed so unavoidable and so urgent that no expense no sacrifice was spared in order to postpone this disastrous crisis. Now, thanks to the indefatigable exertions of men like Montgomery, Walker, Johnson, Godwin-Austen, Schlagintweit, Sewerzow, Semenow, Baron Osten-Saken, Poltarazki, Struve, and many other recent explorers, whose important labours will be thoroughly discussed in the supplementary volume of Humboldt's 'Asie centrale,' the ominous crisis so positively prophecied, and so unanimously feared, turns out to be nothing more than a fantastical dream; for surely nothing could be more fantastic, nothing fitter to remind us of the stories of the thousand-and-one nights, than to see a large army with heavy artillery, not only hover like ghosts during two or three months amidst dense clouds and eternal snows, but even, after such laborious gymnastics, descend in the country of the enemy and defeat the English troops, who would be quietly and comfortably expecting the curious visitors. Well, that is precisely the marvellous fact which must be admitted by the advocates of a Russian invasion of India; for we possess now numerous trustworthy documents which prove most positively that, even in the very probable case when whole Turkestan is to become a

Russian province, whatever may be the starting-point of a Russian army intended to reach the Punjab, no less than two, and perhaps even three months, spent amidst snowy, desert mountains, are required before such an army is allowed to put their frost-bitten feet on English territory. I am far from denying that among the advocates of a Russian invasion there are men of deep science and of unquestionable good faith; but they all start either from the one or from the other of these two very arbitrary hypotheses, namely, that what has been done once may be performed again, or what is now impossible may hereafter become possible. In support of the first hypothesis, the numerous invasions of India ascertained by history have been quoted; and a learned French orientalist, M. Quatremère, endeavoured even to prove that the lofty mountains which form the northern boundary of Cashemir, and which hitherto have been considered as not having at any time yielded a passage to a military expedition, have been traversed more than once, as late as in the fifteenth and sixteenth centuries, by considerable armies, which, starting from Kachgar and Jarkand, reached the Punjab across Tibet and Cashemir. But what do such facts prove? Only one thing; that those armies, conducted by Eastern generals and directed against Eastern populations, were placed more or less in the same conditions under which similar expeditions have been successfully performed by Alexander the Great and the Mongol conquerors, conditions widely different from those which would be now imposed upon a Russian or any other invading army, not only because Asiatic adventurers, as well as Macedonian or Roman conquerors, were not encumbered by the troublesome encumbrances of artillery, indispensable to European troops, but also because they possessed over their enemies an overwhelming superiority either of moral or of material strength, whereas now-a-days no invading army would enjoy this last advantage. Even now, if an European army may succeed in dragging their ponderous artillery over large snowy mountainous tracts, as the admirable expedition into Abyssinia has so brilliantly proved, success is possible only under the express condition of having Abyssinians or some other Asiatic population to deal with; for if the country, or even Magdala alone, had been occupied by French, Russian, or Prussian troops, instead of those of Theodorus, the issue of that glorious expedition might have been a most disastrous one. As for those who invoke the contingencies of future times, and put an unlimited confidence in the progress of engineering science, believing that, after all the marvels witnessed by our age, there is no reason why the highest and the most extensive mountains of our globe, those of Central Asia, may not be crossed by railways and pierced by tunnels, the answer to those sanguine expectations is rather easy. Now, even granting (what certainly is an enormous exaggeration) that there is no limit whatever to the conquests of man over nature, we must not forget that the most splendid triumphs of this kind hitherto accomplished (such, for instance, as the almost finished tunnel and the mountain railway of Monte Cenisio, or the gigantic American railways joining the Atlantic to the Pacific) are mere trifles in comparison with works required for the accomplishment of similar performances in the mountainous systems which separate Turkestan from India. Indeed to launch steam-waggons along immense vertical surfaces, or across stupendous glaciers, or to scoop out tunnels running many hundred miles, is now almost as impossible as to employ balloons for the performance of such marvellous travels; and if really the time will come when peculiar steam-engines, or rapid and manageable balloons shall be invented, no doubt this time is so far from us that at the brilliant dawn of that glorious day the civilizing task of England and Russia in Asia will have been fulfilled long before; then the now barbarous populations will be perfectly able to defend themselves without wanting any tutelage, and the newly invented marvellous engines will be used for the transport of travellers and merchandise, but not for military expeditions. In one word, the more we contemplate the real state of things, such as has been revealed to us by the recent explorations of Central Asia, the more we must admit that the phantom of a Russian invasion in India is a worn-out bugbear; and the day may not be distant when people will smile at such prophecies, and when the inhabitants of Bombay will be as little afraid of the appearance of Russian soldiers as the inhabitants of London are of the arrival of French troops; at all events, in both places such visitors would pay very dear for their untoward and uninvited visits. The same thing, but only in an opposite sense, may be said of England and British India what a French poet said, speaking of honour as of a rocky island from which one may get out but never get in again,—

> "L'honneur est une île escarpée et sans bords,
> On n'y peut plus rentrer dès qu'on en est dehors."

Here, on the contrary, those who may get in will never be able to get out safely. Let us, therefore, drop those chimerical but most dangerous illusions, which the study of Central Asia has so happily dissipated, and let us mention another valuable advantage which such studies have bestowed upon us, showing that, if British India is defended by an impregnable natural bulwark, this bulwark is inaccessible only to bloody representatives of war, but not to gentle messengers of peace; for among the results of recent explorations of Central Asia, one of the most remarkable and the most satisfactory is the fact that those complicated mountainous ramifications, which are spread, like a gigantic labyrinth, over the whole of Central Asia, are not devoid of numerous passes and even of considerable local depressions, in the shape of plains, which hereafter may be very useful for the establishment of commercial communications between the remotest points of the stupendous chains of Thian-chan, Kuenlun, Mustagh Dagh, and Himalaya. So, for instance, thanks to the important explorations of the Kuenlun range by Mr. W. H. Johnson during the year 1866, we know that, contrary to what has been admitted hitherto, even by Humboldt, this lofty range does not spread itself beyond 100 miles to the east of the meridian of Ilchi, where it is limited by long plains, through which caravans transporting merchandise may cross the whole country between Ilchi and Leh, and consequently almost as far as the superior valley of the Indus, only six miles distant from Leh. A similar topographical feature seems to characterize equally the vast country between Khatan and Aksu, the last city being situated on the southern slopes of the Thian-chan range; so that nature herself has indicated the lines which, worked out by human art, may, in the future, connect the valley of the Indus with the Thian-chan range, crossing in this manner from north to south a large portion of Central Asia, and possessing the immense advantage of avoiding entirely the rugged inhospitable range of Kuenlun. Even the mysterious Bolor, with its cold gigantic tableland of Pamir, seems not to be quite deprived of natural thoroughfares liable to acquire hereafter a practical importance; at least such a conclusion is suggested by the map of that country constructed by Mr. Hayward, according to the itinerary of a merchant of Jarkand,—a map which will be replaced in a short time by a far more accurate one, for the vast and unknown countries of the Bolor are about to become the object of important explorations which science expects with impatience from the accomplished geographer Colonel Walker, as well as from Mr. Hayward himself. Again, the compact network of various natural roads or paths which unite the valley of the Indus with the range of Thian-chan is more or less connected with other branches of natural communications which penetrate across the mountains of Turkestan and those of Southern Siberia into the hydrographical systems of the Jaxartes, the Oxus, and Ili, as well as into the vast basin of the Balkasch Sea; so, for instance, there is a pass leading from Guldja to Aksu, across the Thian-chan, and another one from the river Ili to Samarkand.

Yet all those natural thoroughfares, although even now of some importance for commercial communications, cannot be of any value to military purposes, because the various passes and depressions are interrupted by rugged mountainous masses, which would stop or delay almost at every step the movement of an army; so that the necessity of performing frequent and tortuous circuits would render the march of a Russian army, encumbered by artillery, perhaps still longer than in a straight line across the mountains, a passage which, as we have seen, is quite out of question. The consequence is that, at the present moment, both roads are almost equally shut to an invading Russia. Nevertheless one may ask if those natural thoroughfares, once developed, would not become as favourable to the transport of troops as to the conveyance of merchandise: no doubt some facility would be offered to the servants of Mars who could be tempted to creep through the open doors of the temple of Minerva; but is not the creation of monuments of peace the best means to render war more odious to the populations among which they have been erected, imparting to them altogether the wish and the strength to oppose and to baffle the criminal designs of reckless intruders? Therefore, instead of fearing the consequences of the development of the natural thoroughfares spread out through Central Asia, it is the interest of England to see them established—the sooner the better; and as such a happy revolution can never take place as long as the countries of Central Asia are not submitted to a regular European government, nothing can be more satisfactory for the sake of humanity in general (but particularly for the material interests of British India) than the recent political events which tend to convert the whole Turkestan into a Russian province, and in this way to throw a bridge over the abyss of Central Asia, in order to unite the valley of the Indus with the valleys of the Jaxartes and the Oxus. I dare say that, if we consider the settlement of Russians in those remote barbarious countries from the point of view revealed recently by science, it must be hailed by the whole of Europe (and by England more than by any other country) as one of the most important and beneficial facts of modern history, and, at the same time, as one of the most astonishing accomplishments of long-postponed providential schemes; for let us not forget that the high political and commercial significance of the valley of the Jaxartes did not escape the genius of Alexander the Great, who founded on that river a city under the name of Alexandria, which was perfectly known in the time of Plinius, who mentions, "Alexandria in ultimis Sogdianorum finibus." Now this city, like many other creations of the great Macedonian conqueror, not sufficiently understood by posterity, did never play the important part to which, undoubtedly, it was destined by its founder; for the Alexandria of the Sogdiani is nothing else than the miserable muddy Khodjend, now in the possession of Russia, a name as little known to the European public as it is difficult to be properly pronounced by European tongues; and still it is not improbable that (thanks to its position in the midst of Turkestan on the border of an important river, the classic Jaxartes) the humble Khodjend may be some day raised to the rank of one of the chief thoroughfares between Europe, Central Asia, and India: in this way the successors of Peter the Great may become the executors of a legacy bequeathed to them by Alexander the Great, whose mysterious testament has remained sealed up during more than 2000 years!

Such are the considerations naturally suggested by the wonderful recent explorations in Central Asia; and I hope they convey a sufficient idea of the high .nterest which must inspire all enlightened persons (but particularly English and Russian) when they hear of the publication of a new, completed, and corrected edition of Baron von Humboldt's 'Asie centrale.' If the diffusion of geographical information about countries little known may in itself be considered as a service rendered to society, what must not be the importance of such information which relieves two powerful nations of a long-expected and seemingly quite unavoidable struggle, and which proves once more that for the promotion of the sacred cause of Christianity and civilization there is on our globe sufficient place for all; and that, moreover, England and Russia are charged by Providence to accomplish this great task in the vast continent of Asia, where each of them has a peculiar mission, which can only successfully be carried out if both combine in their exertions and place their moral and material interest under the mighty safeguard of peace, mutual sympathy, religious toleration, and justice.

Notice of a Bifurcate Stream at Glen Lednoch Head, in Perthshire. *By* Capt. T. P. White, *R.A.*

A small rivulet rises under a craggy hill which separates the drainage systems of the Tay and Earn; for a short distance it takes the course of a well-defined gully, till it is met and divided into two by a slight but immediate rise in the ground, which forms, as it were, the narrow end of a pear-shaped elevation. This is the extremity of a new ridge which, starting from the Forth, carries on the main watershed, hitherto coincident with the direction of the stream. One of the two divergent waters becomes the Finglen Burn, descending into the valley of the Tay; the other, passing into Glen Lednoch, is a feeder of the river Earn, reunion being ultimately established in the Firth of Tay. A loop is thus formed which insulates a large area of the county of Perth.

ECONOMIC SCIENCE AND STATISTICS.

Address by the Right Honourable Sir STAFFORD NORTHCOTE, *Bart., C.B., D.C.L., M.P., President of the Section.*

IF it had not been the custom for those who occupy the position which I have been called on to fill to open the proceedings of the Section with some general remarks, I should have invited you to proceed to the consideration of the papers which will be laid before you, without any preface. For the preface is not only the dullest part of a work, and that which is the most frequently skipped; but, as a matter of authorship, it is the part which ought to be written last, because it ought to be adapted to that which is to follow it; and what that may be, I do not yet fully know.

Forecasting, however, as well as I can, the character of the work which now lies before us, though not prepared as yet to present to you a summary of what you may expect, I cannot doubt that the transactions of the present Meeting will continue to exhibit the tendency of statistical inquiry to take year by year a wider range. That such is its tendency is, I think, not only evident to the observer, but may be said to be a law of the science. For the statist is not animated by a mere spirit of curiosity, nor does he content himself with the simple accumulation of facts. His objects are at once nobler and more practical. He aims at discovering the actual condition of his country, and the causes of that condition, with a view to discover also the methods of improving it. Now, even the true condition of the country is not immediately obvious to the superficial observer; while the causes of the several phenomena which it exhibits lie very deep, and can only be discerned by the aid of patient and extensive inquiries, conducted with skill and discernment, as well as with the most rigid exactitude; and the investigation of the methods by which improvements may be effected imposes a further and at least an equally severe labour. The "Condition of England" question is one which does not lie in a nutshell.

I need not, I am sure, recall to the recollection of such an audience as the present, the interesting Report presented by an eminent member of this Association*, whom we have now the pleasure of seeing amongst us, to the International Statistical Congress of 1860. You will remember how he drew attention to the two great laws which the study of statistics reveals to us, and on which the science rests,—the law of Stability, which teaches us to deduce from the observation of particular phenomena general conclusions, as to the regularity of their recurrence; and the law of Variation, which teaches us in what manner, and within what limits, the conditions of human life, and the current of human action, may be modified or controlled by man. The main interest of our studies is, of course, concentrated on the working of this second law, and on the discovery of the limits within which our power is confined, and here it is that we find the necessity for that extension of the range of our inquiries to which I have adverted.

As in the case of most other sciences and branches of learning, so most assuredly in the case of Statistics, our progress is marked by a series of disappointments. We begin in ignorance and we plunge into error; then we find out our mistakes, and, after having fancied that we had attained to great proficiency, learn, like the wise man of old, that the sum of our knowledge is, that we know nothing. From that point, if we are wise enough and honest enough to profit by our experience, we may indeed begin to make some solid progress; but both wisdom and honesty are needed for the purpose; aye, and courage too, and self-denial. For it is no slight trial to a man, who with much labour and much ingenuity has collected a mass of materials, and has constructed a theory out of them, to find that, through some mistake or oversight, he has gone wrong from the first, and that the whole work must be taken to pieces, the materials sifted and rearranged, and the favourite theory abandoned. No one will go through such a trial who is not supported by a genuine love of truth, and by a hearty conviction that it is a prize worth every sacrifice.

But this lesson, at all events, we learn from the history of these disappointments,

* Dr. Farr.

and from the still more melancholy spectacle which sometimes presents itself of men fighting against facts in support of a theory, and trying to bend them to it, and to suppress what makes against it;—we learn that it is important to spare no pains in the first collection of our materials, to neglect no source of information, and to despise no element of calculation. We learn to be slow to dogmatise, and to be patient of correction and contradiction. And we learn, or ought to learn, that we cannot successfully conduct a statistical inquiry into any particular subject, without keeping our attention alive to the inquiries which other persons are conducting in connexion with other, and, perhaps, apparently remote subjects, and to the bearing which their discoveries may possibly have upon our own.

Let me illustrate what I have been saying by a brief reference to our vital statistics.

Here, in the first place, we have an interesting illustration of the law of Stability and of the law of Variation. We are able to deduce from the statistics of births and of deaths averages of human life on which we can calculate with considerable certainty; and by so doing we are of course enabled to secure some important advantages. But we go further, we distinguish the various causes of death; we separate those which appear preventible from those over which we seem to have little or no control; and we conclude that if we can hit upon the proper remedies, we may so far qualify the rigid law of Stability by invoking the aid of her elastic sister the law of Variation, as to diminish in a sensible degree the rate of mortality, and to lengthen the term of human life. We act on the conclusion, and we apply our remedies. At first we flatter ourselves that we are in a fair way to attain our object; but, just as we are congratulating ourselves on having done so, some disagreeable fact crops up in an unlooked for quarter, which seems to upset our entire theory. We have just now had our attention drawn to a striking illustration of this contingency. Among the most prominent causes of death some years ago, smallpox held a foremost place. To children it was especially fatal. But smallpox, we learnt, was a disease preventible by vaccination. Vaccination was called to our aid, and with great success. The deaths by smallpox were reduced within an exceedingly narrow compass. But it appears while this, the most formidable, foe of childhood has been repelled, infant mortality has not been reduced in anything like a corresponding proportion. Diptheria and scarlatina have taken the place of the vanquished malady; and the law of stability seems to be reasserting its authority, and to be demanding that, whether it be by the one disease or by the other, a like proportion of children shall every year fall victims among us. Our statists, however, are not discouraged by this untoward discovery. They draw from it the true inference,—that the causes of infant mortality, and indeed of human mortality at large, lie deeper than in the prevalence of a particular form of disease; and, while perceiving that vaccination alone will not put a stop to the premature deaths of children, they still believe those premature deaths to be in a measure preventible, and they seek for further methods of prevention. Having found that the repression of a particular disease is not sufficient, they inquire into the predisposing causes which render our children obnoxious to disease generally, eliminating as it were from their inquiry the element of which they have already ascertained the value, and not troubling themselves to look for specifics against scarlatina or diptheria, but for general prophylactics against diseases of whatever kind. In short they broaden the investigation, and seek to ascertain the general conditions of health.

This is in itself a great step in advance; but we must discard the proverb which tells us that it is but the first step which costs trouble. The further the inquiry is carried, the more its difficulties will show themselves. Remedies which, before they have been tried, appear certain to be efficacious, may, when tried, only serve to show that we have not yet reached the root of the matter; while the collateral questions which the investigation will open up will prove, we may be well assured, pretty intricate ones to settle. When we are told that the primary object to aim at is, the "placing a healthy stock of men in conditions of air, water, warmth, food, dwelling, and work, most favourable for their development," we feel that we have a task of pretty fair dimensions before us, and when we learn, among other things, that "a bad land tenure is a cause of death" (a proposition which does not appear to be limited to the case of Tipperary landlords), we may be pardoned for doubting whether any one can assign bounds to the range of the inquiry we have undertaken.

It is therefore both natural, and satisfactory, that statistical inquiry should year by year be extending to wider fields; since no one branch of it can be successfully pursued without speedily bringing us to the necessity of inquiring into the progress which is being made in other branches. The statistics of education, of crime, of pauperism, of labour, of health, of trade, of agriculture, of manufactures, and of every one of the details which enter into the survey of our national condition and prospects, are interdependent, and connect themselves with another. At the same time, not only do they admit of being studied separately, but more true progress will be made by such a method of study. The educational inquirer examines the bearings of juvenile labour, for instance, from one point of view; the sanitary inquirer examines them from another; the inquirer into the causes and conditions of pauperism from a third; and so on. Where their inquiries tend to similar conclusions, each confirms the other all the more for the independence of their lines of argument. Where the conclusions are inconsistent, they are all the more suggestive; and suggestiveness, as it seems to me, is what constitutes the great value of statistics.

The old sarcasm, that you may prove anything by figures, has no doubt much truth in it. In the sense in which the words are usually taken, they convey a protest against crude, and of course still more against unfair, statistics. But we may perhaps affix another idea to them, and one less uncomplimentary to our science. I am sometimes inclined to look at a great mass of statistics, undigested and shapeless as it seems, in the spirit in which the sculptor may be supposed to look at the rude block of marble out of which he is to fetch the form of beauty that lies hid within. Innumerable are the lessons which may be drawn from those hopeless-looking figures, if only the student knows how to search for them; just as the forms which might be developed from the marble are innumerable, if the artist knows how to bring them to light. Remote as the region of statistics appears to be from the region of the imagination, there is no pursuit of which it may more truly be said that its success depends upon a proper exercise of the imaginative faculty. A wholly unimaginative statist is as intolerable as an unimaginative verse writer. A man must know what he is going to look for, and how he will look for it, before he begins his examination of a mass of figures; but he must keep his mind open, throughout the process, to receive the suggestions which the study is sure to produce. He must work upon an hypothesis, but he must be ready to abandon it as soon as he finds it untenable; and he should be quick to form new hypotheses, and to subject his materials to new tests, as occasion arises. For all this kind of work it is of great advantage that other minds should be brought into contact with his own, and that he should profit by the suggestions which their independent inquiries cannot fail to elicit.

It is of course obvious that meetings such as that in which we are now engaged, are likely to advance the study in the direction which I have been indicating. But that is not their sole advantage. It is, I think, no slight one, that we are called on to dispute in public, and to address ourselves to a general audience. If our studies are really valuable, if our methods of conducting them are sound, if we are doing good service to our country, we certainly ought to be able to interest and to attract our hearers. The subjects with which we deal are of general concern; they are not mere matters for closet speculation, nor is it good that we should treat them as if they were. Neither does the discussion of them involve the necessity for the use of strange or technical language; nor is it even necessary that we should weary our hearers with long columns of figures. It is rather a sign of indolence than of profundity when speakers oppress their hearers with technical phrases, and with processes of arithmetic. These should be used in the closet, but should be as sparingly as possible obtruded on the platform. Our methods of inquiry should indeed be strictly scientific; and we should never cease to be on our guard against fallacies, but we should adapt our arguments to the circumstances of human nature, and endeavour to make them attractive by making them intelligible. In a word, if I may borrow an illustration which promises to take root among us, we must make our hearers feel that we are all on the earth together, and that we are not mere aëronauts addressing them from a balloon.

And here may I venture, as a Devonshire man, while bidding you heartily welcome to the county, to bespeak your indulgent consideration of the circumstances of my compatriots? We Devonians do not hurry on in the race of life quite so rapidly as some of our fellow-countrymen. Perhaps I may venture to say without offence that, as compared with north-countrymen, we live slowly. Our birth-rate is below the average of England, and so is our marriage-rate; but then it must be remembered that our death-rate is also low. If you compare us with Lancashire, for instance, you will find that, for less than 32 births per 1000 in proportion to the population here, there are more than 38 per 1000 there [the precise figures for 1867 are Devon 31·75, Lancashire 38·19]; that, for less than 16 marriages per 1000 here, there are more than 19 per 1000 there [Devon 15·72, Lancashire 19·04]. But then, for less than 20 deaths per 1000 here, there are nearly 27 per 1000 there [Devon 19·72, Lancashire 26·83]. So, again, you will find that our children die less rapidly than theirs, and our old people attain to greater ages. The proportion which the deaths of children under 5 years of age bear to the births in the year is, in Devonshire $19\frac{1}{3}$ per cent., and in Lancashire $32\frac{1}{2}$; while the proportion of deaths of people over 65 years of age is, in Devonshire $18\frac{1}{4}$ per cent., and in Lancashire $8\frac{3}{4}$ per cent. Our marriages, too, take place at a more advanced age than do theirs. Of our men only 6·05 per cent. marry under 21 years of age; of theirs 8·45 per cent. do so. For women the proportions are, in Devonshire 16·81 per cent., and in Lancashire 21·10. In short, we are born, we marry, and we die more slowly than they do. But we are not behind them in all things. If the state of education is to be judged of by the proportion of married people who can write their names, we may hold up our heads even by the side of Lancashire. Of our bridegrooms (in 1867) 82·7 per cent. wrote their names like men; of theirs only 76·8 per cent. Our brides did still better in proportion: 78·6 of them wrote their names, while in Lancashire only 56·0 did so. In the matter of wealth no doubt we are behind them; our assessment to the Schedules A, B, D of the income-tax comes to only £10 12*s.* per head of our population, while theirs comes to £13 14*s.* On the other hand I doubt whether we have a very much larger number of paupers in proportion to our population than they have (on the average of the three years 1866–68 they seem to have had 65 able-bodied paupers to every 10,000 of the population, while we had 69). And as regards criminals we fall far short of their ratio; the proportion of persons committed or bailed for trial in 1867 having been in Devonshire less than 4 to 10,000, and in Lancashire 12 to 10,000.

There are many other points on which it would be interesting to compare the two counties; and the comparison would be rendered still more valuable by extending it to other counties, of which these might be taken as the types. But time forbids my entering into the details which would be requisite. I have referred to the point principally for the purpose of reminding you that observations which might have been applicable in one part of England may be very much out of place in another; that each county has lessons of its own to teach, as well as to receive; and that Devonshire, though she does not aspire to the position of Lancashire as the standard bearer of British manufacturing and commercial enterprise, is not without her own claims to respect and admiration in regard of many of the essentials of human happiness.

I return from these local remarks to the wider field which more properly claims our attention; and I desire to invite you, who are so much more competent for the task than I am, to endeavour to realize for yourselves as far as may be the general character and tendencies of the age in which we live. To me it appears to be emphatically, and in the highest sense of the term, a statistical age; an age, that is to say, in which we are inquiring extensively and methodically into the facts by which we are surrounded, comparing ourselves with our neighbours, measuring our progress, and estimating our prospects with unprecedented care. Nor do we stop here; but, giving a practical turn to our inquiries, we study not only to ascertain, but to husband and to develope our resources. Pressed, it may be, by the increasing competition of foreign nations,—pressed, too, by the consideration that our wealth and our desires for enjoyment are increasing far more rapidly than our population, and consequently than our supply of labour,—and conscious, moreover, that the non-reproductive sources of our material wealth, such as our minerals, are being very heavily drawn upon, we are daily casting about to find how this competition may best be sustained, how the balance between capital and labour is to be preserved, and how we can best economize those supplies which we fear may some day fail us.

We are beginning to feel that the time for waste has gone by. It may, perhaps, provoke a sneer from the cynic when he hears that England is becoming anxious as to the possible exhaustion of her coal-measures, and is considering how and where she can find water enough for her population. One cannot help being reminded of the sarcastic remark of the American traveller—that we had a tidy little country enough, but that for his part he was always afraid of tumbling over the edge of it. There is some truth at the bottom of the taunt; but it is not to such considerations that I wish to direct your attention. Rather I desire to point to the satisfactory indications, which such inquiries as I refer to present, of the determination of our people to make a stand against the bane of national prosperity,—Waste. I speak not only of waste of raw materials, but of waste in all its materials, but of waste in all its forms,—waste of power, of labour, of time, of health, and of life. Year by year we are learning to make skill do the work of strength, to draw greater results from equal efforts, and to supply our labourers with every comfort, every advantage which science can devise for enabling them to fight the battle of life on better terms; and hence it comes that the question of education is not only claiming a larger share of our attention, but is presenting itself in new phases; and that we are looking to education in physical science, and even to technical education, with such unwonted interest. We are grappling, I think, more boldly than we ever did before with the difficult problems of our national life, and are advancing to their solution with greater breadth of view and greater confidence of step.

Let me offer an illustration of the economy of labour which is taking place among us, by a reference to some remarkable statistics which have quite recently been laid before us. Last week my friend, Mr. Shaw Lefevre, introduced the Merchant Shipping Bill into the House of Commons; and after pointing out the enormous increase which had taken place in our commercial navy in the last fourteen years, and showing that we had now as much sea-going tonnage as all other nations put together, proceeded to say that, while the amount of tonnage had increased since 1854 by no less than 50 per cent., the number of seamen required to navigate it had increased by only 21 per cent.; that in 1868 we required one man less to work every 100 tons of shipping than we required in 1854, or, in other words, that we could work our present marine with 55,000 fewer men than would have been necessary for the same amount of tonnage fourteen years ago. And to show to how great an extent this economy had been brought about by the introduction of machinery and improved methods of working, Mr. Lefevre gave the particulars of the manning of twenty-two large sailing-vessels in the years 1849, 1859, and 1869 respectively, showing that in the first of those years they required crews amounting to 463 men, in the second to 417, and in the third to no more than 348—the ships being identical, and the voyages nearly the same.

I have dwelt at some length on these figures, because they suggest to me several reflections. The first is one in which I think we may justly indulge, and which is the counterblast to that sarcasm which I quoted just now from an American critic;—that the power of England is not to be measured by the dimensions of this little island, but rather by those of the great empire of the seas which it has so long been our boast to rule. If we were to fall over our country's edge we should only fall into an element which we have made our own. England, it may truly be said, that is, the mere island of Great Britain, is but the shadow of herself, and we might address our rivals in the proud words of the Talbot of Shakespeare—

> "You are deceived, my substance is not here;
> For what you see is but the smallest part
> And least proportion of humanity.
> I tell you, madam, were the whole frame here,
> It is of such a spacious lofty pitch,
> Your roof were not sufficient to contain it."

Justly, then, in our statistical inquiries we take note, not only of the progress of England proper, but of all parts of the great British empire; and this you will observe in looking to the various collections of information which Parliament is annually making for us,—that year by year fuller statistics are produced with relation to our colonies and dependencies. That valuable 'Fifteen Years' Abstract,' which has now reached its sixteenth number for the United Kingdom, has been adapted to the British colonies for four or five years past, and to India for two or three. We have, in addition to these compendious handbooks, several more voluminous collections of tables relating both to our colonies and to foreign countries, enumerating not only their areas, populations, amounts of revenue, expenditure, and debt, and the extent of their trade; but in the cases of many of our colonies giving most useful information as to their moral and social condition, the state of education, of crime, of immigration, of wages, of prices, of land sales, mortgages, savings' banks, and an immense variety of other matters. All these are a testimony to the extended character of our transmarine connexions and interests, and may be taken at once in explanation and in justification of our position as a colonizing power. In spite of all that may be said as to the alteration of the relations between England and her dependencies, she need hardly be called on to abdicate her proud title of the "Mother of Nations," while she can point to these effects of her influence in every quarter of the globe.

Another reflection which occurred to me when I dwelt on those statistics of our shipping just now was this,—our population continues to increase; but it increases far less rapidly than our wealth. That is a fact which, if it stood alone, would indicate that in the struggle between capital and labour the advantage was likely to be on the side of labour, for that the demand would be in excess of the supply. But this advantage is to a considerable extent corrected by the increasing economy of labour indicated by the figures which Mr. Lefevre gives us for a single trade, and which are no doubt equally applicable to other trades.

It is sufficiently obvious that such economy must in the main be advantageous; at the same time we must not forget that the displacement of labour is often the cause of suffering, and sometimes, when it occurs suddenly, of very severe suffering. It may produce, not only individual distress, but, under certain circumstances, even political danger. If it were possible so to reconstruct society as to give every individual member of it a direct share in every gain made by society as a whole, this particular danger would of course vanish. But this is the theory of Socialism; and we have no evidence that, if socialism were in the ascendant, society would make these gains at all. Reasoning leads us to the conclusion that it would not; and the time is probably far distant when England will accept a system which has so obvious a tendency to discourage private and individual enterprise.

Nevertheless, it cannot be denied that Englishmen are beginning to look to Government for assistance, and to distrust individual action, to a much greater extent than formerly.

Some years ago it used to be thought to be the duty of the Government to foster private enterprise by protective laws, monopolies, bounties, and differential duties. The great Free Trade movement overthrew this theory, and left upon us the impression that the more private enterprise was left to itself and the less the Government interfered with it the better. But of late the tide of public opinion has seemed to be setting in a somewhat different direction. Not that we are going back towards the protective system; but that, on the one hand, we are beginning to invite or to urge the Government to take upon itself work for which a few years back we should have deemed it utterly incompetent, and which we should have jealously reserved for private hands; while, on the other hand, our private enterprise is becoming more and more dependent on the assistance of the Government for its own proper organization and development. Thus, in this matter of our Merchant Shipping, while we have been repealing our navigation laws and sweeping away every vestige of a differential duty, we have been creating a code of almost Brobdignagian dimensions for the regulation of every detail of our marine affairs. The choice of proper masters and mates is no longer left to the discretion of the shipowner; he must employ men who have passed a Government examination, and who hold certificates which the Government may cancel in case of any misconduct. The contracts between owners and seamen are regulated by the Government, and are made under the direct superintendence of public officers. The proper construction and fitting of the ships, their sanitary arrangements, the quantity and quality of the provisions and medicines, and the strength and texture of the anchors and chain cables, are all matter for the consideration of the same paternal mind. Nor is this kind of care confined to a single branch of industry. There are many others with which the Government concerns itself, and still more with which it is pressed to do so; while at the same time we are becoming accustomed to its direct action in the management of various classes of business, and are not unwilling to see that action further extended.

Can it then be that we are learning to sink the idea of the individual in the idea of the State? Do the mass of the people, as our constitution becomes more democratic, begin to see in the Government an organ better fitted to do their work than they find in the classes above them? Perhaps, as monopolies are put down, and privileges abated, and education is more generally diffused, and a closer approach to equality is effected, the tendency to deal with questions nationally, rather than by the action of classes or of individuals, may increase. Perhaps, as the competition of foreigners presses upon us with greater severity, and as we become conscious that it is only to be encountered by the aid of all the resources, all the education, all the organization that we can command, it is natural that the desire to invoke the powerful aid of the State in gathering up all the elements of our strength and giving it the best possible direction, should become more and more marked. Perhaps there may be something in the nature of things which renders cooperation more and more necessary as we make greater progress in the work of subduing the universe. In the ruder states of society, when industry is in its infancy, the isolated labour of the individual suffices to procure the simple necessaries of life which he requires. As civilization advances, and greater results are sought, cooperation begins, and the division of labour is resorted to. By degrees we introduce, first the small capitalist, then the larger one, and then the joint-stock company. It may be that the tendency to invoke the aid of the Government is but another step in the same career. Or possibly we may explain it by the fact that the progress of civilization is, as of necessity, accompanied by the growth of new dangers against which precautions have to be taken which the State alone is competent to take. In a civilized society, as we have lately been reminded, deaths by violence, that is to say by accident, have a tendency to increase. In England they are rapidly increasing, and special precautions are needed to render safe that free application of the vast forces of nature to the intercourse and the arts of life which is now so essential to our prosperity. Or, lastly, it may be that in the increasing struggle for wealth the interests of the weaker classes, of the poor, the young, the female, are likely to be set aside unless the State interfere for their protection: and the acknowledged demand for such interference may be another cause for the tendency to which I have referred. Such seems, at all events, to be the tendency of the age, and it is one which it is impossible to notice without some uneasiness. That we have hitherto been somewhat too jealous of the State, and that it would be wise to call in its aid rather more freely, may probably be true. But the greatness of England has been achieved by the self-reliant energies of individual Englishmen, and by the energies of individual Englishmen it will be best maintained.

On the Condition of the Agricultural Labourer.
By WILLIAM BOTLEY, *F.S.A.*

On the Devonshire Association for the Advancement of Science and Art.
By Sir JOHN BOWRING, *LL.D., F.R.S.*

In this paper the author narrated the proceedings of the Devonshire Association, whose purpose was to carry out the same investigations in the Devonshire localities which occupied the attention of the British Association in its far wider and far more important field. Seven volumes had been published of the 'Transactions of the Devonshire Association,' which had held its Annual Meetings at Exeter

Plymouth, Torquay, Tiverton, Tavistock, Barnstaple, Honiton, Dartmouth, and proposed to assemble at Devonport in 1870. Succeeding Sir John, there had been as Presidents, Mr. Spence Bates, Mr. Edw. Vivian, Dr. Daubeny, Earl Russell, Sir J. D. Coleridge, Mr. Pengelly, and Mr. George Bidder, and the next President Elect is Mr. Froude. Scarcely any portion of the local area had been unexplored, and special attention had been given to the attractions of the localities where the Meetings had been held. The number of Members had constantly increased, and pride was felt in the fact that Devonshire had, however imperfectly, and at however remote a distance, imitated the example and followed in the footsteps of the greater Association.

On Penal Law as applied to Prison Discipline.
By Sir John Bowring, *LL.D., F.R.S.*

The object of this paper was to show the very unsatisfactory working of the Prisons Act of 1865, and that while it allowed magistrates and governors to make jail-labour remunerative, it permitted the greatest inattention to this important object; and that consequently the cost of prisoners and the produce of their work was so incredibly various as to make it difficult to believe that the subjects of Great Britain were under the rule of any common legislation. The county prison of Devon was one of the most remarkable instances of the bad effects of routine, for large amounts of money had been spent to provide machinery for wasting labour. A treadmill, at the cost of £1760, imposing in interest alone an annual charge of more than £80, had lately been erected in Exeter prison, though it was well known that the treadmill had been rejected in every prison in Scotland, and was repudiated in most of the prisons of the civilized world; the invention was a calamity, its employment an opprobrium. The labour of the hundreds of convicts passing through that establishment left nothing but heavy cost to the community. It was disgraceful that in an enlightened and inquiring country the cost of felons should vary from *nil* up to more than £120 each per annum. Prison inspectors are helpless when magistrates are obstinate; and to nothing but the application of some sound general principles enforced by parliamentary requirements could we look for any general improvement. The contrasts presented by the best conducted prisons of the United States and the Continent, when compared with our own, is disgraceful to British reputation, whether as regards the reformatory or the pecuniary results of their administration. The author referred with great and hopeful satisfaction to the International Congress proposed to be held in some great European city—he trusted London would be selected—in the coming year, in which the experience of the highest authorities would be brought to bear on this important question. He thought that the number of our prisons was far too great, and ill adapted to these purposes, and that nine-tenths of that number might be usefully sold; and new prisons, on the best models, built not only with a view to economy, but to the higher questions of discipline. Great advantage would be found if particular trades were carried on in particular prisons—shoemaking, for example, in one, tailoring in another—selected with reference to the locality itself. In Belgium the army was clothed by prison labour, in France the Government received £178,000 for work in 1868. In the United States the best prisons left a large balance of profit to the State after the deduction of every outlay. He pressed the necessity of making, as far as possible, retribution to the injured one of the requirements to be laid upon the convict, and gave elaborate reasons for the abolition of the punishment of death.

Some Statistics of Railways in their Relation to the Public.
By Raphael Brandon.

The author showed that the returns made for railway investments had not been such as might have been expected from capital laid out, and that the public had every reason to complain of the present railway system. He suggested that it could only be accomplished by uniting all the railways under one general management, to form them into a separate branch of the public service. The author contended that a passenger should be enabled to travel one journey, of any distance, in a given direction for a sum little more than nominal. In 1868, 310,150,915 passengers travelled on the railways, paying an average fare of $11\frac{1}{4}d.$ to $11\frac{1}{2}d.$ Six times the number of passengers could be carried for a very small (if any) additional expense; and if a universal fare of 3*d.* was charged for any distance for each person, at a very moderate computation, six times the present number of persons would travel, and would produce £23,261,318, being £8,536,516 in excess of the receipts of 1865 from passengers only. This calculation was made supposing that each person pays only a 3*d.* fare; but he would divide them into three classes as now, and fix the fares for any distance at the following rates:—first class, 1*s.*; second, 6*d.*; third, 3*d.* For such first-class passengers who would pay £10 and £5 annually in addition for such distinction should travel in carriages provided exclusively for them. He proposed that separate lines should be constructed for the goods and passenger services; and he would make passengers pay for all luggage that had to be placed in the van, which would largely increase the revenue. There would be, no doubt, many who would say that the idea of carrying a passenger from London to Edinburgh for 3*d.* is preposterous, but they must remember that it was not until Sir Rowland Hill had shown its feasibility that any one thought it was reasonable to take a letter from London to Edinburgh for the same charge as from London to Richmond. Under the most adverse circumstances, for instance, that by his plan not one more passenger was induced to travel, there would still be a gain to the railways of £2,000,000 a year. In conclusion, he showed that the scheme would have a beneficial effect on the labour markets in enabling a working man to remove at once to the district where his skill is in demand, and would thus tend to equalize the value of labour in the country.

On the Want of Statistics on the Question of Mixed Races.
By HYDE CLARKE, *F.S.S., For. Sec. Ethnological Society.*

The author stated that the existing materials are fragmentary, and admit of no comparison, and that the approaching Congress of the English and American Empires should be taken advantage of to obtain figures as to mulattos, half-breeds, Anglo-Maories, eurasians, &c., to determine the question of vitality of mixed races.

On the Distinction between Rent and Land Tax in India.
By HYDE CLARKE, *F.S.S. &c.*

In various parts of India rent and land-tax have been fused into one sum, and hence a serious confusion exists as to the functions and duties of Government in its respective capacities of landowner and tax-receiver. This acts likewise in retarding the establishment of private freeholders in India. The writer urges the desirability of returning to the original distinctions of rent and land-tax. These are observed in other parts of the East. In Turkey and Persia the land-tax commonly represents 10 per cent., but occasionally of late 15 per cent. The remainder of the sum received by the Government may be treated as rent.

Note on Variations in the Rapidity and Rate of Human Thought.
By HYDE CLARKE, *F.S.S. &c.*

The purpose of this note is to extend the range of statistics or the numerical method of investigation. The author states that after an attack of typhus fever, finding his physical system much weakened, he put himself through an examination to test whether his mental system was affected. This he found not to be the case as to quality, but as to speed of thought. By a rough process of test he devised, he found the speed was reduced to one-fourth of the previous power. The correctness of reasoning was not affected, but processes requiring rapidity of thought, as poetical composition, were influenced. It was some years before the former rate of rapidity was restored. The practical conclusions are, that the rate of thought is subject to great fluctuations within the same individual at various periods, that these fluctuations are possibly daily and hourly, and that the differences between different individuals at the same time must be very considerable.

Some Statistics of the National Educational League. *By* JESSE COLLINGS.

On the Technical Education of the Agricultural Labourer.
By J. BAILEY DENTON, *C.E., F.G.S.*

The object of this paper was to show that, in addition to, and associated with, elementary school teaching, technical education in the duties of agricultural labour should be encouraged as a means of making greater the value of manual work. The result, the author contended, would be that the farmer would have better work performed and be better able to pay higher wages, it being a mistake to believe that physical health and strength were alone required to make a farm-labourer all that he need be. The business of the farmer is gradually becoming more like that of other industrial classes, in which technical knowledge and education are highly esteemed. To regulate wages simply by the physical strength of a labourer, without regard to skill or knowledge, cannot be maintained; while to pay higher wages without increasing the quantity or improving the quality of labour could only be maintained by impoverishing the farmer without increasing the produce of the country. It was advanced on the author's own experience, that the farm-labourers of Dorsetshire, Somersetshire, and Cornwall, earning from 7*s.* to 12*s.* a week, performed work of much less value than those of Lincolnshire, Yorkshire, and Northumberland, where wages vary from 12*s.* to 18*s.* a week; and that a northern farmer employing the latter secured a better return for his money than a southern farmer employing the former. By the technical teaching of Dorsetshire labourers, who had originally been employed by the author at from 7*s.* to 10*s.* a week, he had been enabled to pay the same men from 18*s.* to 25*s.* a week with advantage.

The mode of conveying technical information to the children of agricultural labourers which the author recommended, was to teach them at school to read books purposely written on the common objects of the farm, so as to secure an early interest in the duties upon which they would be afterwards engaged. These children's books should deal with the animals, insects, crops, and weeds of the farm, and should be written purposely in language and style as interesting as possible, in order to interest the worst-taught branch of the community. Thus primary and technical education would proceed together. The teachers at the school should be specially qualified to interest children in agricultural objects. As soon as the youths leave school and take part in farming duties, the author proposed that they should be placed under leading labourers in different departments of the farm, and not be allowed to run from one duty to another, as is now the case; and to encourage the best workmen to convey information to youths, it was proposed that examinations should take place periodically, and rewards or prizes be given to the teachers as well as to the taught.

Statistics of Invention illustrating the Policy of a Patent-Law.
By HENRY DIRCKS, *C.E., LL.D.*

The author stated that the time seemed to have arrived for a close inquiry into the policy of a patent law, as the subject was not only likely to come before Parliament next Session, but had also excited the attention of the working classes, as one affecting their interests. He considered it a first requisite in the treatment of the subject to trace the inquiry both historically and statistically. He urged the disadvantage of excessive patent-fees, and showed that under the existing liberal system a great impulse had been given to invention; also that heavy patent-fees, acting like a prohibitory duty on commerce, only served to limit the inventive ingenuity of the country. He referred to the thirteenth century for its gunpowder, and to the fifteenth century for its printing-press, both of which, although unpatented, left a long waste period without any considerable progress. The increase of patents since 1852 he looked upon as affording evidence of the impulse given to the trade and commerce of the country. He objected to the opinion that the inventive faculty was innate in mankind; and likewise to the supposition that we had arrived at a state of improvement in arts and manufactures so eminent that we might now safely cast away all expectancy of future benefits from the protection sought through the medium of patent laws. He contended that the inventor was encouraged in his researches and labours, despite all opprobrium to which he might be subjected, by the expectancy of reaping fame and fortune; and that no process so easily secures these to him as patent law. He cited cases, and gave a table of the progress of the invention of the steam-engine, in support of his statements and arguments; closing with the observation that the inventor was as useful and important to society now as ever he was, and that advance in inventions and improvements was required; and *that* purpose could only be promoted by the protection of a patent law.

On International Coinage. By W. Farr, *M.D., D.C.L., F.R.S.*

Starting from the principle that the current coins should be metric weights of the precious metals, and that the expense of coinage should be taken as a seigniorage from the fine gold in the coin—which would, within limits sufficiently near for all practical purposes, retain its actual value, as its cost of production would remain unchanged—the author proceeds to show that the *decagram*, or ten grams of standard gold, to be called a Victoria, or by any name, would form the most convenient coin of account. It would make a well-defined useful international coin.

A heavy half-sovereign weighs 4 grams; consequently a fourth part of it is one gram by weight, and one half-crown in value. A heavy sovereign weighs 8 grams; a decagram is 10 grams, and in gold is worth 10 half-crowns, or 25 shillings.

1. *The Ten-gram (decagram) of standard gold=the Victoria=the 25-shilling piece.*

The gram is a weight in daily use among the people of France, Italy, Switzerland, and Belgium; its multiples are in all their shops and houses. A coin of standard gold weighing ten grams could be appreciated and be tested by them at any time. But the Napoleon, weighing 6·4516 grams, or a 25-franc piece, weighing 8·0646 grams, is expressed in fractions, not easily comprehensible, while a ten-gram coin of standard gold is perfectly intelligible, and its weight is easily determinable. Under these circumstances no one can be surprised that Cobden's friend, M. Chevalier, one of the highest French economical authorities, should propose a *ten-gram gold unit* as the basis of the monetary system of the world. The metric system of weights and measures will in the end be inevitably adopted, like the Arabic figures, by every civilized nation. That system is the real glory of France, which none can contest or deny, but the glory is incomplete so long as the measuring unit of value is not the gram, or the ten-gram weight of standard gold.

The ten-gram gold unit of money necessarily differs from any of the units now in use; it will be a new international coin; but its scientific basis commends it to the philosophic minds of Germany, Holland, Scandinavia, and Italy; while it has accidentally strong claims on the three nations which coin the largest quantities of gold. France has in it a kind of paternal interest; it is the natural development of her scientific system of weights and measures. The English sovereign weighs almost exactly eight grams; and the passage to a ten-gram coin is easy, as the new coin decimally divided embraces two of the principal subordinate silver coins in use in England. A ten-gram gold coin is almost the exact equivalent of a six-dollar American gold coin. The new scientific coin is a natural development of the English and the American coinage, corresponding in increase of weight with the increase of the existing quantity of gold and the increase in the values of commodities to be measured.

I will endeavour to show how the new unit is deduced directly from the basis of the metric system, and how readily it can be adjusted by slight variations of fineness to our own existing system of money.

All the units of the metric weights and measures are based on one fundamental unit, the metre.

The unit of weight is the *gram*, which is deduced from the weight of a cubic centimetre of distilled water at its maximum density. It would therefore be in strict analogy with this system to take *a gram* of standard gold as the unit of the measure of value; for then, as a cubic centimetre is the volume unit, the weight of its volume of water the weight unit, that weight, or a multiple of it, would be the unit measure of values. This would be simple, logical, and in strict accordance with the basis of the metric system, which renders the passage from linear and superficial to cubic units, from cubic units to weights, so easy. The idea of weight is totally different from the idea of volume, but the two are connected by the intervention of water; so the idea of value is totally different from the idea of weight, but the two are connected by the intervention of standard gold. Then the unit of work, a kilogram lifted a metre in a second, and the measure of the value of that work, would be alike connected with the metric system.

The principal commercial witnesses before the Royal Commission, and the Commissioners themselves, attach the first importance to the fact, that contracts to pay in money should imply contracts to pay fixed weights of fine gold. Now it happens that the English sovereign does weigh, as it comes from the Mint, very closely on 8 grams; it may by the tolerance indeed exceed 8 grams. By simply adding only a small fraction of a grain ($\frac{1}{5}$ grain) to the alloy, leaving the fine gold precisely in its present quantity, we get the sovereign theoretically, as it is practically, 8 grams in weight, the half-sovereign 4 grams, the half of this again 2 grams, worth a crown, and consequently the gram worth half-a-crown, an old favourite.

	Sovereign.		25-Franc Piece.		New English Sovereign of 8 grams.		Victoria. ∀	American 6-Dollar Piece.
	Weight.		Weight.		Weight.			
	Grains.	Grams.	Grains.	Grams.	Grains.	Grams.	Grams.	
Fine gold	113·001	7·3225	112·006	7·2581	113·001	7·3225	9·0000	9·0282
Alloy	10·273	·6657	12·446	·8065	10·458	·6775	1·0000	1·0032
Standard Weight	123·274	7·9882	124·452	8·0646	123·459	8·0000	10·0000	10·0314
Tolerance Weight	·257	·0166	·249	·0161	·247	·0160	·0200	
Coefficient of fineness	Tolerance $\frac{1}{480}$= ·002083; fineness ·916.		Tolerance ·002; fineness ·900		Tolerance ·002; fineness ·915.		Fineness ·900	Fineness ·900
Value of Gold in the Coin	20*s*.		19*s*. 10*d*.		20*s*.		24*s*. 7*d*	
Seigniorage	....		2*d*.		....		5*d*.	
Value of Coin ...	....		20*s*. 0*d*.		....		25*s*. 0*d*.	

The English Mint could any day coin 8-gram sovereigns, and all their subdivisions down to 2 grams, without any difficulty; and it could go a step further by coining a 5-*crown*, that is, a *five-and-twenty shilling* piece of 10 grams (·9153 fine). It will be a new guinea—a guinea amplified, beautified, and decimally divisible into convenient subordinate units. The prime gold unit will thus be enlarged as the gold in use is augmented. We should have three subordinate units; the gram (*guilder*) occupying the first decimal place, would be the equivalent of the half-crown; the decigram equivalent in value to the threepenny piece, and the centigram equivalent in value to the tenth of a threepenny piece = a cent = 1·2 farthing; so that five of the new cents would be of the same value as six of the present farthings = three halfpence. The money of account of all denominations would be gold. Accounts of money and weights of gold would be represented by the same figures.

100 of the grand gold coins would weigh a kilogram; and as 1000 kilograms are a metric ton, 100,000 new coins would be a metric ton of standard gold.

If the Mint assay and stamp kilograms of standard bar gold so as to guarantee the fineness, these kilograms of gold will be convenient forms of bullion, available for exportation, or for deposits in banks. A thousand kilogram bars weigh a metric ton, worth 100,000 of the great gold coins. A *million* of these coins (= ∀1,000,000) would weigh ten tons of standard gold, and be worth a million and quarter pounds of the present sterling.

The multiplication of pounds sterling by ·8 converts them into the ten-gram gold coin. The specific gravity of a new sovereign is 17·58, water being *one*, and this enables us under the metric system to pass from value to weight, from weight to volume.

Accounts are now kept in England in four units, (1) pounds, (2) shillings, (3) pence, (4) farthings. Under the ten-gram gold coinage accounts may be exhibited in two columns.

To illustrate the new *ten-gram gold coinage*, the author gave the revenues of some of the principal States of the world in their present coins, and in the proposed international coins.

The annual State expenditure of 432 million people was 456 million of these ten-gram Victorias (5-crown pieces), that is a little more than a Victoria a head, or more exactly 1 Victoria and 55 cents a head = 1 Victoria, 5 threepennies, and 5 cents = 1 Victoria, 5½ Anglo-Saxon pennies.

2. *Changes in the English Coinage under the Ten-gram gold unit.*

The ten-gram unit of gold ·915 fine, instead of ·916 fine, would contain exactly the same quantity of fine gold as 1¼ sovereign, worth five-and-twenty shillings in the present currency; and if the Mint and Bank cost of making and sustaining the gold coinage is fixed at 15, 10, or 5 centigrams of fine gold for every decagram, the fineness will be ·900, or ·905, or ·910; while the amount of fine gold taken as seigniorage will be worth from *5d.* to *3d.* or to 1½*d.* in the present currency, which will be as much a part of the cost of production as the expenditure at the gold diggings. The cost of producing 9 grams of fine gold is expressed in our currency by 24*s.* 7*d.*, so that if the Mint and Bank cost of converting ten grams of standard gold (·900 fine) into a coin, replacing its wear, is expressed by *5d.*, the value of the ten-gram coin current is 25*s.*, of which it will be the equivalent so long as the customer of the Mint has to send 916 grams of fine gold, or its equivalent in money, for every 10 coins he gets, each containing 9 grams of fine gold.

At the International Conference suggested by the Royal Commission this question of a universal standard of fineness and of seigniorage could be settled; and whatever the decision may be, the change will cause but slight and temporary inconvenience in this country.

3. *Gold Coin.*

England can at once coin the sovereign of 8 grams of standard gold with the slightest possible inconvenience, and without changing its contents of fine gold. The half-sovereign will weigh 4 grams. A gold crown of 2 grams might also be coined.

The only new coin necessarily required is a fine five-crown gold piece of 10 grams, which would probably in time get into circulation as a sort of new guinea, even if it were not at once stamped as the international coin. Large coins are generally more popular than small coins.

Once accepted as the international unit, the 10-gram piece might with advantage become the basis of a decimal money of account for England; the gram of gold, the decigram, and the centigram being the subordinate units, to be represented with some of their multiples in gold, silver, and copper coins. The English standard gold coins under this system are the coin to be called Victoria, or some other name (10 grams), the sovereign (8 grams), the half-sovereign (4 grams), the crown (2 grams); and lower than this it is useless to go, as the coins in gold become too small for use. The sovereign and the half-sovereign in England might ultimately be replaced by the gold Victoria and its half. In France the Napoleon of 20 francs, still circulating, if brought into this system would weigh 6·400 grams; it would in due time be superseded.

4. *Silver Coin.*

Silver coins are said, under the single gold standard, to be counters; there is no restraint on their weight or fineness, and they need not be at first international.

In England the silver coins will represent the same proportions of the gold unit as those now in circulation; but a slight change in weight is required. The silver crown weighs 28·2759 grams ·925 fine, and contains 26·155 grams of fine silver. Now the Mint purchases standard silver at rates ranging from 5*s.* to 5*s.* 2*d.* (say 5*s.* 1*d.*) an ounce of 31·1035 grams; so that if it coined silver without charge, the crown should weigh 30·594, the half-crown 15·297 grams. The half-crown now coined actually weighs 14·138 grams; the difference is the Mint charge (1·159 gram). The fine silver in the half-crown weighs 13·078 grams. By making the half-crown exactly 15 grams and of the same fineness as the five-franc piece, namely, ·900, it will contain 13·500 grams of fine silver; that is, it will weigh more by exactly 0·862 gram than the present half-crown, and it will be better, as half the addition (·422 gram) will be in fine silver. The Mint will still retain under this arrangement 4·59 per cent. of fine silver (one shilling in 21) as the cost of coinage. Then the silver crown will weigh exactly 30 grams, the half-crown 15 grams, the florin 12 grams, the shilling 6 grams, the sixpence 3 grams, the threepenny $1\frac{1}{2}$ gram; and there the silver coinage will stop. Five crowns will contain the same amount of fine silver ($150 \times \cdot 9 = 135$ grams) as six five-franc pieces. A florin will contain nearly the same weight of fine silver (10·80 grams) as the rupee (10·69 grams).

This is only one of the ways in which the object may be obtained of making our silver coins simple multiples of grams of standard silver by varying the fineness. The French have the standard of ·900 fine for their five-franc piece, and the lower standard (·835) for the franc itself and the other silver coins. By making the half-crown of 15 grams ·872 fine, it will contain the same amount of fine silver as it contains at present (13·078 grams), and the Mint will get its present profit. If the silver coin were of the same fineness as the gold, the one gram of gold would, at the average market value, purchase 15·5 grams of silver; but as the expense of coining silver is necessarily greater than the expense of coining gold of the same value, the weight of fine metals in the gold and silver coinage should be in a lower ratio (say 1 to 15), to compensate for the difference in the cost of production.

5. *Bronze Coin.*

The silver threepenny piece represents a decigram of gold, and is the equivalent of 12 farthings of the present currency. The centigram of gold is the lowest unit of value recognized in the new system of account, and it may for the sake of brevity be called a *cent.* The United States' cent is their lowest unit; it is worth nearly two English farthings, and is too large to express the graduated prices of articles of small value. The French centime, on the other hand, is too small a unit for general use in Europe; it is the fifth part of the lowest American unit, and only $\frac{2}{5} = \cdot 4$ of our present farthing. Now the value of the centigram of gold is the mean between the value of the American cent (2 farthings) and the French centime (0·4 farthing)$= \frac{2\cdot 0 + 0\cdot 4}{2} = \frac{2\cdot 4}{2} = 1\cdot 2$ farthing $= 1$ centigram of gold. This *cent* is a convenient low unit, and is admirably suited to use all over the civilized world.

The small centigrams of gold will be represented by bronze coin. The value of the copper coin was formerly expressed in the weight of metal, but this is no longer the case; the bronze in the English penny is worth about a farthing. The three coins in use are convenient counters; and the farthing and halfpenny are usually in accounts written as $\frac{1}{2}$ or $\frac{1}{4}$ of a penny. The ten-cent piece, now in use as a threepenny silver coin, will be conveniently supplemented by bronze coins of 1, 2, 3, 4, and 5 cents; the 5 cents being the half of the silver 10-cent piece would correspond to three halfpence of the present currency. The *cent* will supply a better graduated scale to express prices than the farthing, halfpenny, and penny, and popular demand will soon determine how many of each coin should be struck. Bronze coins of three sizes are now unnecessary, as no attempt is made to express value by weight. One type of coin, inscribed with one cent, two cents, three cents, four cents, and five cents, may suffice. They will form part of the decimalized currency. I annex a scheme of the coins.

6. *Coins and their Signs.*

The money of account it will be borne in mind is, on the new system, in standard gold, and runs thus:—

STANDARD GOLD UNITS OF ACCOUNT.

Signs	∀	*g*	*d*	*c*
VICTORIA	1 decagram =	10 grams =	100 decigrams =	1000 centigrams.
HALF-CROWN ...... (or Guilder)		1 gram =	10 decigrams =	100 centigrams.
THREEPENNY ...... (or Denarius)			1 decigram =	10 centigrams.
CENT			=	1 centigram.

Every one of these four weights of gold may be employed as a measuring-unit.

Call, after the analogy of "Guinea," the prime unit or decagram a *Victoria*, as it is the name of a principal gold-field; then, where large units are required, ∀11·875 will be read = 11 Victorias, 875 centigrams or cents; or ∀11. 8, 75 = 11 Victorias, 8 grams, 75 centigrams; and where a smaller unit is preferred, 118 grams (half-crowns), 75 centigrams or cents. For smaller sums cents alone suffice; for instance, we may say the price of a loaf of bread is 22 *cents,* of a pound of beef 30 *cents.*

Although the coined shilling only consists of eleven-pennyworth of silver, it exactly represents in an account *twelve pence*, or the 20th part of a gold sovereign; and a penny, consisting of a farthing's worth of bronze, represents the value of the 240th part of a sovereign. So, under the gram system, half-a-crown in silver, weighing 15 grams, represents *one* gram of standard gold; a threepenny piece (10 cents) represents the tenth of a gram, or a *decigram* of gold; a bronze cent represents a *centigram* of gold. Value is invariably expressed in weights of standard gold, which are conveniently represented in tangible manageable silver and bronze tokens.

The coins may be thus described: the four fundamental units are printed in SMALL CAPITAL letters:

Standard Gold:—

VICTORIA	Weighing	10 grams (a new coin).	
Sovereign	"	8 grams	Existing coins to remain in circulation for a time.
Half-sovereign ..	"	4 grams	
Crown	"	2 grams (a new coin).	

Standard Silver existing coins to remain in circulation, and to be gradually replaced:

			grams of gold.
Crown	Weighing	30 grams	worth 2·00
HALF-CROWN	"	15 grams	" 1·00
Florin	"	12 grams	" 0·80
Shilling	"	6 grams	" ·40
Sixpence	"	3 grams	" ·20
THREEPENNY	"	1·5 gram	" ·10

Bronze Coins:—				gram of gold.
5 cents	One type of coin with inscribed values. It is like paper money, into which intrinsic value of material does not enter.	(V.)	Weighing 10 grams	worth ·05
4 cents		(IV.)		„ ·04
3 cents		(III.)		„ ·03
2 cents		(II.)		„ ·02
1 CENT		(I.)		„ ·01
½ cent		(½.)		„ ·005

(For a time the penny, halfpenny, and farthing to be utilized.)

7. *Economies of a great Gold Coin.*

One kilogram of standard gold is now coined into 125 sovereigns*, and into 155 Napoleons. Under the ten-gram system it will be coined into 100 Victorias. (1) The expense of coining 100 pieces is less than the expense of coining 125 or 155 pieces. (2) The new coin is easily weighed wherever metrical weights are in use, as it is a round number of grams. (3) The surface of the large coins being less for the equal weight the wear is less. (4) The size is convenient, and the trouble of counting the coins is diminished. (5) The figures in accounts are fewer, and the arithmetical labour is diminished. (6) Large sums are readily comprehended by the mind when expressed in large units. (7) The half-sovereign is convenient in some cases; but to make it the largest coin of account would, for some of the reasons assigned above, be inexpedient. The inexpediency of a ten-franc unit is still more striking. The ten-franc gold unit is on many grounds preferable to the gold franc unit, as Mr. Graham pointed out; but the coin in proportion to value would cost three times as much as the decagram, it would last half as long, and would weigh 3·2258 grams†. The unit of value would not be a unit of weight, it would be 3·2258 grams of the French standard gold. This is a fatal objection to the ten-franc unit as the scientific basis of a permanent system of money.

Silver coin contrasts in all these respects unfavourably with gold coin wherever large sums are in question. (1) To represent the same value as 100 ten-gram pieces of gold weighing a kilogram, about 15½ kilograms of silver are required; more by 6 lbs. than a quarter of a hundredweight. To weigh it in scales is a task. Silver is about 29 times as bulky as gold of the same value. Its coinage in France is three or four times as costly. (2) It is less easily carried, kept, concealed in dangerous places and times. (3) The silver worth 100 ten-gram gold pieces in France is coined into 620 five-franc pieces, and in the same proportion the trouble of coining, counting, and manipulating is multiplied. (4) The silver dollar is subject to similar objections; and (5) inasmuch as many figures increase labour, confuse thought, and increase chances of error, the 3100 francs corresponding to 100 ten-gram gold pieces are five times more objectionable than the dollar as the largest coin of account. The franc at one time suited the small transactions of the French peasantry, and the big five-franc piece satisfied their eye, but large gold units are required now to measure the accumulating revenues and fortunes of the French people. Of all the primary monetary units in use in Europe the franc is the least, and on that account the worst.

Silver coin should therefore among the civilized nations of Europe and America be reduced to its place as a convenient representative unit, and in all the countries which like England enjoy the single gold standard, the quantity of silver in silver coin is to a certain extent arbitrary.

But silver is still the standard in several countries; in India, in China, in Germany, in Holland, and in other nations with which England has very large commercial transactions, it constitutes nearly the whole of the coined currency. Silver has frequently to be transmitted to those countries; the Bank of England has also power to issue its notes against silver bullion; it is therefore of importance to maintain our silver currency as much as possible in harmony with the currency in which silver is the standard wholly or partly. This condition is met by coining silver

* Exactly 125·1846.

† According to the Master of the Mint the cost of making a sovereign is now 3 farthings, and it falls by wear below the legal weight in 18 years; two half-sovereigns cost 6 farthings, and fall below their legal weight in 10 years.—*Return to Order of House of Commons, dated 28th June 1869.*

·900 fine, and by coining the half-crown of 15 grams standard silver, as then 5 crowns will contain the same amount of fine silver as 6 five-franc pieces. The shilling containing six grams of silver, the franc, if of the same fineness, will contain five grams of silver. The silver rupee of India and the silver dollar admit of easy adjustments.

8. *Economies of Decimal Coinage.*

Several units of weight are required, and when the Roman notation was in use the advantages of connecting these units by the factor ten were not clear. It was accordingly never done in England. In troy weight four units are recognized, the grain, the pennyweight, the ounce, and the pound; 24 grains make one pennyweight, 20 pennyweights one ounce, 12 ounces one pound. The money units are based on these weights; 240 pennyweights of silver were a pound, and were so called, *libra*, the origin of our £1. The pound sterling and the penny fell in evil days to a third of their primary weight, still 12 pence became a shilling, 20 shillings = 240 pence = £1. Then the penny was halved and quartered, so there are four money units in use. connected by the factors 20, 12, and 4; thus £1 = 20 shillings = 240 pence = 960 farthings. The clumsy Roman notation was discarded and was displaced by the beautiful Arabic notation, where each figure in a series is ten more, or a tenth less than the same figure to its right or left; hence all the transcendent achievements of modern arithmetic. Unfortunately our money as well as weight and measure units remained unaltered, and all are now in a state so chaotic as to reflect disgrace on the intelligence of England. To perform a simple sum in compound multiplication or division is beyond the powers of ninety-nine in a hundred educated men, who, on leaving school, forget the tables which have perplexed, wearied, and wasted so many of their hours.

It is difficult to estimate the economy of time and thought through the whole of life to be realized by the substitution of units decimally related to each other in the place of the units now in use.

France, Spain, Portugal, Holland, Belgium, Switzerland, Italy, Austria, Russia, Greece, Sweden, Turkey, China, Japan, and the United States of America, have all decimal moneys of account, and England would probably have already enjoyed this inestimable advantage had it not been for the difficulties of dealing with the penny. The penny is the rock on which the late project of decimalization split. The phantom of a duodecimal notation in arithmetic deceived nobody. The price of a great number of articles is measured by the penny. Thus the price of 4 lbs. of bread is $6\frac{1}{2}d.$; mutton is $9\frac{1}{2}d.$, beef $10d.$ a pound. In all such instances the price in gold units can be expressed with great accuracy; and a slight variation of price could give rise to no inconvenience, for the prices are perpetually fluctuating; as they are regulated by supply and demand, prices could be more accurately adjusted and expressed in cents than in pence. The price of 4 lbs. of bread is $6\frac{1}{2}d.$, but what is the price of 1 lb.? That is not easily expressed. Certain articles are so constantly associated with the penny as their price that this coin is looked upon almost as an English institution. There is, for instance, the penny toll of some bridges, the penny postage, and the penny newspaper, to say nothing of many other penny articles. The price is thus expressed because the penny coin exists, just as prices in America are expressed in cents.

9. *Economies of International Coinage.*

The value of money is, like the value of all other commodities, local: 100 pieces of gold in England may purchase a bill to entitle its owner to receive 101 or 100 pieces of the same coin in Australia. The rate of exchange where the same coins are in use is thus expressed in the simplest manner possible. The recognition of one gold coin as the international medium of exchange gives all the contracting countries the same simple *par*. But it is different where the money units are not the same; there the calculations grow so intricate as to be unintelligible to the public, and to be troublesome even to adepts. Many examples may be cited from the pages of Mr. Tait.

Traders, if trade prices of commodities are quoted in international money and measures, will have no difficulty in perceiving at a glance the state of the markets, and the currents of trade.

Travellers with international money will sustain less loss, and less discomfort than they now encounter abroad.

The relations between man and man will thus be enlarged and multiplied in indefinite proportions, when all things are measured, weighed, bought, and sold by the same units.

10. *The 25-franc and the 25-shilling gold unit**.

All the advantages of the decimal notation can be enjoyed under a gold unit of either of these values; but to be scientific, symmetric, international, the 25-franc coin and the sovereign must consist of exactly 8 grams of gold of the same fineness, coined under the same conditions of seigniorage. Then the after-passage from an 8-gram unit to the use of a 10-gram unit will be easy, and will end in a complete identification of decimal money units with metric weights of gold, as everlasting as the basis of the metric system. The inconvenience of the change will be real and transitory, but the benefit to mankind will be perpetual. By a slight sacrifice the present generation will earn the gratitude of posterity, while it will be more than repaid for its pains in the course of two or three years of its own existence.

In the metric measures, weights, and money, the trade of the world will enjoy perfect instruments, facilitating the exchange of commodities as much as the steam-engine accelerates their carriage.

On our National Accounts. By Frank P. Fellowes, *F.S.A., F.S.S.*

The paper, after detailing the steps that were being taken to carry out the recommendations of Mr. Seely's Committee on Admiralty Moneys and Accounts, advocated the adoption of similar methods for other departments of Government. These may be briefly described as having for their object, amongst other reforms, the unification of all accounts having any relation to the Admiralty expenditure. This paper pointed out that with the Admiralty, as with several other departments, there were three great classes of accounts. First, the estimates of money required for the service of each department in the ensuing year. These estimates are voted by the House of Commons in Committee of Supply, and they are divided as below:—Army Estimates, Navy Estimates, Civil Service Estimates (which are divided into seven great classes or subdivisions, called Class I. to VII.), and the revenue departments, being Inland Revenue, Customs, Post-office, and Post-office Packet Service. The second series of accounts are the "Appropriation Accounts," which give the money each department has received from the Treasury as contradistinguished from the money voted by the House of Commons, or, in other words, the money the Treasury has been authorized by Parliament to expend on the special services for which it was voted. These second series follow the order and form of the estimates, and give in one column the money voted, and in the other the money *expended*, so called, but, strictly speaking, this is only the money each department has received from the Treasury, and it may not follow that all this has been expended. The third series of accounts are accounts published by the various departments, giving detailed accounts of the expenditure or of parts thereof, and these the author gave the generic term of Departmental Expense Accounts. This paper pointed out that one of the great objects of the scheme of accounts devised by Mr. Seely and Mr. Fellowes, which scheme is now being introduced into the Admiralty, was the unification of these three series of accounts, and the paper advocated this for the accounts of other departments. By these means the Admiralty estimates, though remaining in the same form as at present, so far as the order and method in which the House of Commons voted the supplies, would be so retabulated and rearranged, that in addition to showing, as now, the salaries it was intended to vote, the wages, the stores proposed to be purchased, there would be given the amount of wages required for shipbuilding and maintaining, salaries required for superintendence and stores for this purpose, so that, in short, the House would have before them the whole amount of the navy estimates, in divisions, as follows:—Division 1, for naval yards, for shipbuilding, repairing, and main-

* "Taking it altogether, the *shilling* is much more frequently and numerously represented in other coinages than the *franc*."—Bullion and Foreign Exchanges. By Ernest Seyd, page 690, where he cites several examples.

taining, then the amounts of Division 1 required for each dockyard, as A, Deptford; B, Sheerness; C, Portsmouth; D, Devonport; E, Pembroke; F, Chatham, and so on: Division 2, Victualling the Navy; then follow the amounts for each Victualling-yard: Division 3, Medical; and so on, till the whole amount of the estimates was incorporated in these and other divisions. The appropriation accounts (series 2) would give the same divisions, and would show the money expended, so called, as distinguished from the money voted, so that the appropriation accounts would be the debtor side to the final expense accounts of—1, the cost of building, repairing, and maintaining the fleet; 2, the cost of victualling, and so on, so that all these accounts would be parts of one great whole system. A similar retabulation was advocated for other departments, where practicable, so that we might have one great account. The author also maintained that the nation ought to know the whole value of the Governmental property of every description, land, buildings, machinery, stock of every description, and that the increase or decrease should be shown by each department at the end of the year. The author recognized the labours of Sir John Bowring, Sir H. Parnell, Mr. Childers, and Mr. Stansfeld in improving our accounts, and urged that it was of national importance that a thoroughly good scheme should be introduced to give the House a greater check on expenditure.

On the Maintenance of Schools in Rural Districts. By the Rev. Canon Girdlestone.

The writer alluded to a general expectation that next session some measure of direct or indirect compulsion, as regards the education of the children of agricultural labourers, would be proposed, and meet with general approval. Out of 14,877 parishes in England and Wales the Committee of Council report that there are only 7406 which have aided schools; that of the remainder 2779 have schools built with State aid, but not fulfilling the conditions of annual State aid, and described, after inspection, as generally more or less inefficient; while, with regard to 4692 parishes, nothing whatever is officially known, though there is reason for supposing that in some of them there are good schools, in many more schools of various degrees of inefficiency, and, in not a few, no schools at all. Canon Girdlestone proceeded to explain the cause of this deficiency of good schools. Most men agreed that the difficulty consists, not in the one great but isolated effort involved in the first building of a school, but in the continuous effort involved in the annual maintenance of it. Canon Girdlestone stated that there can never be any guarantee for there being an efficient school within easy access of every labourer until the land is made to do its duty. He recommended that the children should continue to pay a penny a week, as now, thus avoiding the risk and evil of education becoming a pauperizing dole; that the State grant should be distributed as now; that in every parish or district in which there are not at the present time existing school-buildings in all respects satisfying the requirements of the State, such buildings should be immediately erected with money borrowed wholly on the parochial rates, and to be repaid, like loans from Queen Anne's Bounty for parsonages, by equal instalments in thirty years, or partly in this way and partly by a tax on the land. That Denison's Act should be made compulsory, and so throw upon occupiers of land the charge of educating in the parochial school the children of all receiving outdoor relief—a process which would at one and the same time bring hundreds of idle children under education and increase the funds of the school. And, lastly, that all that portion of school expenses which is now defrayed by voluntary contributions should be satisfied by a tax or rate upon the land. As regarded Devonshire, Canon Girdlestone said that there are aided schools in little more than one-third of the parishes in that county, and there was much reason to fear that in many of the remaining two-thirds the schools were chiefly inefficient, and that in some there were none at all—a state of things which contrasted unfavourably with the condition of the country at large, bad even as that was.

On the Decline of Shipbuilding on the Thames. By John Glover.

On the Economic Progress of New Zealand. *By* ARCHIBALD HAMILTON.

After alluding to the circumstances under which the colony was founded in 1840 (representative institutions granted in 1852, and the control of native affairs handed over to the colonists in 1863), the progress of the colony was exhibited in statistical tables, from which the following are selections:—

From Commercial Returns.

Year.	Imports.			Exports.		
	North.	South.	Total.	North.	South.	Total.
	£	£	£	£	£	£
1853 ...	451,400	146,400	597,800	264,900	38,400	303,300
1858 ...	661,700	479,600	1,141,300	217,500	240,500	458,000
1861 ...	937,400	1,556,400	2,493,800	212,500	1,157,700	1,370,200
1864 ...	2,845,900	4,154,700	7,000,600	638,200	2,763,500	3,401,700
1866 ...	2,003,300	3,891,600	5,894,900	515,600	4,004,500	4,520,100
1867 ...	1,469,200	3,875,400	5,344,600	570,700	4,074,000	4,644,700

From Agricultural and Pastoral Returns.

Year.	Acres Fenced.			Sheep.		
	North.	South.	Total.	North.	South.	Total.
1851 ...	26,800	13,800	40,600	77,800	155,200	233,000
1858 ...	148,100	87,400	235,500	230,800	1,292,500	1,523,300
1861 ...	230,600	179,200	409,800	638,800	2,122,800	2,761,600
1864 ...	330,300	742,100	1,072,400	1,034,100	3,903,200	4,937,300
1867 ...	740,200	2,715,400	3,455,600	1,787,700	6,630,900	8,418,600

Year.	Cattle.			Horses.		
	North.	South.	Total.	North.	South.	Total.
1851 ...	23,700	11,100	34,800	1,900	1,000	2,900
1858 ...	71,600	65,600	137,200	7,500	7,400	14,900
1861 ...	96,300	97,000	193,300	12,800	15,500	28,300
1864 ...	110,300	139,500	249,800	18,300	31,100	49,400
1867 ...	124,500	188,300	312,800	25,500	40,200	65,700

The total exports of gold from 1857 to December 1867 amounted to £14,500,000; for the year 1867, £2,700,000.

The Revenue of the colony stood as follows:—

Year.	North Island only.			Whole Colony.			
	Ordinary.	Territorial.	Total.	Ordinary.	Territorial.	Incidental.	Total.
	£	£	£	£	£	£	£
1853...	64,000	53,000	117,000	80,000	67,000	3,000	150,000
1858...	116·000	50,000	166,000	179,000	162,000	1,000	342,000
1861...	156,000	75,000	231,000	324,000	347,000	20,000	691,000
1864...	306,000	80,000	386,000	816,000	715,000	78,000	1,609,000
1866...	378,000	62,000	440,000	1,086,000	776,000	116,000	1,978,000
1867...	376,000	51,000	427,000	1,226,000	562,000	77,000	1,865,000

And the expenditure for 1862, £1,100,000; 1863, 1,750,000; 1864, £1,860,000; 1865, £2,900,000; 1866, £3,300,000. Ordinary taxation amounted to £5 12*s.* per head of European population; the colonial debt to £3,500,000, with an annual charge of 21*s.* 2*d.* per head.

The population by Census 1867 stood thus:—

Europeans.	Males.	Females.	Children, 15 and under.	Total.
North Island	28,856	19,179	31,878	79,913
South Island	62,728	28,720	47,307	138,755
Total	91,584	47,899	79,185	218,668

Natives.	Males.	Females.	Children, 14 and under.	Total.
1848, estimated	......	......	......	100,000
1858, estimated	31,667	24,303	......	56,049
1867, estimated	15,432	12,780	10,323	38,535

giving the following proportions:—

	Men.	Women.	Boys.	Girls.
Proportion of natives per 1000	433	326	137	104
Proportion of Europeans per 1000	420	215	184	181

The number of emigrants to New Zealand from the United Kingdom has been 111,306.

The remarkable progress attained during the thirty years of its existence is a mere indication of the great natural resources of New Zealand.

After discussing the importance of preserving our Colonies chiefly on economic grounds, the author went on to discuss the general principles which should regulate the policy of the Imperial Government towards the colonies, and applied those principles to the case of New Zealand; contending that we are under engagements to the natives as well as the colonists, and showed that in the North Island, where alone the natives are formidable, the comparative strength of the two races may be estimated thus:—

		Males.
Native Adults in North Island		15,000
Deduct for aged men, regard being had to the services rendered by their women		1,000
Effective Warriors		14,000
European Adults in North Island		28,856
Deduct, above 40 years of age	7656	
Deduct, unfit for service and likely to leave	7000	
		14,656
Capable of bearing arms		14,200

It would neither be consistent with sound policy, good faith, or humanity, to abandon the inhabitants of the North Island to a war of races, ending in the extermination of the Maories.

An Account of the System of Local Taxation in Ireland.
By W. Neilson Hancock, *LL.D.*

The salient difference between the English and Irish systems is found in the Poor-rates. In England Poor-rates are of ancient origin; there was no

Poor-law in Ireland till 1838. The parish vestry was found a convenient organization in England, and a number of other rates, for purposes unconnected with the relief of the poor, are therefore assessed and collected with the Poor-rate. In Ireland, the parish vestry did not exist as a financial committee, and Church-rates were abolished in 1833. A distinct machinery is therefore found in Ireland for the collection of each separate tax.

Grand-Jury Cess is the most important and most ancient local tax in Ireland. Its purposes, generally speaking, correspond to those of the County-rate, Hundred-rate, Police-rate, &c. in England. In the earliest attempts to raise a County-rate in Ireland the machinery of the parish was resorted to (11 & 12 Jac. I. c. 7), but the later enactment (10 Car. I. c. 26. sec. 2) authorized the justices of the county to make the rate with the assent of the Grand Jury. This rate was substantially a copy of the English Act of 22 Hen. VIII., with the exception of the provision requiring the assent of the Grand Jury. This provision was the point of departure from which the systems subsequently diverged. In 1836, Presentment Sessions were created as a check on the grand jury. A Session is held for each barony (a district about the size of a hundred in England), composed of the magistrates of the county and a number of cess-payers chosen by ballot. Presentments must be passed by the Session before they are submitted to the Grand Jury.

The late Committee of the House of Commons (1868) on the Grand Jury Presentments, considered the propriety of substituting elective Baronial and County Boards for the Sessions and Grand Jury. But they have recommended the continuance of the present system with modifications, which would make the Sessions more representative of the general body of cess-payers.

Grand-Jury Cess is applied to the purposes for which County-rate, Hundred-rate, and Police-rate are applied in England. It also contributes to the support of fever hospitals, lunatic asylums, and reformatories, and pays the cost of witnesses for the Crown. Some of these charities would appear more properly payable out of the Poor-rate, but they were established when there was no Poor-rate in Ireland. The Committee on Grand Jury Presentments have recommended that compensation for malicious injury (corresponding to the Hundred-rate) should be limited in amount to £100, and that the holding of the injured person should be exempt from contribution. The charge of the Police or Grand-Jury Cess is now confined to the cost of extra police in disturbed districts. The cost of the Irish constabulary is paid out of the Consolidated Fund since 1847; a boon given to Ireland as compensation for loss which it was expected would be sustained by the abolition of the Corn Laws. As to its incidence, Grand-Jury Cess is divisible into two parts, one for general objects levied off the county, and one for objects of a more local character levied off the barony. It is assessed, applotted, levied, and collected by the Grand Jury and their officers, and is in every way distinct from all other taxes. It is a first charge on the land and hereditaments, and not, like the Poor-rate, assessed on the occupiers. The tax is, however, payable by the occupier, and by him only, as the landlord pays no portion of it, unless he occupies the premises. The Committee of the House of Commons have recommended that in future the payment of Grand-Jury Cess should be divided between the owners and occupiers of land.

Until 1838 there was no Poor-law in Ireland. The Irish Poor-law may be generally described as fettering its administrators more as to general outdoor relief, and less as to medical relief, than the English Poor-law. It is payable by the landlord and the occupier in equal portions. The electoral divisions of the Irish Union correspond in size to the average English parish, and forms an independent district for the purposes of assessment of the rate. Union rating, now introduced into England, was the principle of the original Irish Bill, but the House of Lords substituted electoral rating.

The Acts for the government of towns are similar to the English Acts for the same purpose, but, in respect of many provisions, are considerably behind them. Two important steps towards consolidation have lately been made in Ireland. In the counties of the cities of Dublin, Limerick, and Cork, the powers of Grand Juries of the city taxation have been transferred to the Corporations, and the important town of Belfast has been separated from the counties of Antrim and Down, and a like transfer has been effected. Also in Dublin there is now a Collector-General, who collects by quarterly instalments, and in one bulk sum, the entire of those rates for which the citizens are liable.

In Ireland there are four systems of audit of local taxation. The Grand Jury expenditure is audited by the Judge of Assize as to points of law, and by the Receiver Master in Chancery as to matters of account. The Poor-law taxation of £600,000 is audited as to points of law by the Poor-law Commissioners, and as to matters of account by auditors appointed by them. Town Councils and other municipal bodies are under no system of audit as to points of law, such points being only determinable by a Chancery suit, as in the case of Belfast. The only audit of municipal accounts is performed by auditors selected by the ratepayers and Town Council or Commissioners. The audit best adapted for municipal accounts would be a combination of the Poor-law and Grand Jury systems. As to the question of the legality of the rate or expenditure, the best audit is that enjoyed by the Grand Jury accounts, viz. by the Judge of Assize in the case of Assize towns, or of the County Courts in other cases. As to the final audit, the Committee recommend the Poor-law system.

The valuation for all local rates levied in Ireland is the same, and amounted, in 1865, to £12,986,026, giving for Grand-Jury Cess an average of 1*s.* 7½*d.* in the pound, and Poor-rate 1*s.* 1½*d.*, which make a total average of 2*s.* 9½*d.* The average town rate is about 2*s.* 1*d.* in the pound.

On the Examination Subjects for Admission into the College for Women at Hitchin. By J. Heywood, *F.R.S.*

This institution is designed to hold in relation to girls' schools and home teaching a position analogous to that occupied by the universities towards the public schools for boys. It is proposed to raise the sum required for building and preliminary expenses by public subscription and by the sale of a limited number of presentations. The building had been provided, the students' fees will be fixed on such a scale as to secure that the institution shall be self-supporting. At an examination held at the University of London in July last, twelve ladies out of seventeen passed; and the College will be opened, under the direction of Mrs. Manning, on October 16th next. The whole course will occupy three years. There will be three terms a year; the charge for board, lodging, and instruction will be £35 per term, paid in advance. Efforts will be made to obtain for the students admission to the examination for degrees of the University of Cambridge, and generally to place the College in connexion with that University. Religious instruction and services are in accordance with the principles of the Church of England, but the attendance of students to them is not enforced.

On Municipal Government for Canadian Indian Reserves. By James Heywood, *F.R.S., F.G.S., F.S.A.*

Remarks on the Need of Science for the Development of Agriculture. By James Hunt Holley.

On the Economic Condition of the Agricultural Labourer in England. By Professor Leone Levi, *F.S.A., F.S.S.*

On Agricultural Economics and Wages. By Professor Leone Levi, *F.S.A., F.S.S.*

On Naval Finance. *By* R. MAIN (*of the Admiralty*).

The object of this paper was to show how the cost of the Navy had increased in the last twenty years. During the last twenty years the naval system of this country had undergone no great change, though considerable changes had been introduced both into the construction of men-of-war and the manning of the Navy. These changes had greatly increased naval expenditure; but, in addition, the Navy was much larger now than it was twenty years ago. In that period a Naval Reserve had been added, a Channel squadron maintained, the Coast-guard transferred from the Customs to the Navy, and the force of men kept in permanent reserve at the different ports, to man ships immediately they were commissioned, considerably increased. These additions to the material strength of the Navy amounted alone to nearly two millions sterling; and by cutting any of them off, a great reduction could certainly be effected. But these additions had been made at the express demand of the country, to meet needs which existed as much now as twenty years ago. Then several alterations, of an expensive character, had been made, which had increased the cost of the Navy, since 1849, by about £1,700,000. These were the increase of pay to nearly every class of officers and seamen, which had been carried to such an extent that every officer cost, on an average, about £60 a year more than in 1849, and every seaman more than £10. Food was dearer now than then, and was better in quality, and more liberally bestowed; so that, while the average cost of each man for provisions, &c. was £14 10*s.* in 1849, it was now £18. In addition to these expensive alterations were the improvements in the dockyards and in administration generally. It was difficult to see how any very extensive reductions could be made in this branch of expenditure unless the Navy was reduced to a much smaller size than it was twenty years ago. It is, however, in this branch that the present reductions have been chiefly carried out; but it has required a public spirit and determination of no ordinary character in the present Board of Admiralty to effect here a reduction of even £100,000. Lastly, the increased use of steam in the Navy and the substitution of iron for wooden men-of-war have increased the cost of the Navy now as compared with 1849 by £800,000. Thus, altogether, the increased cost of the Navy in 1868 as compared with 1849, which is about four millions and a half sterling, has been accounted for.

On Assisted Emigration. *By* Dr. R. J. MANN, *F.R.A.S., F.R.G.S.*

The object of this paper was to show that the most promising course in organizing a system of assisted emigration is to provide suitable grants of land in the colonies for selected and well-qualified emigrants, and to give them advances of such means as may be found indispensable to secure them a start in getting a living by the cultivation of their grants, requiring them to repay such sums within a fixed period by easy annual instalments, and holding their land in security until the repayments have been completed. An instance was adduced in illustration of the practicability of such a system, in which thirty-five German families had been sent out to a colony (the colony of Natal), and settled upon the land. These people were embarked in the year 1847, and were entirely without means; and were nearly all of them weavers, and destitute of the most important knowledge of agricultural operations. Yet when the author of this notice visited their settlement, which he did eighteen years subsequently, he found each family in possession of a valuable little estate of from 150 to 200 acres of land, which had been purchased at the rate of from 15*s.* to 30*s.* an acre, and paid for, and with accumulated property in almost every instance amounting to, and in some instances exceeding, £800. There can be no possible doubt that, under a well-conceived and well-managed system, it would be found that thrifty and industrious English, Scotch, and Irish farm-labourers, initiated in the mysteries of the spade and plough, would be able readily to accomplish, at least, as much as was done in that instance by German weavers not having the same special and technical qualifications. Details were then given to show how a capital of £50,000 might be made available in perpetuity to transport and start 500 families, comprising 2500 individuals, to and in a colony like Natal, and then to add to them fifty other families, comprising 250 individuals, every year. It was shown that such a proceeding would alike benefit the community from which the emigrants were taken, and the colonial community to which they were added; and that it would confer an addition upon the public revenue of the colony, through indirect contributions, of some £45,000 within a period of ten years. It was also pointed out that the colony of Natal was eminently adapted for such a course of action, by the abundance of available land in open pasture ready for the plough, by the mildness of its climate, by the cheapness of the necessaries of life, by the large range of natural productions, stretching through sugar, coffee, tobacco, cotton, silk, horses, cattle, sheep, wool, root-crops, and grain-crops of nearly every variety, and by the abundance and cheapness of native labour.

Statistical Notes on some Experiments in Agriculture. By FREDERICK PURDY, *F.S.S., Principal of the Statistical Department, Poor-Law Board.*

The memoranda of the plan and results, which Mr. Lawes has circulated among his friends, give the issue of upwards of 1400 separate experiments, not experiments that can be quickly performed like the ordinary ones of the laboratory, but experiments each requiring one revolution of the seasons for its answer*. It is beyond my scope to attempt a description of these researches in any detail; at the same time I hope to convey some idea of the extreme importance of Mr. Lawes's achievements, by selecting a few salient examples from each process of cultivation employed by that gentleman.

Permanent-Meadow Land.—The area experimented on was about $6\frac{3}{4}$ acres, divided into 20 plots—with few exceptions, duly noted, the same description of manure has been applied year after year to the same plot. The meadow land chosen "has been probably laid down in grass for some centuries."

The yield of the plots unnoticed here range at various distances between the extreme results selected for comparison below.

Experiments on Permanent Meadow-Land.

	Produce per Acre Weighed as Hay.	
	Average of Thirteen Years, 1856-68.	1868 alone.
	cwt.	cwt.
Plot (11 *a*) dressed with artificial manure, which afforded the *maximum* yield	$64\frac{1}{2}$	$72\frac{1}{4}$
Average of two plots (3 and 12) *unmanured* continuously during the thirteen years	24	$20\frac{3}{4}$
Difference in favour of the manured Plot (11 *a*)	$40\frac{1}{2}$	$51\frac{1}{2}$

Note.—The numbers in brackets after the plots, here and hereafter, refer to the enumeration of the original paper.

Chemistry has taught agriculturalists that their husbandry will not draw from the soil or the atmosphere what is neither in the soil nor in the atmosphere. The corollary of this lesson seem to have determined the operations on Plot No. 18. The ground was annually dressed with a mixture, per acre, equal to the respective quantities of potass, soda, lime, magnesia, phosphoric acid, silica, and nitrogen contained in a ton of hay. The average yield of hay for the four years 1865–68, was $32\frac{1}{4}$ cwt., or 8 cwt. in excess of the two unmanured plots represented in the Table above. In 1868 the yield was $27\frac{1}{2}$ cwt. or $6\frac{3}{4}$ cwt. above the produce of the unmanured plots in the same year—just *one-third* of the chemicals was returned to the cultivator by the surplus hay in this year's trial.

Barley.—The area under experiment was about $4\frac{1}{4}$ acres, divided into 28 plots. The grain sown on the same land year after year, and, for the most part, the same manures used continuously on each plot.

* 'Memoranda of the Plan and Results of the Field Experiments conducted on the Farm of John Bennet Lawes, Esq., at Rothampstead, Herts,' May 1869.

Experiments on the Growth of Barley.

	Produce per Acre. Average of Seventeen Years, 1852–68.		
	Dressed Corn.		Total Straw.
	Bushels.	lbs. each.	cwt.
Plot [(4) 4 AAS] dressed with artificial manure, and affording the *maximum* yield	50½	52¾	33¼
Average of two plots (1 O and 6 I) *unmanured* continuously during the seventeen years	21¾	52¼	12½
Difference in favour of the manured plot	28¾	½	20¾

Wheat.—Area under experiment about 13 acres, made into 26 plots. Wheat sown on the same land, without intermission, for twenty-five years. Nearly the same description of manure on the same plot each year, especially during the last seventeen years, to which term the following experiments were limited:—

Experiments on the Growth of Wheat.

	Produce per Acre. Average of Seventeen Years, 1852–68.		
	Dressed Corn.		Total Straw.
	Bushels.	lbs. each.	cwt.
Plot [16 (*a* and *b*)] dressed with artificial manure, and affording the *maximum* yield	39½	58	46½
Average of two plots (3 and 20) *unmanured* continuously during the seventeen years	14¾	57½	14
Difference in favour of the manured plot	24¾	½	32½

I will conclude this sketch with an abbreviated account of a series of rotation experiments extending over twenty years, 1848–67 inclusively. An area of 2½ acres was divided into three plots, each was sown alike year by year, and in this order of succession:—First year, turnips; second year, barley; third year, beans; fourth year, wheat; the fifth, turnips; again and so on throughout the twenty years. Plot 1 was unmanured continuously. Plot 2 manured with phosphate of lime for the *turnips* only, consequently this was manured once in four years. Plot 3 treated with complex manure (artificial entirely) for the *turnips* only, and therefore once in four years like No. 2.

The average results for the corn and roots are given below; the straw and leaf produce are omitted.

Crops in Rotation.	Corn or Roots Produced on		
	Plot 1. Unmanured continually.	Plot 2. Superphosphate of Lime, for Turnips alone.	Plot 3. Complex Manures, for Turnips only.
1st. Swedish turnips ... cwt.	26½	136¼	242½
2nd. Barley .... bshls.*	41½	30½	44
3rd. Beans .... „ *	12½	12½	21½
4th. Wheat .... „ *	33	30½	35½

* All dressed corn.

On the Pressure of Taxation on Real Property. *By* FREDERICK PURDY, *F.S.S., Principal of the Statistical Department, Poor-Law Board.*

[Printed *in extenso* among the Reports, see p. 57.]

On Weights and Measures. *By* W. H. SANKEY.

Contributions to Vital Statistics. *By* JAMES STARK, *M.D.*

On the Population and Mortality of Bombay, derived from the last Census, and the Reports of the Health Officers of Bombay to the latest dates. *By* P. M. TAIT, *F.S.S., F.R.G.S.*

To Sir Bartle Frere, late Governor of Bombay, and Dr. Leith we are mainly indebted for the census taken in 1864. Bombay is the second city, in point of population, in the British Empire, the numbers being 816,562, or very nearly a million, of whom Brahmins, or professing Brahminical creed, are about 71 per cent.; Mahomedans, 18 per cent.; Zoroastrians, 6 per cent.; Christians, only 3·54 per cent.; Bhuddists, 1 per cent.; and the remainder Jews and other races. There are 185 males to every 100 females, the proportion of the sexes up to the age of 13 being nearly equal. Nearly one-fourth of the whole population are unskilled labourers. Of the Brahmins one-third are beggars, and only 2 per cent. teachers or schoolmasters, while amongst the 50,000 Parsees there is not one beggar or mendicant. Caste appears to have little influence in determining the occupation of the Hindoo population. The proportion of the population born in Europe is only six in every 1000. These figures are necessary to give any solution to the results given in the health officers' reports, which are made up to the end of June 1869. The most remarkable fact in connexion with the mortality of Bombay is, that more than one-half of the total casualties are caused by zymotic diseases of the miasmatic order; that is to say, are consequent on defective drainage, impure water, absence of ventilation, and the unclean habits of the community. In Calcutta the chief scourge is, as a rule, cholera; in Bombay, fever. The sea-water invades certain portions of the island of Bombay, turns some acres into a salt swamp, penetrates into the drains, and thus distributes the effluvium far and wide. The mortality from fever is at the minimum during the monsoon months, when the drains throughout the native town are well scoured by the rains; while the sudden rise in the deaths from smallpox is coincident with the time of the influx of Mahomedan pilgrims to Bombay, for the purposes of the Haj. Upon the whole, Bombay is healthier than Calcutta, so far as the figures in the paper carry us, the deaths in the latter during 1866 having been 47 per 1000, while at Bombay they were only 21 per 1000, and in 1867 19 per 1000. The temperature was referred to: and as to rainfalls, there are 80$\frac{1}{3}$ inches in Bombay to 65$\frac{1}{3}$ in Calcutta. During July 1867 the rainfall at the former place was 37 inches. The paper, which will be published in the Journal of the East Indian Association, concluded by fully recognizing the exertions, under extraordinary difficulties, of Mr. Crawford, the municipal commissioner of Bombay, Dr. A. H. Leith, and Dr. T. G. Hewlett, in the interest of sanitary reform, and by declaring that, with an improved conservancy, Bombay could, it is believed, be made as healthy a town for Englishmen to live in as cities of similar size on the continent of Europe.

On the Method of Teaching Physical Science. *By the* Rev. W. TUCKWELL.

The author set forth the leading subjects to be taught, viz.—experimental mechanics, chemistry, systematic botany and physiology. But this last depended on the period to which school education was protracted. The time to be given to science should not be less than three hours a week; at this rate two years might be given to mechanics, two years to chemistry, one year to botany, while the rest, if any remained, would be free for physiology. The author recommended that every school professing to teach science systematically should have a museum; in the playground there should be a botanic garden.

MECHANICAL SCIENCE.

Address by C. William Siemens, *F.R.S., President of the Section.*

In addressing you from this Chair, I feel that I have accepted a task which, however flattering, I should have hesitated to undertake, had I not every reason to rely on your forbearance, and upon the friendly support of those senior members of our profession who by their attendance at these annual gatherings give weight and importance to our proceedings. I also greatly depend on the cooperation of those Members of the British Association who, although devoted chiefly to the cultivation of pure science, are nevertheless ever ready to assist us in our endeavours to apply that science to practical ends.

It is by submitting such subjects as will be brought before us to the double touchstone of science and of practical experience that we shall be able to appreciate real merit, and at the same time assist the authors of the several papers, by a confirmation or rectification of their views; thus redeeming our proceedings from the adherent disadvantage of lack of time to give that full and patient attention which the authors might meet with in bringing their subjects before the purely professional Institutions of Civil Engineers, Mechanical Engineers, or Naval Architects.

In prefacing our proceedings with a few remarks on the leading subjects of the day of special interest to our section, I can scarcely pass over the popular question of technical education.

The Great International Exhibitions proved that, although England still holds her ground as the leading manufacturing country, the nations of the Continent have made great strides to dispute her preeminence in several branches, a result which is generally ascribed to their superior system of technical education. Those desirous of obtaining a clear insight into that system, and the vast scale upon which it is being carried out under Government supervision, cannot do better than read Mr. John Scott Russell's very able volume on this subject: they will no doubt agree with the author in the necessity of energetic steps being taken in this country to promote the work of universal education, although I for one think that objection may fairly be made against the plan of merely imitating the example of our neighbours.

The polytechnic schools of the Continent, not satisfied to impart to the technical student a good knowledge of mathematics and of natural sciences, pretend also to superadd the practical information necessary to constitute them engineers or manufacturers.

This practical information is conveyed to them by professors lacking themselves practical experience, and tends to engender in the students a dogmatical conceit which is likely to stand in the way of originality in the adaptation of new means to new ends in their future career. On this account I should prefer to see a sound "fundamental" education, comprising mathematics, dynamics, chemistry, geology, and physical science, with a sketch only of the technical arts, followed up by professional training such as can only be obtained in the workshop, the office, or the field.

The universal interest evinced throughout the country in the work of education by parliamentary inquiries, by the erection of colleges and professorships, and by the munificence of a leading member of our Section in endowing a hundred scholarships, are proofs that England intends to hold her place also in this question of education amongst the civilized nations; and I am confident that she will accomplish this object in a manner in unison with her practical tendencies and independence of character.

Closely allied to the question of education is that of the system of Letters Patent. A patent is, according to modern views, a contract between the commonwealth and an individual who has discovered a method peculiar to himself of accomplishing a result of general utility. The State, being interested to secure the information and to induce the inventor to put his discovery into execution, grants him the exclusive right of practising it, or of authorizing others to do so, for a limited number of years, in consideration of his making a full and sufficient description of the same. Unfortunately this simple and equitable theory of the patent system is very imperfectly carried out, and is beset with various objectionable practices, which render a patent sometimes an impediment to, rather than a furtherance of, applied science, and sometimes involve the author of an invention in endless legal contentions and disaster, instead of procuring for him the intended reward. These evils are so great and palpable that many persons, including men of undoubted sincerity and sound judgment on most subjects, advocate the entire abolition of the Patent Laws. They argue that the desire to publish the results of our mental labour suffices to ensure to the commonwealth the possession of all new discoveries and inventions, and that justice might be done to meritorious inventors by giving them *national* rewards.

This argument may hold good as regards a scientific discovery, where the labour bestowed is purely mental, and carries with it the pleasurable excitement peculiar to the exercise and advancement of science on the part of the devotee; but a practical invention has to be regarded as the result of a first conception elaborated by experiments, and applied to existing processes in the face of practical difficulties, of prejudice, and of various discouragements, involving also great expenditure of time and money, which no man can well afford to give away; nor can men of merit be expected to advocate their cause before the national tribunal of rewards, where at best only very narrow and imperfect views of the ultimate importance of a new invention would be taken, not to speak of the favouritism to which the doors would be thrown open. Practical men would undoubtedly prefer either to exercise their inventions in secret, where that is possible, or to desist from following up their ideas to the point of their practical realization. If we review the progress of the technical arts of our time, we may trace important practical inventions almost without exception to the Patent Office. In cases where the inventor of a machine, or process, happened to belong to a nation without an efficient patent law, we find that he readily transferred the scene of his activity to the country offering him the greatest encouragement, there to swell the ranks of intelligent workers. Whether we look upon the powerful appliances that fashion shapeless masses of iron and steel into railway wheels or axles, or into the more delicate parts of machiney, whether we look upon the complex machinery in our cotton-factories, our print-works, and paper-mills, or into a Birmingham manufactory, where steel pens, buttons, pins, buckles, screws, pencil-cases, and other objects of general utility are produced by carefully elaborated machinery at an extremely low cost, or whether we look upon our agricultural machinery by which England is enabled to compete without protection against the Russian or Danubian agriculturist, with cheap labour and cheap land to back him, in nearly all cases we find that the machine has been designed and elaborated in its details by a patentee who did not rest satisfied till he had persuaded the manufacturers to adopt the same, and had removed all their real or imaginary objections to the innovation. We also find that the knowledge of its construction reaches the public directly or indirectly through the Patent Office, thus enlarging the basis for further inventive progress.

The greatest illustration of the beneficial working of the Patent Laws was supplied, in my opinion, by James Watt when, just 100 hundred years ago, he patented his invention of a hot working-cylinder and separate steam-engine condenser. After years of contest against those adverse circumstances that beset every important innovation, James Watt, with failing health and scanty means, was only upheld in his struggle by the deep conviction of the ultimate triumph of his cause. This conviction gave him confidence to enlist the cooperation of a second capitalist after the first had failed him, and of asking for an extension of his declining patent.

Without this opportune help Watt could not have succeeded in maturing his invention. He would in all probability have relapsed into the mere instrument-maker, with broken health and broken heart, and the introduction of the steam-engine would not only have been retarded for a generation or two, but its final progress would have been based probably upon the coarser conceptions of Papin, Savory, and Newcomen.

It can easily be shown that the perfect conception of the physical nature of steam, which dwelt, like a Heaven-born inspiration, in Watt's mind, was neither understood by his contemporaries nor by his followers up to very recent times, nor can it be gathered from Watt's imperfect specification. James Watt was not satisfied in excluding the condensing-water from his working-cylinder, and surrounding the same by non-conducting substances, but he placed beween the cylinder and the non-conducting envelope a source of heat in the form of a steam-jacket, filled with steam at a pressure somewhat superior to that of the working steam. His immediate successors not only discarded the steam-jacket, and even condemned it on the superficial plea that the jacket presented a larger and hotter surface for loss by radiation than the cylinder, but expansive working was actually rejected by some of them on the ground that no practical advantage could be obtained by it.

The modern engine, notwithstanding our perfected means of construction, had in fact degenerated in many instances into a virtual steam-meter, constructed apparently with a view of emptying the boiler in the shortest possible space of time.

It is only during the last twenty or thirty years that the subtile action of saturated steam, in condensing upon the sides of the cylinder when under pressure, and of reevaporating when the pressure is relieved towards the end of each stroke, has been again recognized and insisted upon by Le Chatelier and others, who have shown the necessity of a slightly superheated cylinder, in order to realize the expansive force of steam.

The result has been a reduction in the consumption of fuel in our best marine engines from 6 or 8 to below 3 lbs. per gross indicated horse-power.

It is a hopeful circumstance that, during the next Session of Parliament, the whole question of the Patent Laws is likely to be inquired into by a Special Committee, who, it is to be hoped, will act decisively in the general interest, without being influenced by special or professional claims. They will have it in their power to render the Patent Office an educational institution of the highest order.

In viewing the latest achievements of engineering science, two works strike the imagination chiefly by their exceeding magnitude, and by the influence they are likely to exercise upon the traffic of the world. The first of these is the Great Pacific Railway, which, in passing through vast regions hitherto inaccessible to civilized man, and over formidable mountain-chains, joins California with the Atlantic States of the great American Republic. The second is the Suez Shipping Canal, which, notwithstanding adverse prognostications and serious difficulties, will be opened very shortly to the commerce of the world. These works must greatly extend the range of commercial enterprise in the North Pacific and Indian Seas. The new waterway to India will, owing to the difficult navigation of the Red Sea, be in effect only available for ships propelled by steam, and will give a stimulus to that branch of engineering.

Telegraph communication with America has been rendered more secure against interruption by the successful submersion of the French Transatlantic Cable. On the other hand, telegraphic communication with India still remains in a very unsatisfactory condition, owing to imperfect lines and divided administration. To supply a remedy for this public evil, the Indo-European Telegraph Company will shortly open its special lines for Indian correspondence. In Northern Russia the construction of a land line is far advanced to connect St. Petersburgh with the mouth of the Amour River, on completion of which only a submarine link between the Amour and San Francisco will be wanting, to complete the telegraphic girdle round the earth.

With these great highways of speech once established, a network of submarine and aërial wires will soon follow to bind all inhabited portions of our globe together into a closer community of interests, which, if followed up by steam communication by land and by sea, will open out a great and meritorious field for the activity of the civil and the mechanical engineer.

But while great works have to be carried out in distant parts, still more remains to be accomplished nearer home. The railway of to-day has not only taken the place of high roads and canals, for the transmission of goods and passengers between our great centres of industry and population, but is already superseding by-roads leading to places of inferior importance; it competes with the mule in carrying minerals over mountain-passes, and with the omnibus in our great cities. If a river cannot be spanned by a bridge without hindering navigation, a tunnel is forthwith in contemplation; or, if that should not be practicable, the transit of trains is yet accomplished by the establishment of a large steam-ferry.

It is one of the questions of the day to decide by which plan the British Channel should be crossed, to relieve the unfortunate traveller to the Continent of the exceeding discomfort and delay inseparable from the existing most imperfect arrangements. Considering that this question has now been taken up by some of our leading engineers, and is also entertained by the two interested governments, we may look forward to its speedy and satisfactory solution.

So long as the attention of railway engineers was confined to the construction of main lines, it was necessary for them to provide for a heavy traffic and high speeds, and these desiderata are best met by a level permanent way, by easy curves and heavy rails of the strongest possible materials, namely, cast steel; but in extending the system to the corners of the earth, cheapness of construction and maintenance, for a moderate speed and a moderate amount of traffic, become a matter of necessity.

Instead of plunging through hill and mountain, and of crossing and recrossing rivers by a series of monumental works, the modern railway passes in zigzag up the steep incline and conforms to the windings of the narrow gorge; it can only be worked by light rolling-stock of flexible construction, furnished with increased power of adhesion and great brake-power. Yet by the aid of the electric telegraph, in regulating the progress of each train, the number of trains may be so increased as to produce nevertheless a large aggregate of traffic, and it is held by some that even our trunk lines would be worked more advantageously by light rolling-stock.

The brake-power on several of the French and Spanish railways has been greatly increased by an ingenious arrangement conceived by Monsieur Le Chatelier, of applying what has been termed "Contre vapeur" to the engine, converting it for the time being into a pump forcing steam and water into its own boiler. It is difficult to overestimate the beneficial effects likely to result from this invention.

While the extension of communication occupies the attention of perhaps the greater number of our engineers, others are engaged upon weapons of offensive and defensive warfare. We have scarcely recovered our wonder at the terrific destruction dealt by the Armstrong gun, the Whitworth bolt, or the steel barrel consolidated under Krupp's gigantic steam hammer, when we hear of a shield of such solidity and toughness as to bid defiance to them all. A larger gun or a harder bolt by Palliser or Grüson is the successful answer to this challenge, when again defensive plating, of greater tenacity to absorb the power residing in the shot, or of such imposing weight and hardness combined as to resist the projectile absolutely (causing it to be broken up by the force residing within itself) is brought forward.

The ram of war with heavy iron sides, which a few years since was thought the most formidable, as it certainly was the most costly weapon ever devised, is already being superseded by vessels of the "Captain type" as designed by Captain Coles, and carried out by Messrs. Laird Brothers, with turrets (armed with guns by Armstrong of gigantic power) that resist the heaviest firing, both on account of their extraordinary thickness, and of the angular direction in which the shot is likely to strike.

By an ingenious device Captain Moncreiff lowers his gun upon its rocking carriage after firing, and thereby does away with embrasures (the weak places in protecting works), while at the same time he gains the advantage of reloading his gun in comparative safety.

It is presumed that in thus raising formidable engines of offensive and defensive warfare the civilized nations of the earth will pause before putting them into earnest operation; but, if they should do so, it is consolatory to think that they could not work them for long without effecting the total exhaustion of their treasuries, already drained to the utmost in their construction.

While science and mechanical skill combine to produce these wondrous results, the germs of further and still greater achievements are matured in our mechanical workshops, in our forges, and in our metallurgical smelting works; it is there that the materials of construction are prepared, refined, and put into such forms as to render greater and still greater ends attainable. Here a great revolution of our constructive art has been prepared by the production, in large quantities and at moderate cost, of a material of more than twice the strength of iron, which, instead of being fibrous, has its full strength in every direction, and which can be modulated to every degree of ductility, approaching the hardness of the diamond on the one hand, and the proverbial toughness of leather on the other. To call this material cast steel seems to attribute to it brittleness and uncertainty of temper, which, however, are by no means its necessary characteristics. This new material, as prepared for constructive purposes, may indeed be both hard and tough, as is illustrated by the hard steel rope that has so materially contributed to the practical success of steam ploughing.

Machinery-steel has gradually come into use since about 1850, when Krupp of Essen commenced to supply large ingots that were shaped into railway tyres, axles, cannon, &c., by melting steel in halls containing hundreds of melting-crucibles.

The Bessemer process, in dispensing with the process of puddling, and in utilizing the carbon contained in the pig-iron to effect the fusion of the final metal, has given a vast extension to the application of cast steel for railway bars, &c.

This process is limited, however, in its application to superior brands of pig-iron, containing much carbon and no sulphur or phosphorus, which latter impurities are so destructive to the quality of steel. The puddling process will still have to be resorted to, unless the process of decarburization proposed by Mr. Heaton should be able to compete with it, to purify these inferior pig-irons which constitute the bulk of our productions, and the puddled iron cannot be brought to the condition of cast steel except through the process of fusion. This fusion is accomplished successfully in masses of from three to five tons on the open bed of a regenerative gas furnace at the Landore Siemens-Steel Works and at other places. At the same works cast steel is also produced, to a limited extent as yet, from iron ore which, being operated upon in large masses, is reduced to the metallic state and liquified by the aid of a certain proportion of pig metal. The regenerative gas furnace, the application of which to glass-houses, to forges, &c., has made considerable progress, is unquestionably well suited for their operations, because it combines an intensity of heat limited only by the point of fusion of the most refractory material, with extreme mildness of draught and chemical neutrality of flame.

These and other processes of recent origin tend towards the production at a comparatively cheap rate of a very high-class material that must shortly supersede iron for almost all structural purposes. As yet engineers hesitate, and very properly so, to construct their bridges, their vessels, and their rolling-stock of the material produced by these processes, because no exhaustive experiments have been published as yet fixing the limit to which they may safely be loaded in extension, in compression, and in torsion, and because no sufficient information has been obtained regarding the tests by which their quality can best be ascertained.

This great want is in a fair way of being supplied by the experimental researches that have been carried on for some time at Her Majesty's Dockyard at Woolwich under a committee appointed for that purpose by the Institute of Civil Engineers. In the mean time excellent service has been rendered by Mr. Kirkaldy in giving us, in a perfectly reliable manner, the resisting-power and ductility of any sample of material which we wish to submit to his tests.

The results of Mr. Whitworth's experiments, tending to render the hammer and the rolls partly unnecessary, by consolidating cast steel while in a semifluid state, in strong iron moulds, by hydraulic pressure, are looked upon with general interest.

But, assuming that the new material has been reduced to the utmost degree of uniformity and cheapness, and that its limits of strength are fully ascertained, there remains still the task for the civil and mechanical engineer to prepare designs suitable for the development of its peculiar qualities. If, in constructing a girder, for example, a design were to be adopted that had been worked out for iron, and if all the scantlings were simply reduced in the inverse proportion of the absolute and relative strength of the new material as compared with iron, such a girder would assuredly collapse when the test-weight was applied, for the simple reason that the reduced sectional area of each part, in proportion to its length, would be insufficient to give stiffness. You might as well almost take a design for a wooden structure and carry it out in iron by simply reducing the section of each part. The advantages of using the stronger material become most apparent if applied, for instance, to large bridges, where the principal strain upon each part is produced by the weight of the structure itself; for, supposing that the new material can be safely weighted to double the bearing strain of iron, and that the weight of the structure were reduced to one-half accordingly, there would still remain a large excess of available strength, in consequence of the reduced total weight, and this would justify a further reduction of the amount of the material employed. In constructing works in foreign parts, the reduced cost of carriage furnishes also a powerful argument in favour of the stronger material, although its first cost per ton might largely exceed that of iron.

The inquiries of the Royal Coal Commission into the extent and management of our coal-fields appear to be reassuring as regards the danger of their becoming soon exhausted; nevertheless, the importance of economising these precious deposits in the production of steam-power in metallurgical operations and in domestic use can hardly be over-estimated. The calorific power residing in a pound of coal of a given analysis can now be accurately expressed in units of heat, which again are represented by equivalent units of force or of chemical action; therefore, if we ascertain the consumption of coal of a steam-engine or of a furnace employed in metallurgical operations, we are able to tell, by the light of physical science, what proportion of the heat of combustion is utilized and what proportion is lost. Having arrived at this point we can also trace the channels through which loss takes place, and in diminishing these, by judicious improvement, we shall more and more approach those standards of ultimate perfection which we can never reach, but which we should nevertheless keep stedfastly before our eyes. Thus a pound of ordinary coal is capable of producing 12,000 (Fahrenheit) units of heat, which equal 9,240,000 foot-lbs. or units of force, whereas the very best performances of our pumping engines do not exceed the limit of 1,000,000 foot-lbs. of force per pound of coal consumed. In like manner 1 lb. of coal should be capable of heating 33 lbs. of iron to the welding-point (of, say, 3000° Fahrenheit), whereas, in an ordinary furnace, not 2 lbs. of iron are so heated with 1 lb. of coal. These figures serve to show the great field for further improvement that lies yet before us.

Although heat may be said to be the moving principle by which all things in nature are accomplished, an excess of it is not only hurtful to some of our processes, such as brewing, and destructive to our nutriments, but to those living in hot climates, or sitting in crowded rooms, an excess of temperature is fully as great a source of discomfort as excessive cold can be. Why then, may I ask, should we not resort largely to refrigeration in summer as well as to calorification in winter, if it can be shown that the one can be done at nearly the same cost as the other? So long as we rely for refrigeration upon our ice-cellars, or upon importation of ice from distant parts, we shall have to look upon it as a costly luxury only; but by the use of properly constructed machines, it will be possible, I believe, to produce refrigeration at an extremely moderate expenditure of fuel and labour. A machine has already been constructed capable of producing 9 lbs. of ice (or its equivalent) for 1 lb. of coal, whereas the equivalent values of positive heat developed in the combustion of 1 lb. of coal and of negative heat residing in 1 lb. of ice is about as 12,000 to 170, or as 1 to 70. This result already justifies the employment of refrigerating machines upon a large scale; but it is hard to say what practical results may yet be reached with an improved machine on strictly dynamical principles, because such a machine seems not to be tied in its results to any definite theoretical limits. In changing, for example, a pound of water from liquid into the gaseous state, a given number of units of heat are required, that may be produced by the combustion of coal or by the expenditure of force; but in changing the same pound of water into ice, heat is not lost but gained in the operation, which heat must be traceable to another part of the machine, either as sensible heat or as developed force. It would lead me too far to enter here into particulars on this question, which is one not without interest for the physicist and the mechanical engineer.

There are several other subjects I should have gladly mentioned were I not afraid of encroaching unduly upon our time; some of these will, however, be brought before the Section in the form of distinct papers, and will, I trust, lead to interesting discussions.

Description of a proposed Cast-iron Tube for carrying a Railway across the Channel between the Coasts of England and France. By JOHN FREDERIC BATEMAN, *F.R.S., M.Inst.C.E., and* JULIAN JOHN RÈVY, *M.Inst.C.E., Vienna.*

The advantages which would accrue from a continuous railway communication between England and France are great beyond any possibility of estimate.

From time to time various proposals for effecting this object have been before the public—by a tunnel to be driven beneath the bed of the sea, through the chalk, which is supposed to be continuous—by submerged roadways and tubes—by large ferry-boats carrying trains on board—and by bridges to be carried on piers formed on islands to be sunk in the Straits. To the latter proposition there are so many obvious objections, that it is hardly necessary to discuss its practicability.

A large ferry-boat, of great length and breadth, large enough to receive a whole ordinary train on board, and driven at high speed by powerful engines, would unquestionably be a material improvement upon the present miserable means of conveyance. Such boats cannot, however, be employed, except by the construction of special harbours on each coast, which would be works of difficulty and expense. However successfully such a scheme might be worked out, the annoyance attending a sea-passage in rough weather, although mitigated, would not be removed; and it would frequently occur in the course of the year that the traffic would be interrupted by fogs and bad weather. Under any circumstances ferry-boats across the channel would be very far from a complete and perfect railway communication.

With reference to a tunnel, it has been proposed to drive one of ordinary size for a double line of railway, which shall descend by a gradient of 1 in 60 on each side of the channel to a depth of about 270 feet below the bed of the sea. The total length of the tunnel would be thirty miles, of which twenty-two would be beneath the sea.

The uncertainty of the strata in the bed of the channel, and the dangers to which any tunnelling operations for some twenty miles under the sea would be subject in the event of meeting with open stratification or dislocated material, are such as would in all probability deter capitalists from entering on so hazardous an enterprise, and would baffle and overpower both engineering skill and all mechanical appliances. Still the project of a tunnel is entertained and advocated by engineers of great standing and reputation, and must only be discarded on a better system being proved to be available.

The distance to be crossed, and the cost to be incurred, require that the mode to be adopted shall be absolutely free from *serious* doubt and risk, and shall be as evidently capable of accomplishment as the most ordinary mechanical operation. Some degree of uncertainty must exist in every contrivance and speculation; but, unless a scheme can be proposed which will be free from all doubt and objection so far as human knowledge and foresight can extend, it will hardly deserve, and will probably not receive, the support of the public.

Our object has been to devise a scheme by which all difficulties of operating in water should be avoided. We propose to lay a tube of cast-iron on the bottom of the sea, between coast and coast, to be commenced on one side of the channel, and to be built up within the inside of a horizontal cylinder, or bell, or chamber, which shall be constantly pushed forward as the building up of the tube proceeds. The bell or chamber within which the tube is to be constructed will be about 80 feet in length, 18 feet internal diameter, and composed of cast-iron rings 8 inches thick, securely bolted together. The interior of the bell will be bored out to a true cylindrical surface like the inside of a steam cylinder. The tube to be constructed within it will consist of cast-iron plates in segments 4 inches in thickness, connected by flanges, bolted together inside the tube, leaving a clear diameter of 13 feet when finished. Surrounding this tube and forming part of it, will be constructed annular disks or diaphragms, the outside circumference of which will accurately fit the interior of the bell. These diaphragms will be furnished with arrangements for making perfectly watertight joints for the purpose of excluding sea-water and securing a dry chamber, within which the various operations for building up the tube, and for pressing forward the bell as each ring of the tube is added, will be performed. There will always be three and generally four of these watertight joints contained within the bell. A clear space between the end of the tube and the end or projecting part of the bell, of 36 feet, will be left as a chamber for the various operations. Within this chamber, powerful hydraulic presses, using the built and completed portion of the tube as a fulcrum, will, as each ring is completed, push forward the bell to a sufficient distance to admit the addition of another ring to the tube. The bell will slide over the watertight joints described, one of which will be left behind as the bell is projected forward, leaving three always in operation against the sea. The weight of the bell and of the machinery within it will be a little in excess of the weight of water displaced, and therefore the only resistance to be overcome by the hydraulic presses when pushing forward the bell, is the friction due to the slight difference in weight and the head or column of water pressing upon the sectional area of the bell against its forward motion. In like manner, the specific gravity of the tube will be a little in excess of the weight of water which it displaces; and in order to obtain a firm footing upon the bottom of the sea, the tube will be weighted by a lining of brick in cement, and for further protection will be tied to the ground by screw piles, which will pass through stuffing boxes in the bottom of the tube. These piles will, during the construction of the tube within the bell-chamber, be introduced in the annular space between the outside of the tube and the inside of the bell, and will be screwed into the ground as they are left behind by the progression of the bell. The hydraulic presses and the other hydraulic machinery, which will be employed for lifting and fixing the various segments of the tube, will be supplied with the power required for working them from accumulators on shore, on Sir William Armstrong's system, and the supply of fresh air required for the sustenance of the workmen employed within the bell and within the tube will be insured also by steam power on shore. As the tube is completed, the rails will be laid within it for the trains of waggons to be employed in bringing up segments of the rings as they may be required for the construction of the tube, and for taking back the waste water from the hydraulic presses, or any water from leakage during the construction.

The tube will be formed of rings of 10 feet in length, each ring consisting of six segments, all precisely alike, turned and faced at the flanges or joints, and fitted together on shore previous to being taken into the bell, so that on their arrival the segments may, with perfect certainty and precision, be attached to each other. Every detail of construction has been designed, and so far as we can see, no contingency has been left unprovided for. The possibility of injury by anchors or wrecks, or submarine currents has also been investigated. The tube when laid will be secure from all dangers arising from such causes.

The building of the tube will be commenced on dry land above the level of the sea, and will be gradually submerged as the tube lengthens. The operations on dry land will be attended with more difficulty than those under water; but all these circumstances have been carefully considered and provided for. The rings forming the tube will be made by special machinery, to be expressly constructed for facilitating the work and economising the cost. This machinery is all designed and specified. The first half-mile will test the feasibility of construction; for that will have to be built both above and under water. When once fairly under water, the progress should be rapid, and it is estimated that the whole undertaking may be easily completed in five years from the commencement.

The precise line to be taken betwixt the English and French coasts can hardly be determined without a more minute survey of the bottom of the Channel than at present exists. It will probably be between a point in close proximity to Dover on the English coast, and a point in close proximity to Cape Grisnez on the French coast. From an examination of the Admiralty Charts, and of such information as at present exists, the sea-bed on this line appears to be the most uniform in level, and, while free from hard rocks and broken ground, to consist of coarse sand, gravel, and clay. The average depth of water is about 110 feet, the maximum about 200 feet. On the line suggested the water increases in depth on both sides of the Channel more rapidly than elsewhere, although in no instance will the gradient be more than about 1 in 100. The tube, when completed, will occupy about 16 feet in depth above the present bottom of the sea. Up to the point on each shore at which the depth of water above the top of the tube would reach, say 30 feet at low water, an open pier, or other protection, would have to be constructed for the purpose of pointing out its position, and of preventing vessels striking against the tube. These piers may be rendered subservient to harbour improvements. The tube at each end would gradually emerge from the water, and on arriving above the level of the sea would be connected with the existing railway systems, so that the same carriage may travel all the way from London to Paris, or, if Captain Tyler's anticipations be realized, all the way from John O'Groat's to Bombay.

The distance across the Channel on the line chosen is about twenty-two miles. The tube as proposed is large enough for the passage of carriages of the present ordinary construction, and to avoid the objections to the use of locomotives in a tube of so great a length, and the nuisance which would be thereby created, and taking advantage of the perfect circular form which the mechanical operation of turning, facing, &c., will insure, it is proposed to work the traffic by pneumatic pressure. The air will be exhausted on one side of the train and forced in on the other, and so the required difference of pressure will be given for carrying the train through at any determined speed. Powerful steam-engines, with the necessary apparatus for exhausting and forcing the air into the tube, will be erected on shore at each end; and supposing one tube only to exist, the traffic will be worked alternately in each direction.

This system of working the traffic will secure a constant supply of the purest air, which will accompany every train; and sitting in a train on its passage through the tube, will be as pleasant and agreeable, in respect of ventilation, as sitting in the open air on the sea-side or in the best ventilated drawing-room.

By this system of working and by adopting the best description of materials and rolling-stock, there would scarcely exist the chance of accident—no collision could take place. There would never be foul air within the tube to annoy the passengers or to hinder the traffic by the necessity of removing the tainted air before another train could pass through. The pneumatic system, though hitherto tried on a small scale only, is undoubtedly one which, by the proper choice of means, can be certainly and easily, as well as cheaply worked, and in so long a tunnel, we believe it to be in every way preferable to locomotive power, although that also could be adopted.

It has been found by calculations, that, for moving a large amount of tonnage and a great number of passengers, the most economical arrangement will be to send combined goods and passenger trains through the tube at twenty miles an hour, with occasional express trains at thirty miles an hour. Thus, an ordinary or slow train would occupy about sixty-six minutes in the transit, and a quick or express train about forty-five minutes. In this way the tube, if fully worked, would permit the passage of sixteen ordinary slow trains (eight each way), and six express trains (three each way), each conveying both goods and passengers—about 10,000 tons of goods per day, or upwards of 3,000,000 per annum, and 5,000 passengers, or nearly 2,000,000 per annum—might be taken through, or a less amount of goods and a larger number of passengers, or *vice versâ*, if circumstances rendered other proportions necessary or desirable.

The horse-power required for working the traffic with the above number of ordinary and express trains, will be, on the average, 1750 indicated, or about 400 nominal horse-power at each end.

The journey from London to Paris may be easily performed in eight hours, or less, without any break or change of carriage, and the annoyance, delay, and interruption attending a sea-passage would be altogether avoided.

The estimated cost of the whole undertaking, including the stations and approaches at each end, the engine power and machinery, the interest of outlay during construction and engineering superintendence, with a large margin for contingencies, is £8,000,000.

The tube is capable of conveying, on the pneumatic plan of working the trains, with ease, 10,000 tons of goods per day, and we may reasonably calculate that the amount of traffic will be limited only by the power which may exist of passing it through the tube.

The annual working expenses will consist of maintenance, which will be light, of the cost and wear and tear of the pumping-engines, and of the ordinary expenses of management, the whole of which would be most amply covered by £150,000.

It would be easy to enlarge on the advantages to the whole world which such a bond of union would bring about, especially to the two great nations which would be thereby most intimately connected; but in a dry and scientific description of the means by which this important work of communication is proposed to be accomplished, such language would be out of place. Let it be proved to be a practicable undertaking, and the best or most promising which has been suggested, and it may well claim the support and the material assistance of the Governments of England and France, as well as of all the nations of Europe.

On the Utilization of Town Sewage. By T. D. Barry.

The author believed that, in the case of the irrigation system, it was the water, and not the sewage, which promoted the growth of the crops, and that injurious miasmata always arose from irrigated fields. He preferred a system of filtration. The effluent water could be made clear and innocuous, whilst the suspended or solid matter could be sold to the farmer at a price which would pay the cost of filtration. At Leamington this course is successfully adopted.

On a Navigable Floating Dock.
By Vice-Admiral Sir Edward Belcher, *K.C.B., F.R.A.S.*

On an Air-engine. By J. T. Chillingworth.

On the Birmingham Wire-Gauge. By Latimer Clark.

This was a continuation of the subject which had been brought before the Association on two previous occasions, the object being to promote the establishment of some universal wire-gauge. This the author considered would be satisfactorily attained by reestablishing the Birmingham gauge on a rational basis, and rectified from the irregularities which have crept into it, partly for want of some recognized standard, and partly by reason of the impurities of the materials, from the properties of which it was originally determined.

On the Hydraulic Buffer, and Experiments on the Flow of Liquids through small Orifices at High Velocities. By Colonel H. Clerk, *R.A., F.R.S.*

The hydraulic buffer was first applied for the purpose of checking the recoil of guns in 1867. It consists of a wrought-iron cylinder closed at one end, the other end fitted with a cap and stuffing-box, through which a piston-rod passes. The piston fits well in the cylinder, and is perforated with four small holes. The diameter of these holes, and the length of cylinder and piston-rod are determined by the amount of recoil required, or the space in which the moving body has to be brought to rest.

The cylinder is not filled entirely with water, enough air-space being left to allow of the displacement of the piston-rod, and to act as an air-buffer, to take off the first violence of the blow. In actual practice, oil is used instead of water.

In order to ascertain the action of this description of buffer with high velocities, some experiments were made, and described in this paper. They consisted in allowing a truck loaded with various weights to run down an incline plane, so as to attain a velocity from 10 feet to 44 feet per second, with which initial velocity the piston was driven through the water. By means of a rotating-drum fixed above the cylinder, and a pencil attached to the piston-rod, a curve was obtained from which the velocity of the piston-rod during the whole of its motion can be determined, and a formula obtained for calculating the various dimensions of the buffer required for any impinging weight, at any velocity.

The smoothness and ease with which a body moving at a velocity of 44 feet per second (or thirty miles an hour) was brought to rest renders it probable that this description of buffer may be found useful for many purposes, especially as a stationary buffer on railways.

On certain Economical Improvements in obtaining Motive Power. *By* R. Eaton.

[For Abstract of this Paper, see Appendix.]

On Government Action with regard to Boiler Explosions. *By* Lavington E. Fletcher.

On the Hydraulic Internal Scraping of the Torquay Water-main. *By* R. E. Froude.

Torquay is supplied with water from Dartmoor by a cast-iron main $13\frac{3}{4}$ miles in length, and having an aggregate fall of 370 feet between the inlet and the outlet at the standard reservoir. The diameter for the first eight miles is 10 inches, for the remainder 9 inches, an intermediate town drawing a regulated supply at the point of change. In 1843, six years after the opening of the work, the delivery, which appears from the first to have been defective, was found to be barely half what the recognized formulæ promised.

The defect was attributed to internal oxidation; but as this, though forming a rough carbuncular surface, did not much exceed $\frac{1}{8}$ of an inch in average thickness, the obstruction would have been insignificant according to the commonly received view, that the water detained in the roughnesses would furnish a smooth surface for the internal column to glide through; and it followed that either the received view needed some correction, or that local obstructions must have been established by accumulations of sediment or otherwise in the many deep depressions of ground-surface traversed by the main.

Under the directions of Mr. W. Froude a novel and effective test was devised and employed for the determination of this question.

A very delicate and accurate pressure-gauge was applied to the main, at short and selected intervals throughout its length; a method of drilling the necessary holes and fitting the connecting taps, without emptying the main, having been contrived, which prevented any escape of water during the operation under the heaviest pressures.

Columns of water equivalent to the pressures thus tested were calculated: and the heights of these being laid down on the section of the line of main, at the positions of the several gauge-stations, or, in other words, being added to the datum-heights of those stations, the resulting elevation of the column-summits were found to form, for the 10-inch and 9-inch pipes respectively, perfectly uniform gradients, showing that in each the consumption of pressure per mile was also uniform throughout, and that there could be no local obstructions.

The incrusted oxide thus appeared to be the only known cause of obstruction; and the late Mr. Appold, with characteristic acuteness and boldness, suggested that it would be possible to force a suitably constructed scraping implement, along the main internally, by the existing hydraulic pressure, so as to remove the incrustation.

In accordance with his directions, a stout bar about 5 feet long was armed at the tail-end with two expansive cup-shaped and cup-leathered pistons, placed with such an interval between them, as to ensure the maintenance of pressure while passing stop-valves and branches. Its front end was armed with four pairs of scrapers, each formed of flat iron bar, bent flatways like the letter U reversed, the cross strokes forming cutting edges which the spring of the metal pressed against the sides of the pipe, the whole circumference of which they together embraced, and intended to act not unlike the patent road-scraper. The cutting edges were "skewed" so as to prevent their dropping into, and laying hold of any pipe-joints more than usually open; a regulated flow of water was permitted to pass the piston, so as to drive the scrapings forward.

The Torquay Local Board, on whom the responsibility rested, were induced, on Mr. Froude's strong recommendation, to allow the implement to be tried on a mile of main; not without hesitation, for the shortness of the existing water-supply enhanced the anxiety attending so novel and bold an experiment, which, should the scraper stick fast, might involve serious delay in the reinstatement of the delivery; the main had to be cut and closed again in two places, at all events. The scraper, happily, travelled the mile without difficulty; and the pressure-gauge test, tried before the operation, and again after the flow had been reinstated, showed, by the consequent reduction of pressure at the upper end of the distance, and its increase at the lower end, that the scraped pipe drew away the water from above, and delivered it below with greatly increased freedom: 21 feet of "head" had previously been consumed on the distance, 7 feet only were consumed on it subsequently,—a difference promising an improvement of 75 per cent. in the delivery, when the pipe should be scraped throughout*.

One material cause of anxiety was removed, by finding that the grating noise made by the scraper *in transitu* indicated its exact position to all observers who accompanied it. Thus encouraged, the Local Board entrusted to Mr. Froude the completion of the work throughout; but the experience gained in the trial showed that an amended scraper and complete appliances would be required for it.

Lengths of pipe, fitted with moveable covers to admit of the insertion of the scraper, were interpolated at suitable positions; and a new scraper was made fitted with hard steel cutters, pressed against the pipe by independent steel springs,—improvements which the preliminary trial had shown to be essential to a persistent and vigorous scraping action. In the extended operation, serious difficulties which fortunately had not appeared in the preliminary trial, were encountered in the large number of stones (some several inches in diameter) which had been carelessly enclosed in the pipe when laid; and it became necessary to clear the way for the scraper by passing first a strong cast-iron cup, which comminuted the smaller stones and picked up the large ones, and eventually the whole work was completed. For reasons too long to state here, the improvement first attained was only 40, not 70 per cent., as had been hoped; but subsequent repeated scrapings with a very improved pattern of scraper, which does not, however, admit of brief description, have increased the delivery by considerably over 100 per cent.; it was only 317 gallons per minute before operations were commenced, it was 655 after the most recent scraping; and the operation is now so simplified and well understood, that but for the change of diameter, which involves a change of scraper, the whole length of main could be traversed without any pause.

It is found that very soon after the scraping a perceptible decline of delivery takes place, probably owing to a gradual erosion of the smeared smoothness, which is likely to be an immediate result of the operation; and besides, minute pustules of oxide begin at once to form, and it is evident that mere infinitesimal roughness sensibly obstructs the flow, but in its practical aspect the operation is perfectly successful.

On some Difficulties in the received View of Fluid Friction.

By William Froude.

The very great variations in frictional resistance exhibited by the flow of water

* Mr. Appold died the day before this first successful trial of his suggestion.

through the Torquay water-main, under small variations in smoothness of internal surface, suggest the necessity of a revision of the theory of "fluid friction," which in its commonly accepted form, ignores the effect of "quality of surface" entirely, and in which, even as amended by later able writers, less importance is attached to it than the variations referred to prove it to possess.

The theory appears defective in two other important respects.

(1) In assigning to pipes of different diameters, under the same hydraulic gradient, a flow proportioned to the power $(\frac{5}{2})$ of the diameter, it proceeds on the assumption that the ratio of the mean velocity to the maximum velocity is the same in pipes of all diameters. This is equivalent to assuming, either that the velocity of the central particles of a flowing column does not exceed that of the circumferential particles more in a 12-inch than in a 6-inch pipe; or that particles of water can glide more freely past the semi-rough surface of the pipe, than they can glide past each other; whereas, since the latter alternative seems absurd, we ought to expect that within the 12-inch pipe, the particles occupying the central 6 inches must possess, in addition to the velocity of those immediately surrounding them, the whole mean velocity which they would have possessed if flowing independently in a 6-inch pipe; an expectation irreconcileable with the law that the delivery with a given hydraulic gradient is as the power $(\frac{5}{2})$ of the diameter.

(2) The commonly received theory assigns to every square foot of an extended plane, drawn edgeways through undisturbed fluid, one and the same intensity of frictional resistance; and this is expressed in terms of the velocity of the surface, calculated with reference to the undisturbed part of the fluid, and is supposed to create an equal resistance per square foot throughout the plane; whereas it is certain that the anterior portions of the surface, in rubbing against the particles which it passes, and experiencing resistance from them, *must* impress on them equivalent force in the direction of its motion, and *must* impart to them some velocity in that direction. Thus, though it may be in some sense asserted that the anterior portions of the plane rub against the contiguous particles with the entire velocity of the plane, since these particles are undisturbed, this cannot be truly asserted of the posterior portions of the plane, since the particles against which these rub have already received a velocity conformable to that of the plane; and a "state of motion" will be thus produced in the contiguous particles involving a widening body of fluid, and with increasing velocity imparted to it, as we recede foot by foot sternward along the plane; forming, in fact, a "current," created and left behind, by the transit of the plane, such that if we could integrate the volume of current created in each unit of time, and the exact velocity possessed by each of its particles, the aggregate momentum must be precisely that which is due to the frictional resistance of the entire plane acting during that unit of time. Obviously the sternward portions of the plane moving forward in such a favouring current, must experience a less intense frictional resistance than the anterior portions.

A consideration of these objections to the received theory, the latter especially, suggests the question, how the velocity of the surface relatively to the fluid is properly to be estimated, as relevant to, or as governing the intensity of frictional resistance. And in attempting to arrive at this, it is plainly necessary to take account of the manner in which, and the distance to which, the velocity which the rubbing surface imparts to the particles, spreads into the fluid.

With a view to this, the following propositions seem relevant and admissible.

(1) A surface free from such roughnesses and prominences as to produce eddies, if of such quality that the fluid thoroughly *wets* it, will experience the same resistance in moving past the particles which resist it, as if it had itself consisted of particles of the fluid.

(2) No particles of the contiguous fluid can be strictly regarded as sliding past the surface, or, *vice versâ*, in the sense in which a solid slides past a solid; but between the complete motion of the surface, and the complete quiescence of the fluid where it is yet undisturbed, a graduated state of motion must exist, the *manner* of the graduation governing the intensity of the force transmitted from particle to particle.

(3) When a plane slides edgeways through undisturbed fluid, part of the force which it transmits into the fluid around it is employed in giving motion to the par-

ticles which it affects, and as these in turn, when put in motion, affect other particles outside them, the remainder of the force is transmitted to those particles. Hence it becomes desirable to conceive an arrangement under which the force would be transmitted entire, instead of being partly absorbed in momentum, and to trace the law of transmitted motion which would correspond with this.

(4) Such a state must be conceived to exist if we imagine two parallel planes, of infinite extension each way, having the intervening space filled with fluid, and having possessed for an infinite period equal edgeways velocities (say v) in opposite directions. The transmission of motion and of force in the intervening fluid must have become established and permanent, and the following propositions would seem true respecting it.

(*a*) Each plane must be experiencing throughout its surface a definite frictional force per square foot, acting in the direction of the plane, equal and opposite in the two planes, and the force must be transmitted statically from plane to plane by the state of motion in the intervening fluid.

(*b*) Along the imaginary plane which bisects the intervening space, the particles of fluid must be stationary, since they are similarly situated with respect to the two equal opposite forces and motions.

(*c*) Between the imaginary central plane, and each of the two moving planes, the particles must possess a graduated motion corresponding with that of the nearer plane.

If we further imagine the whole intervening space to be subdivided into laminæ or layers of equal infinitesimal thickness, say 1, 2, 3, . . . n, it would seem that, to transmit the definite force unchanged from layer to layer, No. 1 must be gliding past No. 2 exactly as fast as No. 2 past No. 3, and so on throughout, from one outer plane to the other, for these are to be judged as adherent to the fluid, as the fluid to itself (see prop. 1); since that supposition, exclusively, secures throughout an identity in the relative motions of similarly placed contiguous particles: if we were to suppose different gradations of velocity in relation to lateral space, or thickness of layer, in different parts of the series of layers, it would follow that different relative motions of similarly placed contiguous particles would develope the same amount of force.

The character of this graduated transition of velocity may be best explained by observing that if at any moment a straight filament were laid at right angles across the interval between the planes, and were to accept the motion of the particles which it traversed, it would remain straight, while it continued to describe a growing rectilinear angle, the angle being as the time, and the centre of motion being the centre of the space between the planes where the particles are stationary.

The conception of this angle will be relied on as important in the course of the investigation, and it will, for convenience, be termed the "filamental" angle (ϕ), and will be taken account of as described in some definite infinitesimal interval of time, Δt.

Bearing in mind the graduated transition of velocity, it follows that if we were to substitute for any one of the interior layers a plane similar to the original planes, assigning to it the velocity of the layer for which it is substituted, we might remove the fluid external to it on one side without in any degree altering the state of relative motion (as expressed by the filamental angle) and of force, in the layers of fluid which remained.

The absolute velocity of this plane might be less in any assignable ratio than that of the original planes, yet it would experience the same resistance per square foot as they; and it follows that the frictional force experienced by a surface moving past the particles of a fluid, is independent of the absolute velocity of the plane, so long as the filamental angle is unchanged. If, retaining the original planes and the space between them unaltered, we assign to them an established velocity, say m times as great as before, the filamental angle will also have become m times as great, expressing the circumstance that the relative motion of similarly placed contiguous particles is increased in that ratio, and that a condition appropriate to a difference of frictional force has been established. The force of fluid friction must be regarded as governed, not by the absolute velocity of the moving surface, but by its velocity as related to that of contiguous particles, expressed in terms which take account of their lateral distance from it; these conditions constitute the angle ϕ, and are fully represented by it.

The best experiments seem to show generally that the force of fluid friction is as the square of the velocity; and as it is probable that for any given plane moved with various velocities the integral value of ϕ throughout the area will in each case be as the velocity, it would seem that we may substitute for the ordinary expression $F=kv^2a$ (in which F is the force per square foot at every point in the area, v the absolute velocity of the plane in relation to the wholly undisturbed fluid, and a the area) $F=\int k\phi^2\,da$, where ϕ is the value of filamental angle which the existing conditions have called into play at each particular point in the area.

If to an infinitely extended plane, immersed in an infinitely extended fluid, we suddenly assign a definite velocity and maintain it, motion will gradually spread itself into the fluid from the plane, the layers nearest the plane having always the greater velocity, and each experiencing an acceleration depending on the difference of frictional force measured at its two faces. If the thickness of any layer be represented by dh, then $\frac{d\phi}{dh}$ will be the difference of filamental angle, and $2k\phi\frac{d\phi}{dh}$ the difference of force.

On this basis a differential equation might be constructed showing the rate at which the velocity would penetrate the fluid in the case supposed, and this might be extended to the case of a finite plane penetrating an undisturbed mass of fluid with a definite velocity.

On Roads and Railways in Northern India, as affected by the Abrading and Transporting Power of Water.

By THOMAS LOGIN, *C.E., F.R.S.E., and Memb. C.E. Inst.*

[A communication ordered to be printed *in extenso* in the Proceedings.]

At the last Meeting of this Association the author drew attention to the "Abrading and Transporting Power of Water," when he ventured to bring forward his views regarding this important subject. Since that time he has studied the subject still more, and in the theory then brought forward he has been more and more confirmed.

As many of those present may not have seen or heard what these views are, he briefly recapitulated the most prominent points before entering on the question of their practical application to engineering works.

1. All silt-bearing streams when in train only transport a given proportion of earthy matter.

2. That the proportion depends on the velocity, and the nature of the materials transported.

3. Any increase of the velocity must cause a tendency to cutting, and any decrease to deposit.

4. That a silt-bearing stream is retarded by having to exert a force sufficient to transport certain proportions of certain descriptions of earthy matter, consequently the slope required for a given velocity under such circumstances must be greater somewhat than if the water was pure.

From these conclusions he arrived at certain deductions regarding the flow of water down irrigation canals, which at present it is not necessary to dwell on, and he went on to state that, so far as his personal observations extended, they went to show that, though the transporting power of water increased with the velocity, yet it diminished as the depth increased, and suggested that this was possibly owing to the rotatory motion of fluids, which are supposed to follow some figure more of the nature of the involutes of circles rather than straight lines.

Having got so far, he stated his belief that it signified little what may be the cross section or velocity of a stream while passing over or through a work, so long as it could again resume its natural section and velocity immediately on leaving it.

The main object of his former paper was to show how the above-mentioned conclusions affected the question as to the proper velocity to give to artificial rivers, that is, irrigation canals in India and elsewhere, and on the present occasion he proposed confining his attention to the rivers of Northern India, with suggestions as to how they should be bridged.

To do so, however, probably it will be best to give a general description of the plains of Northern India without attempting to infringe on the work of the geologist, but simply to state what is now to be found, and what changes in nature have lately taken place and are at present being worked out.

The plains of Northern India may be considered under two great divisions, namely, the Gangetic Valley and the Valley of the Indus. Approximately it may be said that from the head of the Bay of Bengal to where the Ganges escapes from the hills is a little short of 1200 miles. The general shape of the surface of the country would in section be the quadrant of a very flat ellipse, with a small portion of both ends cut off*; the total fall, rather less than 1000 feet, commencing with rapid slopes near the hills, and ending with a fall of only one or two inches in the mile at the sea. These plains consist of alluvial deposits to unknown depths in alternate strata of clay and sand; but in addition to this are to be found extensive beds of limestone, known in India by the name of "kunkur."

As a general rule, the uppermost stratum is a rich light clay from 5 to 10 feet in depth, with sand below it, and it is chiefly owing to this that Upper India is so very productive. Strata of clay, sand, and "kunkur" are met with at various depths, and of various thicknesses, and all have a general parallelism to the surface, but how or when deposited the author will not attempt to discuss.

These plains are cut up by deep troughs or valleys, usually from 5 to 10 miles broad, of various depths, from that of 10 to even 100 feet. A section of one of them was before the Section; it is through these valleys that the large rivers which are fed by the melting of the snow now meander.

These valleys are known in India by the name of "Khadirs," and as there is nothing similar to them that the author is aware of in England, it will be best to adhere to this local name in contradistinction to what is called Bhangir, or the high-level plain already referred to. The formation of these "Khadirs" is, however, a matter of interest to the engineer, so the author will state his views as to how they were scooped out and are now being filled up.

In the great valley of the Dehra Doon, lying between the Ganges and the Jumna, and beyond the Sewalic range, where the ground chiefly consists of boulders and sand, with a covering of vegetable soil, there are evident marks to show that these two rivers stood at much higher levels than at the present day. It is also very evident that the sea extended several hundred miles further inland than the present head of the Bay of Bengal, so that at no very distant period, speaking of time in a geological sense, the chief rivers of Northern India must have had, when escaping from the hills, their beds higher than at present, and their channels shorter; so, with slopes more rapid, the transporting power of these rivers must have been much greater than now, and a violent cutting back on the bed has taken place from the sea, scooping out these deep troughs to excessive depths through the alluvial plains.

This also would further add to the declivity of the beds of these rivers near the foot of the hills, and thus boulders could be transported for many miles further into the plains than they are at present.

It is thus the author would account for sand only being found to great depths in the valleys of the large rivers some distance down their course, as, for example, on the Beas, where the Delhi Railway crosses it; also near the foot of the hills, shingle and boulders some twenty miles down the course of these rivers are to be found a few feet below the sand, as in the case of the Dadoopoor dam at the head of the Jumna Canal, where the foundations rest on shingle at a depth of about 10 feet below the bed.

With sand overlying boulders and shingle it can only be supposed that the beds of the rivers are here being raised, and as the Delta is extending year by year out into the Bay of Bengal, the river here also is becoming higher, so it is natural to suppose that all along the course of the river between these points a similar process is going on. This is a very important point to know; for though this silting up may

* Possibly this curve may be parabolic.

be imperceptible, yet it clearly shows that there is no danger to any permanent work by a general depression of the beds of these rivers going on, as some suppose, because any scooping out of the bed is only local, and can be met by local remedies.

Borings in the beds of torrents which drain the southern slopes of the hills, and not the interior, and which meander over the plains rather than intersect them, give very different results to what are found in the valleys of the large rivers, as alternate strata of clay, sand, and kunkur are found.

It is necessary to know the rainfall at various points to understand certain natural features, and the changes now going on. In the Gangetic valley the rainfall is considerable, being, on an average, nearly

20 inches a year at Delhi,
30 " " Meerut,
40 " " Roorkie.

The level of the Bhangir here being so very much above that of the Khadir, a gradual wearing down of the Bhangir is going on; thus the high level plains between the Ganges and the Jumna, commonly called "the Doab," is cut up by several large streams. With such a rainfall as there is all over the Doab, it is natural to suppose that there must be some line marking out the catchment basins of each stream, and that this line, by its being least exposed to the action of running water, remains the highest, and is neither more nor less than the "backbone of the country," not caused by any upheaval, but simply that it is worn down *less* than any other portion of the plains. It is along this ridge or ridges that irrigation canals should be led; but as the plains are so level, the general direction of these ridges is difficult to determine. This at once explains why so many cross sections of the country have to be taken to discover the best line for an irrigation canal and its branches, which are not necessary with a road or a railway where *distance* becomes so important an element.

The author would now make a few remarks on the valley of the Indus, that is, the plains which form the "Doabs" of the Punjab, which are similar, geologically, to those of the Gangetic valley, the only difference being that they have not any deep rivers intersecting the plains, nor ridges similar to what are found in the North-western Provinces.

Take, for example, the Richna Doab, the high level plains between the Ravee and the Chanab rivers, which is 50 miles broad near Lahore, where the Bhangir is only about 10 feet above the Khadir of the Ravee; and on the Chanab side at Wuzeerabad the difference of level is only 17 feet, so that in a lateral direction there can be very little fall.

Again, the rainfall is very little compared with what there is in the valley of the Ganges, as approximately it is at Jhung 4 inches yearly, or $\frac{1}{5}$ of the fall at Delhi.

Cheeniot, 8″ .... $\frac{1}{4}$ Meerut,
Sealkote, 30″ .... $\frac{3}{4}$ Roorkie,

and these points are respectively about equidistant from the hills. The fact is that the land *absorbs* all the rain which falls, so that at fifty miles below the hills every vestige of drainage-lines disappears. Not that no drainage passes over this line, for it is on this parallel that the Lahore and Peshawur road runs; and 13,470 running feet of gaps, in addition to 37 bridges and culverts of various sizes, are left in this embankment to pass off the cross drainage which comes down from the neighbouring country above, where the rain is more plentiful; yet with all this waterway, in a distance altogether of 59 miles (including the valley of the Ravee), in July 1866 "*the flood topped the road for over 8 miles in length, and made very extensive breaches, scouring out the embankment below the level of the country.*"

It appears to the author that in such a case it would perhaps have been better either to divert the drainage higher up, or to *have had no road whatever raised, but to have allowed the flood to pass quietly off over the road.* The effect in this case, by increasing the velocity at certain points, has been, for the comparatively *pure* water which had harmlessly flowed through fields of cultivation, to sweep away several miles more of the embankment, thus showing "that with increased velocity there must be abrasion." Where floods even at higher velocities are *not* obstructed, no such action takes place. The author in October 1863 laid down a causeway of "kunkur" metal across the Khadir of the Sutledge at Loodvanah level with the surface of the country, and up to 1867 it was standing, and for anything he knows to the contrary, it may be there still. Thus a number of floods have passed over it at great velocities, yet as the water had its *proper load* of silt there has been no cutting.

But to continue, the Richna Doab being so little raised above the Khadirs, there could be no great fall east or west; consequently, with a plain fifty miles broad with a considerable fall towards the sea, the tendency would be for the floods to spread themselves over it, and as the rainfall is so little, this drainage is ultimately absorbed. There is therefore no *wearing down* of this plain by the action of water; so instead of there being any natural ridges, the surface of the country is so uniform that the author found by one of his trial cross-sections, with points taken at every 400 feet, in a distance of six miles in a straight line, that the highest point did not exceed in height the most depressed more than 3 feet, though the fall of the country at right angles to this line was some 2 feet in the mile. It is this uniformity of the plain and the richness of the soil that make the Richna Doab so peculiarly well adapted for irrigation, and in this opinion the author is supported by the late chief engineer of the Punjab, Lord Napier of Magdala.

The courses of rivers in India are very changeable, so much so that Government have to collect the land-rents in the neighbourhood of these rivers on a different system to other parts, so as to admit of change of proprietorship as the course of the river shifts. These deep troughs or valleys, called "khadirs," are the limits through which the rivers change their courses from time to time; and though the course may be said to be always serpentine, the changes are not exactly so, but follow that of the valley; thus there is a gradual movement of all the bends downwards, so that after a given number of years, say half a century, the river may be exactly as it was fifty years before, but at the end of twenty-five years every bend would be found at the opposite side of the valley.

Sometimes the changes are more or less sudden, when instead of the channel moving gradually down, these bends are diverted, and the two ends get silted up; thus these diverted channels often become a marsh, and are known by different names in different countries, such as "broads" in Norfolk, "lagoons" in America, "jheels" in Upper India, "dhars" in Bengal, and "choungs" in Burmah. One remarkable feature of them is that they are on a lower level generally than the main river, proving that the rivers are raising their beds; but it is this peculiarity that makes it all the more necessary to guard against the tendency of the main stream returning to its deserted channels, and it is to this the author would more particularly call attention, for he believes that hereafter it may be a work of no little difficulty to prevent this where the large rivers are crossed by railways.

During high floods a large body of inundation water passes down the valley, which is all more or less under water, but its flow is retarded for various reasons, chiefly owing to vegetation; consequently, comparatively speaking, the water is pure, and does not hold in suspension anything like the same proportion of earthy matter that the main stream does.

To give sufficient waterway by flood-openings to pass off all the inundation at its natural velocity would require exceedingly large bridges. To increase the velocity through the bridges implies a heading-up of the water with a still greater reduction in the velocity on the up-stream side of the embankment, which necessitates a still further reduction of the silt held in suspension.

The water thus lightened of its load, rushes through the flood-openings and reaches the down-stream side at an increased velocity, in nearly a pure state; and as it must take up a proportion of earthy matter due to this velocity, a violent action takes place below the bridge. Nay, sometimes owing to this increased velocity on the up-stream side, a scooping out takes place above the bridge; and if the bridge happens to have a raised flooring, it simply becomes a submerged weir, doing harm instead of good by deranging the flow. If floorings are to be used, they should be as inverts to rest the bridge on, and not raised to a higher level than the foundations. In nine cases out of ten it would be better to break up all raised floorings, and throw the material round the pier foundations, rather than give a plunging direction to the water down-stream.

If this view be correct, it at once proves that with loose sand to unknown depths, the only safe mode for bridging the large rivers is to have deep foundations, which necessitate great spans, and iron girder bridges, and as the sand pump makes the sinking such a simple matter now, the difference of 10 feet more or less of depth in cost is insignificant. (In Madras, where there is an unlimited supply of heavy material, the case may be different, and there shallow foundations may be more economical.) An extra depth of 10 feet or so, however, is nearly tantamount to doubling the sectional area of the waterway, and as water does not move in straight lines, it matters little what the shape of the section may be when passing through a bridge; thus the waterway may be doubled without adding to the breadth, but by deepening the bed. By this means, without adding much to the cost of a bridge, not only the main stream, but also the inundation water could all be passed through the one bridge, and thus a great saving effected by having no flood-openings, and consequently no danger of the main river taking to these side openings, while the only inconvenience would be to cause the flood to last a few hours longer than it otherwise would.

But, however, where the embankment crossing a valley is of a great length, all the water could not drain back to the main stream, after the flood had passed off, particularly when, as has been already shown, the ground is much lower away back from the river than at its banks. To get rid of this water, siphons with spoon-mouthed openings at both ends should be provided, so that though the water could rush through the greater length of the siphon at a velocity of even 10 feet a second, yet it would approach and leave the siphon at the natural velocity of perhaps not more than 2 feet a second. Thus no violent action could take place either above or below, and at the points of admission and egress, the water would have the proper load of silt due to its velocity.

From all the author has read, seen, and heard, he cannot help thinking that a large proportion of the late accidents on works in India is to be attributed to the causes assigned in this paper, namely, an excessive velocity given to a stream that has already been partially deprived of its natural load of earthy matter, thereby causing a violent action below, and sometimes even above bridge.

The importance of the questions now raised as to bridging rivers in India is daily becoming greater; for, while this paper was being prepared, the Government of India has determined to construct the Lahore and Peshawur Railway, which line must cross, not only the Ravee, the Chanab, and the Jhilum, but also the Indus passing over the Richna Doab, which has been described above. Should, therefore, the suggestions now made be correct, it is evident that hundreds of thousands of pounds may be saved by adopting them, and thus, a proper knowledge of these laws arrived at, may enable the engineer to make this line of railway, which is supposed to be one of the most difficult lines to construct in India, with perfect confidence of success, and at possibly less cost than many of those now constructed.

The author would only now add, that the knowledge of the abrading and transporting power of water is not only desirable in designing roads, railways, or canals, but affects every question connected with hydraulic works in all countries. It would occupy too much time to allude to them further; but he may, however, venture to ask what would be the financial state of Southern India (which now does not pay) if harbours were constructed on sound principles, so as not to be silted up?

Time will not admit of the author's describing a modification of the siphons, which he thinks, in some instances, may be introduced with economy for crossing minor streams, instead of bridging them in the usual manner; but he believes not only can this be done with advantage, but also, with spoon-mouthed siphons, in Bengal inundation water may be carried through embankments in regulated volumes, so as to be available for irrigation, thus adding both to the fertility of the soil and the salubrity of the climate, while the embankments would protect the country from those devastating floods which so often destroy both life and property.

Description of a New System of House Ventilation. *By* J. D. MORRISON.

The main features of this novel system of warming and ventilating, consist in so circulating pure fresh air (through a warming chamber) into the room, and of foul air (through the fire) into the chimney, that all local currents are resolved into *one*, which, describing an unbroken circuit, forms an upper warmer current from the fire to the opposite wall, and an under colder current from the wall back again to the fire, when, after supporting combustion, the products escape up the chimney. The vacuum thus produced by the warmer current through the chimney creates the now colder current from the atmosphere, which, passing through the heating-chamber, supports the respiration of any number of men.

On an Improved Vertical Annular High-pressure Steam-boiler.
By WILLIAM SMITH, *C.E., F.C.S., F.G.S.*

This paper described an improved vertical high-pressure annular steam-boiler, recently invented by Messrs. Allibon and Manbré, and manufactured by Messrs. Allibon, Noyes and Co., of the Rosherville Iron-works, Northfleet, as it fulfils to a remarkable extent the conditions indispensable in a steam-generator, and that, too, with an extreme simplicity of construction. Now the boiler stands by itself in this latter respect. The body of the boiler and the fire-box are constructed separately as distinct parts, the water and flue-spaces being disposed annularly. The outer part consists of the external skin or shell of the boiler, and a concentric inner cylinder is rivetted thereto near the bottom, a wrought-iron ring being interposed to keep the proper distance apart. This inner cylinder is also firmly stayed to the shell by screwed stays placed at suitable distances apart.

To the top of this inner cylinder a tube-plate is rivetted, which is also connected to a central pendant annular water-space, descending to within a short distance of the furnace-bars.

Thus the fire-box proper consists of two rings forming an annular water-space round the furnace, the inner ring being made slightly conical to give a better heating-surface, and at the same time permit the steam to get away freely. The top of this fire-box is connected to the tube-plate by a series of short lap-welded tapered tubes, screwed at both ends.

In the boilers first constructed on the Allibon and Manbré system, the central pendant portion was merely a receiver, pocket, or "pot," but in the boilers now constructed by them an important modification has been introduced to this portion of the boiler. The central portion forms part of the fire-box, to which it is connected by the short horizontal tubes or flue-passages shown at the top of the central pendant portion. The products of combustion, on reaching the top of the fire-box, are deflected by the upper tube-plate, and descend between the outer ring of the fire-box and the inner cylinder or body of the boiler, until they arrive at the bottom, where they pass into an annular flue surrounding the base of the boiler, and from thence by an oblong flue or uptake to the chimney.

The flue-passages are made sufficiently large to allow of their being cleaned easily, and any repairs effected.

The annular flue surrounding the base of the boiler may also be converted into a feed water-heater by jacketting or surrounding it with a water-space.

The feed is pumped in by a circulating pump; a check-valve and a relief-valve being provided to prevent any excess of pressure.

This system possesses all the well-known advantages of vertical independent boilers, rendering unnecessary the heavy item of expenditure for the setting of Cornish and other enclosed boilers, whilst it allows of free inspection, and the consequent ready detection of leakage or other defects, and thus tends materially to diminish the risk of explosion.

Amongst some of the leading features of this boiler may be included the thorough circulation of water which is insured, the large extent of effective heating-surface, the rapid boiling off of large volumes of steam, the thorough utilization of the products of combustion, simplicity in construction of the several parts, and great strength of the whole as a steam-generator.

When applied as a marine boiler, the advantages of this plan are very great, requiring only a very small cubic space compared with the heating-surface. Finally, the very good results obtained from boilers made according to this invention have fully realized the most sanguine expectations formed of its merits.

On a Method of determining the true amount of Evaporation from a Water-Surface. By G. J. Symons, *F.M.S., and* Rogers Field.

[For Abstract of this Paper, see Section A, page 25.]

Railway Passengers' and Guards' Communication. By S. Alfred Varley, *Assoc. Inst. C.E.*

The author remarked that the subject had occupied considerable attention, that he had been engaged upon it during the last four years, and he thought there would be some points of interest in a description of a system of communication which was applied in 1866, and is at the present time in use on the Royal train in which Her Majesty travels to and from the North ; the system referred to had also been applied to an ordinary train, and daily used for more than eighteen months.

The author stated there was a belief on the part of some (but by no means all of the railway authorities) that, owing to the subtle nature of electricity, it was not suitable for the purpose of train intercommunication; but he thought this belief arose chiefly from a want of acquaintance with the progress made by those who have made the practical application of electricity their special study, and he believed the time would come when electricity would be universally acknowledged to be the best medium for signalling upon the rolling-stock of this country.

The author remarked the application of electricity to signalling in trains, considered in the abstract as an electrical problem, was a simple one ; the mechanical difficulties in its application, however, had been somewhat complex, and the solution of these difficulties had depended chiefly upon the mechanical construction of the various parts.

The conditions laid down by the railway authorities as necessary, were that the system should be simple and not liable to derangement, that passengers should be able easily to signal in an emergency, and that the apparatus should be detective to prevent the repudiation of a signal when once given ; besides this it was suggested, for the sake of economy, that the apparatus should be portable, so that it could be moved from one train to another if required.

Numerous electrical systems had been proposed, but only three had been practically applied.

The first on the list was Mr. Preece's, in use on the London and South-Western Railway ; the second was Mr. C. V. Walker's, in use on the South-Eastern Railway ; the third the joint invention of Mr. Martin and Mr. S. A. Varley, and in use upon the London and North-Western Railway.

The three systems referred to differed from one another in the mechanical construction of the couplings, the alarums, the galvanic batteries, and the carriage signalling apparatus ; he did not, however, propose to discuss their respective merits, but would confine himself to a description of the system with which he was associated.

An insulated wire was run underneath the carriages, the coupling bars and ironwork of the carriages were connected electrically together, and the circuit was completed, when the apparatus was in use, through the insulated wire, the apparatus, the ironwork, and the railway metals.

Two insulated wires, the one connected to the ironwork, the other to the insulated wire running under the vehicles, were led up into the compartments of each carriage, and bringing these into contact with one another closed the circuit through the galvanic batteries and the alarums in the vans, and on the engine.

The connexions between vehicle and vehicle composing the train were effected by means of two coupling-ropes containing flexible conductors ; this enabled the carriages to be joined together at either end, and gave a double connexion between each vehicle.

The coupling-ropes were made by wrapping a wire spirally round a hempen core ;

seven of these were then laid longitudinally and bound together by a serving of hemp protected by an insulating compound; each rope therefore contained seven separate conductors; and in practice the ropes were found to be very durable; for as the conducting-wires touched one another throughout, should one or all of them be broken, continuity would be still maintained by the ends of some of the wires touching, and unless the rope was actually severed the electrical continuity was still complete.

Malleable cast-iron eyes were attached to the ends of the coupling-ropes where the connexions were made, and these were grasped by strong iron hooks actuated by powerful springs placed in cast-iron boxes attached to the carriages.

The eyes of the couplings were coated with copper at the points of contact, and pressed against a plate of brass attached to the hooks, by this means very perfect contact was secured.

The apparatus in the vans consisted of a battery and an electrical alarum; these were placed in boxes; and the connexions were made by simply hanging them on brass studs.

The vans were supplied also with ringing keys, to enable the guards to signal to one another.

The apparatus on the engine was a portable alarum, and the power to work it was obtained from the galvanic battery in the leading van.

The carriage-apparatus consisted of a lever handle in a metal box, which when pulled closed the circuit and became locked; all the alarums were set ringing, and continued to ring until the apparatus had been reset by a special key.

The cost of maintenance was almost nominal, and no electrical knowledge was required in its management, all the operations of testing being mechanical; the connexions also being double, any faulty coupling was readily detected, and the system rendered most reliable, as the apparatus would work even in the unlikely event of a faulty coupling in every carriage.

To meet the wishes of the Board of Trade, some of the railway companies had electrical systems applied to ordinary passenger-trains, and the system referred to by the author was fitted up on an express train running 250 miles daily between London and Wolverhampton. This train was started from all the stations at which it stopped by means of the apparatus, and its working reported by the guards, and in this way it was tested twenty-two times daily.

Many thousands of signals have been sent and recorded, the apparatus having been at work on the train more than eighteen months, and its performance, as shown by the guards' reports, has been marked by the most unvarying regularity.

The distinguishing features claimed for this system are :—

I. The construction of the flexible conductors renders it almost impossible for the electrical continuity to fail.

II. Very perfect contact is obtained by the construction of the hook-and-eye coupling, the surfaces of contact being made of brass and copper—metals not liable to oxidation; the act of coupling cleans the contact surfaces, and the hook-and-eye couplings are firmly grasped by powerful springs.

III. The couplings release themselves without damage, if the carriages be forcibly separated, and the breaking away of a train can be indicated.

IV. The connexions being double between each vehicle, the efficiency of the system is not impaired even in the unlikely event of there being several faulty connexions in a train.

V. The apparatus and connexions can be tested at any time, and any defect localized without special electrical knowledge.

VI. The connexions in the vans and on the engine being made by hanging up the apparatus, and the batteries and alarums being portable, they can be readily shifted from one train to another, or replaced, if necessary.

VII. Greater striking-power is obtained in the construction of the alarums than in the usual construction of continuous ringing bells; and all the parts being mounted upon one piece of cast iron, they are very durable, and not liable to derangement.

VIII. The carriage apparatus and all parts of the system are constructed to stand very rough treatment without damage.

IX. The apparatus is not expensive in its first cost, and the cost of its maintenance is almost nominal.

X. The system has had the advantage of being practically tested for more than eighteen months upon an ordinary train running daily 250 miles and tested twenty-two times each day; and the result of this trial, as shown by the guard's daily report, has proved the efficiency of its working as well as the ease and cheapness of its maintenance.

On the Penetration of Armour Plates by Shells with Heavy Bursting Charges Fired Obliquely. By Sir JOSEPH WHITWORTH, *Bart., LL.D., F.R.S.*

[Printed *in extenso* among the Reports, see page 430.]

APPENDIX.

Abstracts received too late for insertion in order.

On the Physiological Action of Hydrate of Chloral. By BENJAMIN W. RICHARDSON, *M.D., F.R.S.*

The following paper was drawn up by the desire of the President of the Biological Section and the Department of Physiology during the Meeting. In opening the subject, the author first expressed his thanks to Mr. Daniel Hanbury, of Plough Court, who had supplied him with a specimen of the hydrate of chloral, and had also been so good as to abstract from Liebreich's papers the principal facts and opinions on which the introduction of the hydrate into medical practice was based. In brief, hydrate of chloral is a white crystalline body, soluble in water, and yielding a solution not disagreeable to the taste. It is made by the addition of water to the substance chloral. Chloral, the composition of which is $C_2 HCl_3 O$, is the final product of the action of dry chlorine on ethylic alcohol. It is an oily fluid, thin, colourless, volatile. The specific gravity is 1·502 at 64° Fahr., and it boils at 202° Fahr. It has a vapour-density of 73, taking hydrogen as unity. The odour is pungent. When chloral is treated with a little water, heat is evolved, and small stellate white crystals are formed as the fluid solidifies. The solid substance is the hydrate of chloral, $C_2 HCl_3 OH_2 O$. The hydrate is slowly volatilized if it be exposed to the air, and the odour of it, were it not pungent, is so like melon as to be hardly distinguishable from melon. When heat is applied to the hydrate, it distils over without undergoing decomposition.

When to a watery solution of hydrate of chloral caustic soda or potassa is added, the hydrate is decomposed, chloroform ($CHCl_3$) is set free, and a formate of sodium or potassium, according to the alkali used, is formed. It was on a knowledge of this decomposition by an alkali that Liebreich was led to test the action of the substance physiologically. He conceived the idea that in the living blood the same change could be effected, and that the chloroform would be liberated so slowly that anæsthesia of a prolonged kind would result. To try this, he subjected animals to the action of chloral, and even man, and proved that sleep could be rapidly induced without the second stage of excitement common to the action of chloroform when it is given by inhalation. Liebreich produced in a rabbit, by a dose of 0·5 grm. of the hydrate of chloral, a sleep which lasted nine hours. This dose was equivalent to 0·35 of chloral, and to 0·29 of chloroform. The symptoms, he found, were like those produced by chloroform. In some cases he gave the hydrate to the human subject. The first case was that of a lunatic, to whom he administered 1·35 grm. No irritation was set up, and five hours of sleep was obtained. In a second case, he gave internally a dose of 3·5 grms. to a man suffering from melancholia, by which he produced a sleep of sixteen hours.

Such was an epitome of the facts placed before the author at the time when he commenced to make his experiments. In setting out on his own account, he first prepared a standard solution of the hydrate. He found that 30 grains dissolved in 40 grains of water, and formed a saturated solution, the whole making up exactly the fluid drachm. The standard solution prepared in this way was very convenient.

The author next proceeded to inquire whether, by the addition of the hydrate to fresh blood, chloroform was liberated. This was proved to be the fact; the odour of chloroform was very distinct from the blood, and chloroform itself was distilled over from the blood, and condensed by cold into a receiver.

The narcotic power of the hydrate was then tried on pigeons, rabbits, and frogs. The standard solution, named above, was employed, and was administered either by the mouth or by hypodermic injection. The action was equally effective by both methods. The general results were confirmatory of Liebreich's own experience to a very considerable extent. They are as follows:—In pigeons, weighing from $8\frac{1}{2}$ to 11 ounces, narcotism was produced readily by the administration of from $1\frac{1}{2}$ to $2\frac{1}{2}$ grains of the hydrate. In these animals the dose of $2\frac{1}{2}$ grains was the extreme that could be borne with safety, and a dose of $1\frac{1}{2}$ grain was sufficient to produce sleep and insensibility. The full dose of $2\frac{1}{2}$ grains produced drowsiness in a few minutes, and deep sleep with entire insensibility in twenty minutes. Before going to sleep there was in every case, whether the dose was large or small, vomiting. As the sleep and the insensibility came on, there was in every instance a fall of animal temperature, and even in cases where recovery followed, this decrease was often to the extent of five degrees. The respirations also fell in proportion, declining in one case from 34 to 19 in the minute during the stage of insensibility. From the full dose that could be borne by the pigeon, the sleep which followed lasted from three and a half to four hours. Six hours at least was required for perfect recovery. During the first stages of narcotism in pigeons the evolution of chloroform by the breath was most distinctly marked.

In rabbits weighing from 83 to 88 ounces, thirty grains of the hydrate were required in order to produce deep sleep and insensibility. A smaller dose caused drowsiness and want of power in the hinder extremities, but no distinct insensibility.

When the full effect is produced in rabbits from the administration of the large dose, the drowsiness comes on in a few minutes; it is followed by want of power in the hinder limbs, and in fifteen minutes by deep sleep and complete insensibility. The pupil dilates, and becomes irregular; the respiration falls (in one case from 60 to 39 in the minute), and the temperature declines 6° Fahr.; sensibility returns with the rise in number of respiratory movements, but in some cases falls again during the process of recovery. The drowsiness, or, if the animal is left alone, what may be called sleep, lasts from five and a half to six hours. But it was observed that the period of actual anæsthesia was very short, lasting not longer than half an hour, after which the skin seemed rather more than naturally sensitive to touch. During recovery there are tremors of the muscles almost like rigors from cold; they are due probably to great failure of animal temperature.

In frogs a grain of the hydrate causes almost instant insensibility, coma, and death.

In further prosecution of his research, the author tested, on similar subjects, the effect of chloroform, bichloride of methylene, tetrachloride of carbon, butylic alcohol, and chloride of amyl. In all the observations with these substances, the narcotizing agent was used by hypodermic injection. It was found, as a result of these inquiries, that 7 grains of chloroform, 5 of tetrachloride of carbon, and 7 of chloride of amyl, produced the same physiological effect as 2 grains of the hydrate. Seven grains of bichloride of methylene induced a shorter insensibility. A rabbit subjected to 30 grains of chloroform slept four hours and twenty-five minutes; and a pigeon subjected to 7 grains slept three hours and twenty-five minutes. All these agents caused vomiting in birds, before the insensibillty was pronounced, the same as did the hydrate; but in no animal was there any sign of the stage of excitement which is seen when the same agents are administered by inhalation. This fact is most important, as indicating the difference of action of the same remedy by difference in the mode of administration. The temperature of the body was reduced by the agents named above, but not so determinately as by the hydrate.

Two animals, pigeons, made to go into profound sleep, the one by the hydrate, the other by chloroform (each substance administered subcutaneously), were placed together, and the symptoms were compared. The sleep from the chloroform was calmer; there was freedom from convulsive tremors, which were present in the animal under the hydrate, and recovery was, it was thought, steadier. It was observed, and the fact was well worthy of note, that no irritation was caused in the skin or subjacent parts by the injection of the chloroform and other chlorides.

The neutralizing action of the hydrate on strychnine was tried, and it was determined that the substance arrests the development of the tetanic action of the poison for a short period, and maintains life a little longer afterwards, but does not avert death. This subject deserves further elucidation.

When the hydrate of chloral is given in an excessive dose it kills: there are continuance of sleep, convulsion, and a fall of temperature of full 8° before death.

The post-mortem appearances were noticed after a poisonous dose. The vessels of the brain are found turgid with blood. The blood is fluid, and coagulation is delayed (in a bird to a period of three minutes), but afterwards a loose coagulum is formed. The colour of the brain-substance is darkish pink. The muscles generally contain a large quantity of blood, which exudes from them, on incision, freely. This blood coagulates with moderate firmness. Immediately after death all motion of the heart is found to be arrested. The organ is left with blood on both sides, but with more in the right than the left side. The colour of the blood on the two sides is natural, and the coagulation of this blood is moderately firm. The other organs of the body are natural.

Other observations were made on the changes which the blood undergoes when the hydrate of chloral is added to it. The corpuscles undergo shrinking, and are crenate; and when excess of hydrate is added the blood is decomposed in the same way as when treated with formic acid. The summary of the author's work may be put as follows:—

Hydrate of chloral, administered by the mouth or by hypodermic injection, produces, as Liebreich states, prolonged sleep.

The sleep it induces, as Liebreich also shows, is not preceded by the stage of excitement so well known when chloroform is administered by inhalation.

The narcotic condition is due to the chloroform liberated from the hydrate in the organism, and all the narcotic effects are identical with those caused by chloroform.

In birds the hydrate produces vomiting in the same manner, and to as full a degree, as does chloroform itself.

The sleep produced by hydrate of chloral is prolonged, and during the sleep there is a period of perfect anæsthesia; but this stage is comparatively of short duration.

The action of the hydrate is (as Liebreich assumes) first on the volitional centres of the cerebrum; next, on the chord; and lastly, on the heart.

Practical Applications.

Whether hydrate of chloral will replace opium and the other narcotics is a point on which the author was not prepared to speak. It is not probable it will supersede the volatile anæsthetics for the purpose of removing pain during the performance of surgical operations, but it might be employed to obtain and keep up the sleep in cases of painful disease. This research had, however, led to the fact that chloroform, when injected subcutaneously in efficient doses, leads to as perfect and as prolonged a narcotism as the hydrate, with an absence of other symptoms caused by the hydrate, and which are unfavourable to its action. This was a new truth in regard to chloroform, and might place it favourably by the side of the hydrate for hypodermic use. Lastly, as the hydrate acts by causing a decomposition of the blood, *i. e.* by undergoing decomposition itself and seizing the natural alkali of the blood, it adds to the blood the formate of sodium. How far this is useful or injurious remains to be discovered. But while putting these views as to practical application at once and fairly forward, the author said it was due to Liebreich to add that his (Liebreich's) theory and his experiments have done fine service in a physiological point of view. They have shown in one decisive instance that a given chemical substance is decomposed in the living body by virtue of pure chemical change, and that the symptoms produced are caused by one of the products of that decomposition. The knowledge thus definitively obtained admits of being applied over and over again in the course of therapeutical inquiry.

On the Natives of Vancouver's Island and British Columbia. *By* Dr. Richard King.

The natives are called Flat Heads, of which there are four varieties,—the elongated head from before backwards, the conical head, the square head, and the elongated head from side to side. These artificial heads are produced by pressure on the forehead and bandaging on the sides until the child is a year old. The author called this series of deformities the deformity *artificial*, in which there is mere displacement of brain, or a *conformity of error*; but he described a deformity which is going on to a great extent in civilized life, which he named deformity *natural*, or *non-conformity of error*, in which case it is not mere displacement of brain, but an alteration of the oval shape of the brain, which he attributed to the mode of nursing.

The alteration that takes place in the Flat Heads is mere displacement of the cerebral mass and of the cerebro-spinal fluid, which has neither mentally nor physically any deteriorating effect. The frontal sinuses are, however, almost entirely obliterated; but whether the sense of smell is affected is a problem yet to be solved.

The Flat Heads are peculiar to America, if we except the Avaren, a Turco-Ural race inhabiting the countries between the Don and the Volga, and they are now restricted to certain tribes in the neighbourhood of the Columbia River. The same habit prevailed among the ancient Peruvians; and it only shows the infant state of the ethnologist, when Tiedemann and Pentland maintained that these Flat Heads owed their singular configuration, not to art, but to a natural peculiarity.

The native population of Vancouver's Island is estimated at 18,000, but, as in all cases of estimates of the uncivilized races, wandering as they do, this estimate cannot be relied upon. By far the most numerous and powerful tribes live on the west coast, or on the outward sea-board of the island, and the white man is respected by them. The natives generally are in a very degraded state; occasionally industrious trustworthy individuals are to be met with, but, as a body, for continuous labours they cannot be depended on.

The fauna of the island is very rich, but the natives restrict themselves entirely to fish, and a small esculent plant, called Camass, which they collect and store up for winter, and also cook them as we do potatoes by boiling and baking. The Camass digging is a great season of reunion for the women of the various tribes, and answers to our haymaking or harvest-home.

On the Occasional Definition of the Convolutions of the Brain on the exterior of the Head. Illustrated by a Cast. *By* T. S. Prideaux.

The general outline of the skull, with the exception of its base, is convex, presenting a flowing curve. Occasionally, however, and perhaps more frequently in the forehead than elsewhere, the outline of a convolution is so prominently defined on the skull as to be very apparent on the exterior of the head through all the integuments. Now, could we discover the cause which underlies this exceptional configuration of the brain, we could scarcely fail of being much enlightened as to the laws which preside over the development of this organ. Are we to regard this peculiarity as an indication of progress towards perfection, or the reverse? The result of the author's observations leads him to think there can be little doubt of the greater frequency of this occurrence in civilized than in savage races. Minute examination reveals great differences in the proportion which the sizes of the convolutions bear to each other in brains of the same general size. In two foreheads of the same breadth, for example in A, the convolutions seated in the mesial line shall be much wider than in B, whilst in B the lateral convolutions shall be much wider than in A.

As in different families or races the features of the face bear very different proportions in size to each other, a certain average proportion being characteristic of each, so with the convolutions and groups of convolutions of the brain. The theory proposed by the author as an explanation of the protuberance of isolated cerebral convolutions is, that either exercise or the crossing of races by marriage has caused offsprings to be born with a predisposition towards the more energetic manifestation of a function than the extent of surface allotted to it by the brain type of its race will furnish; that this extent of surface not being susceptible of being widened without subverting the general packing and arrangement, and the proportion of the convolutions and the figure of the brain as a whole belonging to the type, Nature effects her purpose of enlarging an isolated organ by thrusting the skull outwards. This theory requires that the cerebral convolutions most frequently protuberant shall be those appropriated to functions which the progress of civilization has a tendency to cultivate and render more active than they are found in a ruder state of society; and if the author is right in believing that the convolutions which, in the frequency with which they occur defined on the exterior of the head, surpass all others are those of the organs of music and causality, he thinks it must be admitted that so far the test does not fail. Gall especially described two different forms of development presented by the organ of music.. In some of the most eminent composers, the external corners of the forehead are enlarged and rounded towards the temples, giving extent of superficies to the organ without defining its outline. In others equally celebrated, the organ presents a well-defined prominence in the form of a pyramid, the base of which rests above the eye, whilst the apex reaches halfway up the forehead and terminates at its exterior edge. Gall gives the Mozarts, father and son, Michael Haydn, Paer, Dussek, Crescentini, and several others, as examples of the first conformation; Beethoven, Joseph Haydn, J. J. Rousseau, Gluck, &c. as examples of the second; and the author adds to the list of great musicians presenting the outline of the organ in a well-defined pyramidal form, the names of Mendelssohn and Weber. He is acquainted with a lady who possessed from childhood an extraordinary genius for music, in whom the organ presents the first form. The configuration of the corners of the forehead is such as to provide a wide extent of surface for the organ of music, but no defined outline is perceptible. This lady married into a family singularly wanting in musical capacity. She has two daughters, who, without equalling their mother in genius, inherit from her a capacity for music much above the average. Their heads, however, follow in general outline the type of their father's family; they lack the spacious temporal region of their mother, and present the organ of music in the pyramidal form; and this form is beyond doubt that which is most commonly met with in England. On an average the author has his attention arrested at least once in six months by seeing a very conspicuous development of the organ of music in the pyramidal form in a complete stranger; when circumstances permit he always endeavours to ascertain whether the endowment with the faculty is commensurate with the development of the organ, and he has never yet received a negative answer.

On the Economical Condition and Wages of the Agricultural Labourer in England. By Professor LEONE LEVI, *F.S.A., F.S.S.*

1. That the great causes of low wages in Agriculture, as compared with other industries, appear to be the prevalence of physical labour and the permanent and general excess of labourers.

2. That it being highly important for the welfare of the labourer to raise the

condition of agricultural labour from that of unskilled to skilled labour, it is necessary to extend elementary education, to promote technical education among farmers and stewards, and to offer liberal remuneration for superior skill and careful working in any of the operations of farm-labour by the extension of payment by piecework, and the greater adoption of machinery.

3. That, with a view to the greater efficiency of labourers, nothing is more important than that the labourer should receive wages sufficient to maintain him in a condition of health and vigour.

4. That, in order to modify the excess of labourers in agriculture, it is requisite to remove any obstacle, by the law of settlement or otherwise, to the free removal of labourers from county to county, to promote emigration direct from the country districts, to extend the cultivation of land, and to increase the commerce and manufacture of the country.

5. That the difference existing in agricultural wages in different counties in the kingdom, though greatly modified by the allowance in kind in some of them only, mainly arises from a greater or less excess of labour, greater or less efficiency of labour, different degrees of productiveness of the soil, difference in the capital invested in agriculture, and the presence of other industries.

6. That, for the purpose of encouraging the investment of capital in agriculture, it is important to extend the custom of granting long leases, to secure compensations for agricultural improvements, and to remove any inequalities in the burden of taxation wherever they exist, and to extend as far as possible railway accommodation in agricultural districts.

7. That, having regard to the advantages connected with the system of yearly hiring, as the best mode of securing a continuity of labour in the same service, and of promoting the welfare and contentment of the labourers, it is highly desirable to extend the custom in all counties, provided it may be introduced without the objectionable practice of hiring fairs and markets, substituting for them registry offices in all the market towns.

8. That, whilst payment in kind is objectionable, as it is liable to great abuse, produces much uncertainty, throwing the dangers of the market on the party less able to bear them, it is still more objectionable where any part of the wages is paid in the shape of cider or spirits.

That the bondage system prevailing in Northumberland operates most unjustly to the labourer, and acts most disadvantageously on the moral condition of women in that district.

10. That, upon a comparison of the purely agricultural with the purely industrial counties, the agricultural exhibit a smaller rate of births, deaths, and marriages, a better state of education among the adults, especially among women, nearly an equal proportional number of children at school, less drunkenness and less crime, but more pauperism and more illegitimacy than the industrial counties.

11. That the house accommodation in the rural districts appears to demand decided improvement, many of the old cottages being inconsistent with the moral and physical well-being of their inhabitants.

12. That it were much to be desired that to every cottage a small garden should be attached; and that, where that is impossible, an allotment of land conveniently situated should be granted with it.

13. That for the purpose of stimulating habits of self-reliance and independence of character among the agricultural labourers, it is most important to restrict as much as possible the operation of the Poor-Law, to promote the establishment of savings' banks, insurance companies, and friendly societies under proper control, and to limit to the utmost extent the licensing of public-houses, and the inordinate consumption of spirits.

14. That, taking into account the large excess of agricultural labourers, and the probability of a still further displacement of labour in proportion with the introduction of machinery and skill, the need of regulating the efflux of such labourers to the towns and manufacturing districts in relation to the power of commerce and manufactures to absorb them, the importance of procuring the contentment of such agricultural population, and the universal desire of the most industrious among them to own a plot of land or to farm it on his own account, as well as

the great advantage of offering means for the investment of savings in the mode most consonant with their habits, and in almost the only way within their reach, it seems highly expedient, even regardless of other economic considerations of a conflicting character, that facilities should be afforded for the purchase of lots of land of reasonable size, capable of being cultivated by the proprietors themselves, that any land now held by corporate or public bodies should be appropriated for that purpose, and that in each estate, divided into large holdings, a limited number of small holdings, varying in extent from 30 to 100 acres, should be set aside, to serve as stepping-stones for the labourer to rise to the position of a farmer.

15. That it is important that the agricultural statistics published by the Board of Trade should be extended, so as to show the number and extent of land-proprietors, the number and acreage of farm-holdings, the wages of agricultural labourers, and, as far as can be ascertained, the produce of the soil.

On certain Economical Improvements in obtaining Motive Power. *By* RICHARD EATON.

Referring to the fact that work and heat are now generally admitted to be convertible terms, and showing that the steam-engine in its most improved state is not able to develope into useful work much more than one-tenth of the mechanical power due to the combustion of coal, the paper brought out the fact that whilst 2218 heat-units would be the cost of obtaining 150 cubic feet of air at 60 lbs. pressure, to produce the same volume of steam at this pressure would require 29,350 heat-units. The improvements forming the subject of the paper were invented and patented by Mr. George Warsop, of Nottingham, with the assistance of the author of the paper.

Cold air is taken in by an air-pump which is worked by an ordinary steam-engine, and the air is forced on, in its compressed state, through an air-pipe, past such parts of the flues and funnel as contain waste heat or gases, such waste heat being thus taken up by the air, which finally passes, at a temperature of about 600° Fahr., by a self-acting clack valve into the boiling water at the base of the boiler. Within the boiler the air is distributed, and rises through the water. The cohesion of the water is diminished by the presence of the air, and ebullition takes place more easily.

Carefully conducted experiments on the plan adopted by the Royal Agricultural Society of England, and made by one of the consulting Engineers of the Society, proved that 47 per cent. more work was obtained out of a given quantity of fuel by this system than by steam only. Other advantages also were referred to; and an announcement was made that the fullest possible investigations would be instituted and reported. It is to be hoped that the results will be brought before the notice of the British Association at the Meeting next year.

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[*An asterisk (*) signifies that no abstract of the communication is given.*]

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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.

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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.*

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* 15*s*.

CONTENTS :—A. Cayley, Report on the Recent Progress of Theoretical Dynamics ;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds ; —James Oldham, C.E., continuation of Report on Steam Navigation at Hull ;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships ;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall ;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{-\alpha} t \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, 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* 20*s*.

CONTENTS :—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena ;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58 ;—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* 15s.

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* 15s.

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.

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